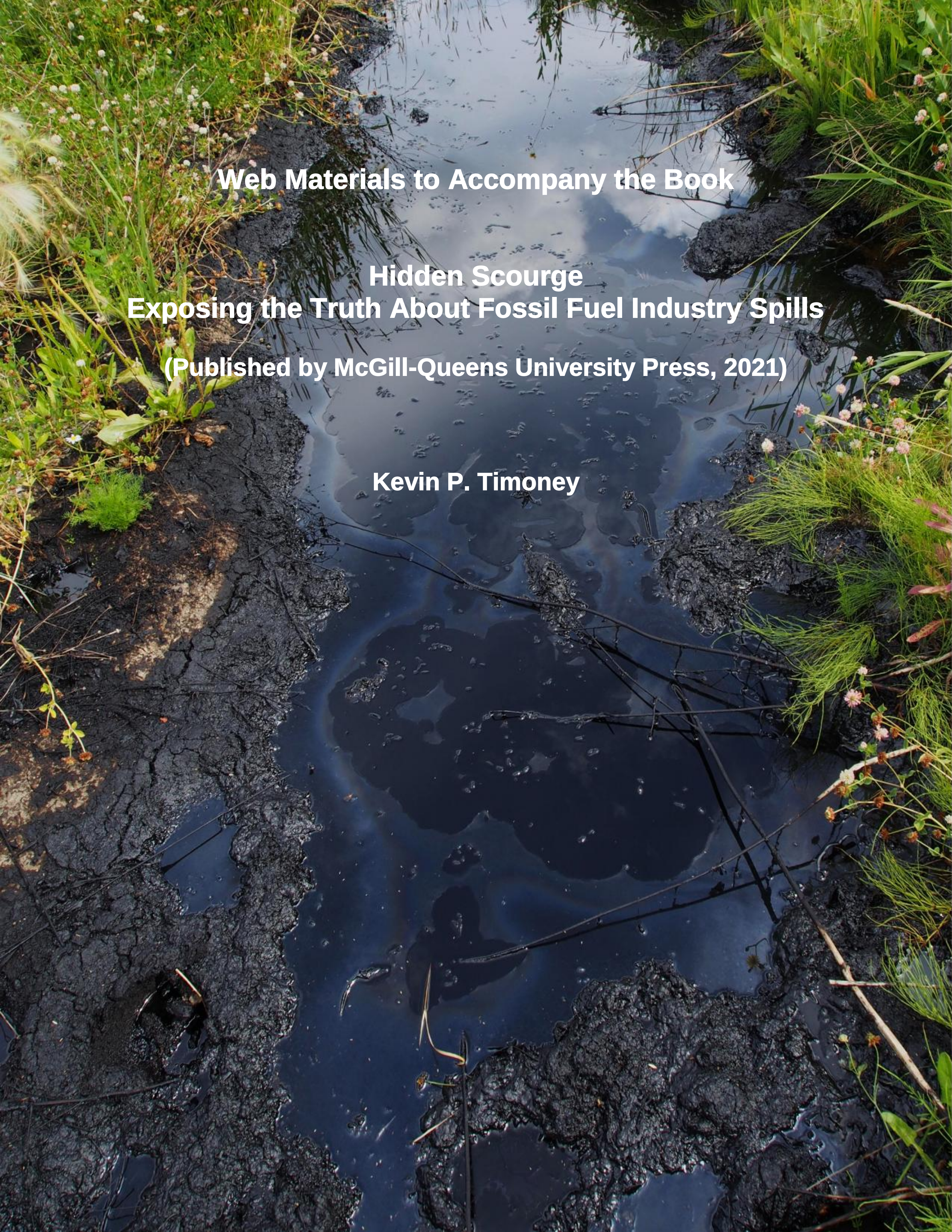
Web Materials to Accompany the Book

Hidden Scourge
Exposing the Truth About Fossil Fuel Industry Spills

(Published by McGill-Queens University Press, 2021)

Kevin P. Timoney



These web materials provide supplementary information to accompany the book *Hidden Scourge: Exposing the Truth about Fossil Fuel Industry Spills* by Kevin P. Timoney (McGill-Queens University Press, 2021).

Hidden Scourge is organized into 18 chapters. In order to make the book concise, affordable, and non-technical, I have placed much of the scientific detail and documentation in these web materials and have organized them to correspond to the book chapters. For example, Web 2 contains material that pertains to Chapter 2 and so on. The book includes a glossary of terms that may be useful as you read these web materials.

This free online appendix can be used alone but you might find it a bit like reading a dictionary or encyclopedia. Because the book covers topics not presented here and provides overview and discussion, the web materials will make more sense when used along with the book. If *Hidden Scourge* paints the big picture, the web materials provide the frame, canvas, and paint.

As a public service, the web materials include collated data on the spills reported from Alberta, Saskatchewan, North Dakota, Montana, and the Canadian Energy Regulator (file: Spills Master.xlsx), an AER-sourced file of all Alberta industry wells by category (abandoned, etc., file: SurfaceHolesShapefile.zip), and a document of maps and discussion of issues pertaining to spills and industrial wells (file: Spills Maps). Used together, the maps and data provide sufficient information to understand the frequency, type, reported volume, and geographic distribution of spills and wells and their associated impacts. The file "Readme" provides additional background about these web materials.

The table of contents is bookmarked; use Ctrl+mouse click to jump to the material you wish to view. The index beginning on page 261 should help you to find the subject matter that interests you. Because these web materials are in digital format, you can also use the search facility on your computer. Readers with questions or comments may email me at: lorax.ted@gmail.com.

As *Hidden Scourge* has moved through the publication process, the endless drip, drip, drip of revelations that document this ecological and social tragedy have presented me with a challenge. Just when I thought the story was complete, more information came to light, which has caused me to update the book and these web materials repeatedly. The story of the fossil fuel industry's assault on the planet and the social fabric will not end until we have stopped the profligate extraction and burning of hydrocarbons. Since late 2020 I've tried to close the book, literally, so that endless revisions and updates don't further delay the book's publication. Recent events have simply reinforced the book's findings and conclusions. But out of due diligence, I have summarized the more important developments current to August 2021 in the Addendum here.

Hidden Scourge began when I observed spill clean-up data that were too good to be true. As I dug deeper into the data, it dawned on me that I was studying symptoms of a greater malignancy, that the untruthful data were symptoms of a metastasis that had spread through our governments and our society. The spills and their effects were not being reported truthfully because the regulators had been corrupted. The perpetrators of the harm were also the beneficiaries of vast profits because, by capturing the regulator, they were absolved from protecting the environment and people from harm. By controlling information, the industry controlled the discussion, funded their quisling politicians, and externalized their liabilities onto the public. By directing their crony politicians to enact policies that undermined public funding of the public interest, industry then controlled the funding relevant to their activities. Industry came to control not only funding of their regulators, they also came to oversee and/or fund environmental monitoring programs (such as RAMP and ABMI), and university research, and, as we know, those who control the funding, control what is studied, reported, and taught in the schools, and significantly, what is ignored.

The mess in which we find ourselves is not simply environmental. At its core, it is also a matter of climate and social justice. Global-scale ecological damage coupled with disinformation used by the fossil fuel meta-organization to maintain its power have destabilized the Earth's climate and continue to undermine our prospects to effect the energy transition. It does no good to appeal to the better natures of the perpetrators of the global carnage; they have none.

Those who fight for environmental, social, and climate justice are fighting the same enemy. Poverty, racism, damaged ecosystems and communities, poor health, disinformation, and powerlessness are conjoined symptoms of the capture of governments by vested interests. We the 99 % have sat back while the 1 % have emptied our pockets, drained the public purse, sown discord among us, and left us with crushing liabilities. We have been content to act like sheep, oblivious to what is happening beyond our personal pastures.

Now is the time for transformational change. We need economies that protect rather than destroy our planet and our social fabric. We need to replace suicidal subsidies to the fossil fuel industry with policies that facilitate the energy transition. We need to elect leaders with intelligence, vision, and courage.

There are reasons to be hopeful. Young people are rising up and leading the way. The energy transition is gaining momentum with solar and wind powering a new future. Financial institutions, investment funds, and insurance companies have seen that future and are shifting their significant resources away from activities that endanger that future. Courts are stepping up with decisions that require companies to meet their legal responsibilities. Technological advances and major projects are announced almost weekly. Governments, municipalities, companies, and citizens' groups are thinking outside the old box and embarking on a new path forward.

I hope that *Hidden Scourge* helps us to lift our heads and realize we need not remain powerless.

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Hidden Scourge Chapter Summaries

Part 1 Hiding in Plain Sight

Chapter 1 Covert Spills

Exploitation of fossil fuels causes environmental damage on a daily basis. Often the effects are hidden.

There are no web materials.

Chapter 2 The Data and How They Were Analyzed

I used three main lines of evidence to evaluate spills from conventional oil and gas production: field data, regulatory data, and the scientific literature.

Chapter 3 An Overview of Spills

An overview of the number, kinds, sources, and locations of spills.

Part 2 The Incident and the Aftermath

Chapter 4 The Effects of Spills

A brief review of the science on inland spills with a focus on Canadian and northern case studies. Documentation of the spill signature.

Chapter 5 The Effects of Other Fossil Fuel Industry Activities

A brief review of the science on the effects of pipelines, well sites, seismic lines, and other industrial activities.

Part 3 Regulatory Evidence

Chapter 6 Inaccurate Locations, Suspect Spill Data, and the Falcon Effect

An examination of the validity and accuracy of regulatory data with emphasis on spill locations, the number of spills, spill volumes, and spill recoveries.

Chapter 7 Spill Forensics

Further analyses of the validity and accuracy of regulatory data.

Chapter 8 Exploring the Unknown: Missing Spills

Thousands of spills and covert releases are missing from the regulator’s records. The two largest releases in Alberta history are both missing from the AER’s database. Missing releases pose social and economic liabilities and environmental uncertainty.

Part 4 Scientific Evidence

Chapter 9 Spill Effects on Soil and Water Chemistry on the Dene Tha Lands

Science has demonstrated that spills leave a chemical signature that can persist indefinitely. The field data corroborate that finding.

Chapter 10 Spill and Related Effects on the Vegetation and Flora in Four Study Regions

An examination of field data from four study regions that documents a spill signature.

Chapter 11 Behind the Firewall: The Pace-Spyglass Oil Spill

In depth study of the Pace-Spyglass crude oil spill demonstrates poor management, long-term damage, and failure to inform the public.

Chapter 12 Exposure to Contaminants at the Spill Sites

Fieldwork documented ecological damage, persistent contamination, no effective wildlife deterrents, and no monitoring at spill sites.

Chapter 13 The Regulator's Failure to Document Spill Effects on Habitat and Wildlife

Failure to document spill effects has been occurring for decades. The science indicates that crude oil and saline spills harm habitat and wildlife at a rate about 40 times higher than reported by the AER's data.

Chapter 14 Cumulative Effects

Pervasive ecological effects and failed reclamation demonstrate that the fossil fuel industry is causing wholesale, long-term damage to ecosystems.

Part 5 Out of the Rabbit Hole and into the Light

Chapter 15 Misinformation and the Meta-Organization

The public deserves accurate, reliable, and timely information about the impacts of the fossil fuel industry. Instead, the hydrocarbon meta-organization provides misinformation and disinformation.

Chapter 16 A Captured Regulator

Regulatory capture occurs when regulators, government, political parties, industry, lobby groups, consultants, academics, and monitoring agencies exchange information, money, and staff to the mutual benefit of the organization. Such capture damages our democracy and our ecosystems and cripples our society. It sows doubt and confusion and prevents economies from adapting to a changing world.

Chapter 17 Conclusions: Better Sad Truths Than Happy Lies

The hidden scourge of fossil fuel exploitation extends beyond corrupt data and poor management to the degradation of ecosystems and the corruption of our democracy.

There are no web materials.

Chapter 18 The Way Home

Pervasive spills, contamination, ecological degradation, disinformation, and corrupt data are symptoms of a life-threatening disease caused by our addiction to carbon. Incremental change cannot save us. We need transformational change.

Web 2 Background information on the field study sites

Web 2.1. The Freedom of Information Request

And so began the long journey down the rabbit hole.

Beginning in summer 2015, I made requests in writing and over the phone to the Alberta Energy Regulator and to energy companies and their contractors involved in the spills studied during the fieldwork. I requested post-spill chemistry, contamination, environmental, and reclamation reports or data. I conducted a similar search online.

Initially, I made requests to the Alberta Energy Regulator (AER) for incident information for four spills: the Pace-Spyglass oil spill (incident number 20121047), the Apache 15-09 saline spill (20131107), the Barnwell saline spill (20150240), and the Nuvista saline spill (20152246). After corresponding via emails and speaking with seven different staff at the AER, I submitted a modified written request for information on 1 December 2015. I received a four page FIS record on 14 January 2016 that contained summary information on eight spills, two that were requested and six that were not requested. I contacted AER to inform them of the errors. AER responded with a two page reply containing four incidents, two of which were requested and two of which were not requested. Overall, I received summary information for 12 spills, four of which were requested and eight of which were not requested.

The information provided by the AER was incomplete and contained errors. No energy companies provided information about the spills.

Therefore I submitted a Freedom of Information request (FOIP) on 10 September 2016 for information about all incidents occurring at the named locations (legals provided below) over the period 1 January 1980 (1970 for location 9) to 6 September 2016. The request was for:

"All data, maps, reports, images, correspondence between AER, licensees, Government of Alberta and third parties' reports (e.g. Matrix, NAIT) and related information pertaining to: [note: AER changed the wording in the request; the Keepers of the Water Council request stated: "all data, maps, reports, images, correspondence between AER and the licensee (energy company) and Alberta government, third party reports (such as by Matrix, NAIT), and related information that pertain to:"
a) volumes spilled and recovered; b) spill type (e.g. oil, bitumen, processed water, formation water, etc.); c) reclamation reports; d) spill release reports; e) spill soil and water chemistry data (e.g. contaminants, hydrocarbons, anions, cations, etc.); f) species planted; g) well status (e.g. active, reclamation certified, reclamation exempt, abandoned, etc.) and whether the incident(s) have been "released" (i.e. there is a release clean-up date); h) environmental/vegetation/wildlife reports; and i) AER and Government of Alberta enforcement actions for the following locations:
1. Barnwell (04-25-114-06 W6)... 2. Apache (15-09-116-06 W6)... 3. Spyglass (Pace) (14-21-108-07 W6)... 4. Nuvista spill (10-19-112-04 W6)... 5. BP Zama spill (14-12-116-06 W6)... 6. Amber Energy and Sunoma Energy (16-21-114-06 W6)... 7. Apache (11-26-118-08 W6)... 8. Beaver Pond oil spill (NW 13-109-06 W6)... and 9. Early 1970s oil (well) spill (14-07-114-05 W6)..." (McPhail 2016; Mori 2016).

Here is a summary of the results of the FOIP:

1. Barnwell: No records were found, but one incident was found for the adjacent legal 04-36-114-06-W6 that was part of an open investigation at time of request. This incident was the spill requested but the <u>regulator did not release any records</u>. The location I specified in the FOIP for this spill was correct; the spill did not take place in the location stated by the regulator.
2. Apache 15-09: AER reported that it compiled 2743 records for this spill. It released 2733 pages.
3. Spyglass (Pace): AER compiled 773 pages; 770 pages were released.
4. Nuvista: The spill was part of an open investigation at time of request. <u>No records were released</u>.
5. BP Zama (Apache Zama): AER released 319 pages. Most of the records were irrelevant to the location.
6. Site A, Amber Energy and Sunoma Energy: AER released 45 pages. The information released appears irrelevant to the spill (Web 8.2).
7. Apache2 11-26: The spill was part of an open investigation at time of request. <u>No records were released</u>. However, Apache pleaded guilty to the spill on 30 September 2016 (Canadian Press 2016), <u>seven months</u> <u>before</u> the FOIP was closed, yet no records were released.
8. Beaver Pond: <u>No records were found</u> (Web 2.6).
9. Site B: AER compiled 10 pages; 10 pages were released, none of which were relevant to the spill.

The AER's decision letter (Mori 2016, 29 November 2016) stated that it provided access to 3346 pages out of the 3890 pages. It added: "Of the 3890 total records compiled: 536 are being withheld pending Third Party consultation process (explained earlier in the letter); The AER has decided to withhold 8 records, pursuant to section 17(4)(a) and "not responsive". 2,692 records/pages withheld pending an affected Third Party's right to request review by the Office of the Information and Privacy Commissioner of the AER's Access Decision; and With respect to the remaining 654 records/pages and after considering relevant factors, the AER has decided to disclose 81 records/pages ..."

As of 21 March 2017, 851 pages had been received; on 3 May 2017, 3081 pages were received. The AER closed the file in May 2017.

Web 2.1.1. Overview of the FOIP Experience

The experience of attempting to retrieve relevant and credible information on the spills was, to put it politely, educational. As it turned out, the FOIP process provided little useful information about the spills. Instead, it provided evidence of how the AER fails to provide timely, relevant, and complete information. The process required one and a half years, numerous phone calls and emails, and countless hours of my time trying to make sense of vague, irrelevant, and incomplete information that trickled out over time.

I found myself having to take walks to clear my head to make sense of irrelevant information, often in duplicate copies, and having to search for information that didn't exist. The information consisted largely of engineering reports (such as pipeline failure technical information), response and communications plans, photographs of equipment, duplicated FIS records, engineering field notes and data, information on unrelated incidents, blank pages, invoices, and correspondence. With the exception of the Apache 15-09 spill, little or no environmental information was released.

Searching the pages for relevant information proved to be an onerous task because, despite my request that the information be provided as searchable text, AER provided the information as pictures. It's the equivalent of giving a photograph of a glass of water to a man dying of thirst.

Suppose you're interested in the effects of spills on birds and need to find every mention of the word "birds" in 3800 pages. If the information is in text format, you can find every occurrence of birds in under 10 minutes. If the information is instead presented as images, there are no occurrences of the word "birds" because "birds" is a picture of the word. So instead of the search taking 10 minutes, it takes 10 hours. Now repeat this process for "warbler", "sparrow", "raven", "heron", and so on. Considering that when a page is scanned, there's the option to scan as text or as image, with no extra time or effort required on the part of the AER, the regulator's refusal to supply information as searchable text seems needlessly intransigent. At the very least, it makes information difficult to find and to use.

Once in a while I found something of interest, such as an AER inspection of the Apache 15-09 spill on 22 June 2016. Recall that the Apache 15-09 saline spill began sometime around 5 May 2015 and resulted in release of an estimated 15,363 m^3 of highly saline water that caused extensive ecological damage (Web 2.3, 6.1, and Figures 12.11-13). Three years after the spill, an AER inspector (with a bachelor's degree) visited the site and wrote: "Large spill from a few years ago located at this site. Historical off site contamination to the east of the lease. Although map shows offsite impact it is still contained in the developed area. (PLA). Minor impact and should be considered low risk in comparison to other sites. No water impacts anticipated."

This statement is amazing in what it reveals of an AER "inspection". Despite the facts that the spill affected a minimum area of 42 ha, that the damage was visible from satellite imagery, and that Apache was found guilty of harming the environment, the inspector failed to note the extensive offsite damage, concluded the spill was low risk, and did not anticipate water impacts that had already occurred. It's also noteworthy that the inspector revealed the existence of historical off site contamination to the east of the lease, yet no information about such contamination was found in the FOIP.

Here is another example of the lack of ecological understanding shown after spills, again from the Apache 15-09 spill: "Prior to commencing pumping in any new pond areas it is important that the Wildlife Management Team is given the opportunity to remove any aquatic organisms." How the removal of all aquatic organisms was to be accomplished and how those organisms would be kept alive after removal from their aquatic environment is not stated.

Poring over the information, it felt as if I had requested a magnetic resonance image (MRI) and was instead given a photograph of a magnet. I needed to speak with someone inside the AER who could explain how my requests for, among other information, reclamation reports, spill soil and water chemistry data, environmental, vegetation, and wildlife reports, and enforcement actions went unanswered. But no one would or could explain.

I knew from various statements in the FOIP that monitoring data existed for the spills. I also had access to a significant amount of "behind the firewall" information on the Pace-Spyglass spill. But only a small fraction of the requested information was released. I don't know why. Was it incompetence or willful denial of information? It was perhaps a combination of the two, but I suppose I'll never know.

In short, the experience revealed that the FOIP process as practiced by the AER is broken. It's an experience I would not wish on another person and would not willingly repeat. I can't help but think that for those whose objective it is to deprive the public of information, while appearing to comply with the law, the FOIP process at the AER works well. But for the rest of us, the AER's failure to provide information is inexcusable. For further evidence, please see Addendum 3.2.

Web 2.2. Locations of the fieldwork plots and sites in northwestern Alberta
(Figure 2.2 in book).[a] Note the discrepancies between the spill locations provided by the regulator and the actual spill locations determined during the fieldwork.

Site	Latitude (AER)	Longitude (AER)	Latitude (this study)	Longitude (this study)	Notes
Plot 1, Barnwell	58°55'57"	118°51'59"	58°55'56.2"	118° 51'28.8"	spill (excavated); rectangular plot 0.03 ha, 8 by 37.5 m, parallel to pond edge; "Barnwell Spill"; legal: 04-25 (36)-114-06-W6
Plot 2, Barnwell			58°55'58.0"	118° 51'27.8"	pipeline ROW, disturbed; circular plot 0.03 ha, north of excavation; "Barnwell ROW"
Plot 3, Barnwell			58°55'57.3"	118° 51'32.2"	control; circular plot 0.03 ha, WNW of excavation; "Barnwell Control"
Plot 4, Apache	59°03'50"	118°57'10"	59°03'44.1"	118° 57'10.0"	spill (excavated); rectangular plot 0.03 ha, 10 by 30 m, parallel to excavated pond edge; "Apache Spill", legal: 15-9-116-06-W6
Plot 5, Apache			59°03'44.5"	118° 57'11.5"	control; rectangular plot 0.03 ha, 10 by 30 m; NW of excavation; "Apache Control"; plot of natural vegetation surrounded by disturbance
Plot 6, BP Zama			59°03'50.8"	118° 52'10.3"	multiple spills and disturbances; circular plot 0.03 ha; "Zama BP Spill"; legal: 14-12-116-6-W6; see Plot 10 for control
Plot 7, Beaver Pond			58°27'57.1"	118° 51'44.7"	spill; circular plot 0.01 ha; "Beaver Pond Oil Spill"
Plot 8, Pace-Spyglass	58°23'48"	119°06'26"	58°23'49.0"	119°06'28.8"	spill; circular plot 0.01 ha; "Pace-Spyglass Oil Spill"; legal: 14-21-108-07 W6
Plot 9, Pace-Spyglass			58°23'45.5"	119°06'24.2"	control; circular plot 0.03 ha; "Pace-Spyglass Control 1 (bog)"
Plot 10, BP Zama			59°03'50.1"	118°52'05.7"	control; rectangular plot 0.03 ha, 8 by 37.5 m, parallel to pipeline disturbance; "Zama BP Spill Control"
Plot 11, Pace-Spyglass			58°23'51.8"	119°06'20.8"	control; circular plot 0.01 ha; "Pace-Spyglass Oil Control 2" (marsh-fen transition)"
Site A1, Amber	58°55'09.7"	118°56'01.7"	58°55'03.6"	118°56'02.6"	multiple disturbances (heavy machinery, spills?); legal: 16-21-114-6-W6; site ~25 m NE of A2 and 40 m SW of the oil storage tanks; AER spill site is 186 m N of Site A1 at bearing of 4°; AER location inaccurate
Site A2, Amber	58°55'09.7"	118°56'01.7"	58°55'03.0"	118°56'03.9"	oil spill; legal: 16-21-114-6-W6; site 2 m S of oil sump pit, sampled for F1-F4 hydrocarbons and salinity profile; AER spill site is 222 m N of Site A2 at bearing of 12.6°; AER spill location inaccurate because the two spills described (see Web 8.2) took place at the crude oil group battery site, not north of the battery site; neither of the two spills on record appear to be the spill studied in 2016
Site B			58°52'47.2"	118°50'52.6"	historic oil spill at well, early 1970s; spill was NE of point observation; oil flowed into creek here; site of concern to Dene Tha; reconnaissance; this spill needs documentation (no AER records exist)
Site C, Apache2			59°16'41.5"	119°14'35.0"	Apache2 saline spill; legal 11-26-118-08-W6; two plots

Nuvista	58°44’08”	118°39’15”	legal: 10-19-112-04-W6; site of concern to Dene Tha First Nation; site could not be sampled due to persistent flooding during summer 2016; ancillary data provided by DTFN

[a] converted from LSD system to latitude and longitude

Web 2.3. Summaries of incidents examined during the fieldwork.

Site	Notes
Barnwell, 04-25 (36)	AER FIS external record report (3 Nov 2015, released January 2016) stated: pipeline spill due to external corrosion; spill of 0.2 m^3 crude oil and 0.8 m^3 of salt/produced water on 22 January 2015; recovered volumes not provided; incident number 20150240; there was release off-site, environment was "muskeg/stagnant water"; it was a "sensitive" area; there was "no affect" on wildlife/livestock; "no affect" on the public; area affected was "100 square meters or less"; there was no release clean-up date provided; the licensee was Barnwell of Canada Limited. The AER FIS database provides a different account of the spill contents: 5000 m^3 of raw production gas released, 0 recovered; 0 m^3 of waste released, 16,000 m^3 recovered; 60 m^3 crude oil released, 50 m^3 recovered; and 100 m^3 salt/produced water released, 40 m^3 recovered. Plots 1-3. See Web 2.4a, Web 2.5a-c (illustrates that the area affected exceeds 100 m^2, which was ~ 25 m by 50 m or roughly 1250 m^2). Note the discrepancies in spill volumes between the FIS external record and the FIS database.
Apache, 15-09	AER FIS external record report (3 Nov 2015, released January 2016) stated: pipeline spill due to internal corrosion; release of 2.0 m^3 crude oil, volume recovered left blank; release of "9500" m^3 of salt/produced water, 70 m^3 recovered; incident date 1 June 2013; incident number 20131107; there was release off-site, environment was "muskeg/stagnant water"; it was a "sensitive" area; there was "no affect" on wildlife/livestock; "no affect" on the public; area affected "over 1000 square meters"; no release clean-up date provided; licensee was Apache Canada Ltd The AER FIS database (incident 20131107) provides a different account of the spill: 200 m^3 of raw production gas released, 0 recovered; 0 m^3 of waste released, 400 m^3 recovered; 0 m^3 contaminated surface water released, 50 m^3 recovered; and 9500 m^3 salt/produced water released, 70 m^3 recovered. But, according to AER (2015), the actual estimated volume of the saline spill was 15,363 m^3. That report also states that the release began on or about 5 May 2013 and was not reported until 1 June 2013, 27 days later. The delay in reporting was attributed by AER to inadequate leak detection (AER 2015). Plots 4-5. See Web 2.4b, Web 2.5d-e. Much of the AER-provided data are confusing or incorrect (see Web 6.1).
BP Zama 14-12	This site has a complex disturbance and spill history. See Web 8.1 for incidents associated with this location. Plots 6, 10. See Web 2.4c, Web 2.5f-h.
Beaver Pond	According to the Dene Tha First Nation, the leak was discovered by a company constructing a new pipeline during the winter of 2005-2006. The source of the crude oil spill was most likely the old Imperial pipeline RL-13 (RL-11). The leak was discovered where a new pipeline (RL-10) crossed RL-13 in NE 24-109-06-W6. Southwest of that crossing, RL-13 becomes RL-11 and traverses under the Beaver Pond valley in NW 13-109-06-W6 en route to Mobil Rainbow 11-11. The crude oil release may have travelled along the pipeline trench and later surfaced where the pipeline traversed the Beaver Creek valley. A "pig" may have been run down the pipeline to clean out the line which may have forced crude oil out of the abandoned pipeline and into the Beaver Pond valley. Boss Services of the Dene Tha First Nation worked on the spill clean-up. Both Plot 7 and the pipeline break are in NW13-109-06-W6; there are no AER incidents listed for that location. The closest AER incident site with recent incidents is at 09-17-109-05-W6 (58.4652 N, 118.785 W, 4.5 km due east of the Beaver Pond Spill plot). See Web 2.6 for the location of the spill discovery and other incidents in the area. The absence of this spill from AER records and the difficulty of documenting this spill demonstrate the problematic bookkeeping practices of the AER. See Web 2.4d, Web 2.5i-j.
Pace-Spyglass, 14-21	AER FIS external record report (3 Nov 2015, released January 2016) stated: the spill took place at source "other injection/disposal"; cause: "equipment failure internal corrosion"; spill of 800 m^3 of crude oil, recovered volume 800 m^3; incident date 19 May 2012; incident number 20121047; there was release offsite into "muskeg/stagnant water"; not a "sensitive" area; "no affect" on wildlife/livestock or the public; area affected > 1000 m^2; release clean-up date 12 September 2012; licensee was A5LK Pace Oil & Gas Ltd. Plots 8, 9, 11. See Web 2.4e, Web 2.5k-m.
Site A, Amber	There are two AER spill records for this site in the FIS database: (1) release of 8 m^3 crude oil on 17 August 1998, 8 m^3 recovered; release off site = no, "sensitive" area = no, release clean-up date 9 June 1999; Sunoma Energy Corp.; reason: metal fatigue (incident 19982113). (2) release of 50 m^3 crude oil on 23 December 1998, 0 m^3 recovered; release off site = no; not a "sensitive" area; release clean-up date 26 August 1999; Amber Energy Inc.; reason: pump failure (incident 19983070). These records do not appear to apply to the spill assessed. AER records provide the wrong location for this site. The spill studied in the fieldwork may be related to the 1998 spill, to an undocumented underground pipeline, or to undocumented leaking from an oil sump pit. See Web 2.4f, Web 2.5n-p.

Site B	A FOIP was made to AER for details about this spill. The location submitted was for the probable source well (14-07-114-05W6). Three records were found, but all are irrelevant to the 1970s spill (17 March 2003, satisfactory inspection; 24 July 2008, unsatisfactory inspection due to “oil or salt water staining on lease”; and 24 June 2010, satisfactory inspection). The 2008 spill that resulted in “oil or salt water staining” is missing from the AER FIS database because the regulator does not classify these releases as “spills”. No AER records were found for this early 1970s spill. Only information found was an eyewitness account from a Dene Tha member who was employed in the oil clean-up. See Web 2.4g, Web 2.5q-r.
Site C, Apache2, 11-26	A FOIP was made to AER for details about this spill (incident 20132123), but no information was supplied. Available information about the spill items is contradictory. AER listed the following spill contents: 27 m^3 waste released, 27 m^3 recovered; 6900 m^3 contaminated surface water released, 6900 m^3 recovered; 100 m^3 raw production gas released, 0 m^3 recovered; 1813.8 m^3 salt/produced water released, 1813 m^3 recovered; “no affect” on wildlife/habitat; environment “muskeg/stagnant water”; release off-site; not a “sensitive area”; area affected > 1000 m^2; release clean-up date 28 February 2015. An early press release stated a 100-200 m^3 spill reportedly took place on 25 October 2013. A later press release by Apache (2013) stated that the affected area was 5.09 ha, that a “team of approximately 30 people, including external wildlife and environmental experts, are currently responding to this incident”; and that “no effect on area wildlife has been identified at this time.” Despite the FOIP request, no data that verify a lack of environmental and wildlife effects were received from the AER. AER stated (Wagener 2015a) that the pipeline failure is believed to have occurred on 2 October 2013 while report of the spill to the regulator took place on 25 October 2013, a delay of 23 days. Canadian Press (2016) stated that the spill was 1800 m^3 of produced water, and that the spill affected 3.8 ha of public land. The news article stated that, on 30 September 2016, Apache pled guilty to this spill and to another spill (on 21 January 2014, near Whitecourt of “just under two million litres” of produced water). The court ordered Apache to pay a fine of $350,000 “with most of the funds going to a creative sentencing project in which Alberta Innovates Technology Futures will research remediating salt-affected soil.” The fine was directed towards researching remediation on salt-affected soils, an admission that, after decades of saline spills, reclamation on salinized soils still faces serious challenges. See Web 2.4h, Web 2.5s-u.
Nuvista, 10-19	This spill reportedly took place on 14 August 2015 in Hay Lake IR 209 (incident 20152246). AER FIS external record report (3 Nov 2015, released January 2016) stated: spill took place at a multiphase pipeline due to an unknown cause. Release of 0.0 m^3 waste, 0.9 m^3 recovered; release of 7.0 m^3 crude oil, recovered volume blank; release of 93.0 m^3 salt/produced water, recovered volume blank; release of 0.0 m^3 liquid waste, 15503 m^3 recovered. There was release offsite into “muskeg/stagnant water”; it was not a sensitive area and there was “no affect” on wildlife or habitat and “no affect” on the public; > 1000 m^2 affected; there was no release clean-up date provided. The AER FIS database provides a different account of the spill contents: 0 m^3 of liquid waste released, 15,503 m^3 recovered; 0 m^3 of waste released, 30,700 m^3 recovered; 25.6 m^3 crude oil released, 0 m^3 recovered; and 340.4 m^3 salt/produced water released, 0 m^3 recovered. See Web 2.4i, Web 2.5v.

Web 2.4. Aerial views of the spill sites with associated energy infrastructure.
Yellow and red lines denote pipelines and other linear infrastructure.

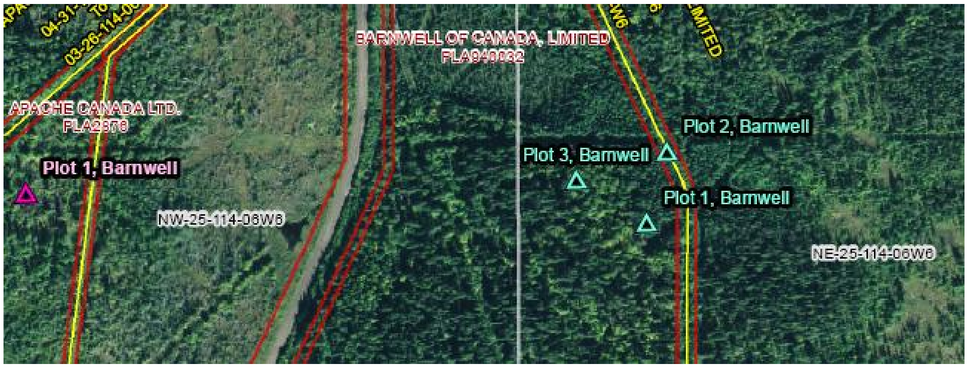


Figure a. Barnwell Plots 1, 2, and 3 (this study, turquoise symbols; magenta symbol is the inaccurate AER location for the spill). Image courtesy of Dene Tha First Nation.

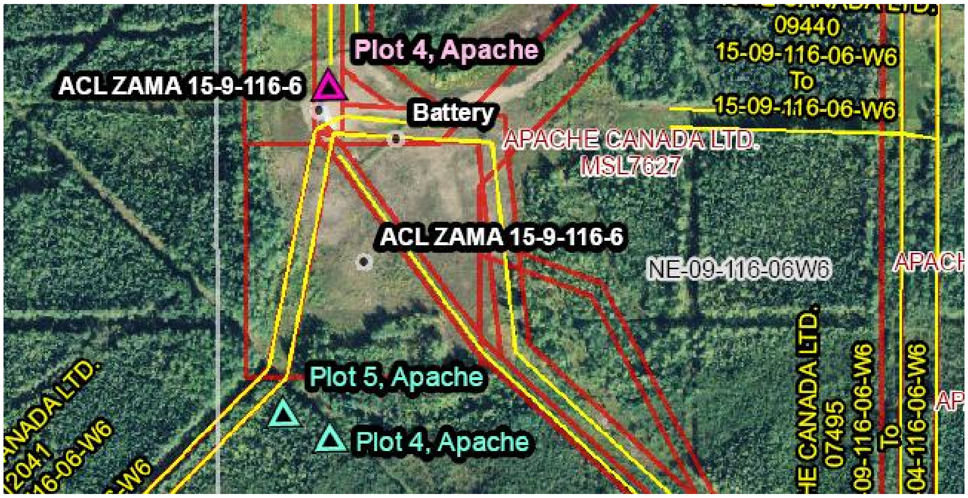


Figure b. Apache 15-09 Plots 4 and 5 (this study, turquoise symbols; magenta symbol is the AER location for the spill). Image pre-dates the spill. Image courtesy of Dene Tha First Nation.

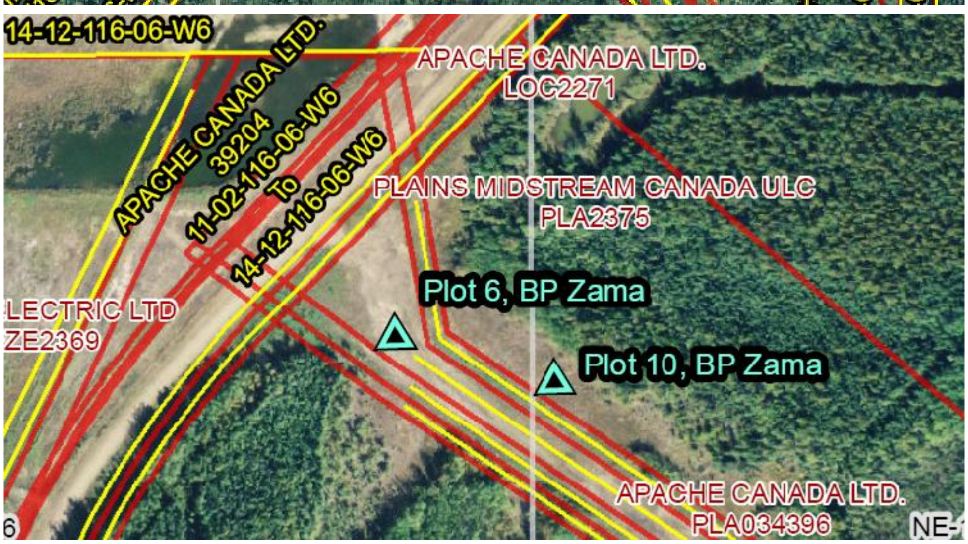


Figure c. BP Zama Plots 6 and 10. Image courtesy of Dene Tha First Nation.

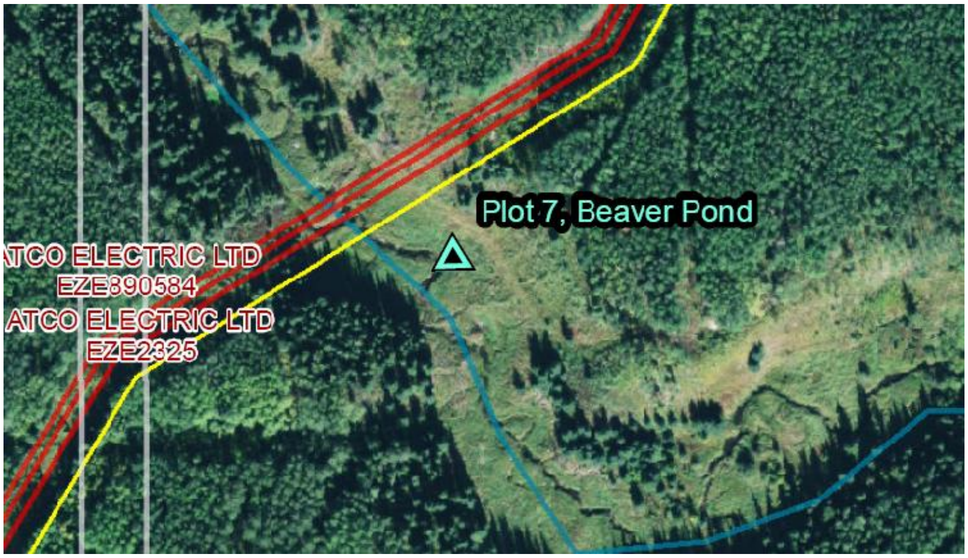


Figure d. Beaver Pond spill. There are no known AER records for this spill. Image courtesy of Dene Tha First Nation.

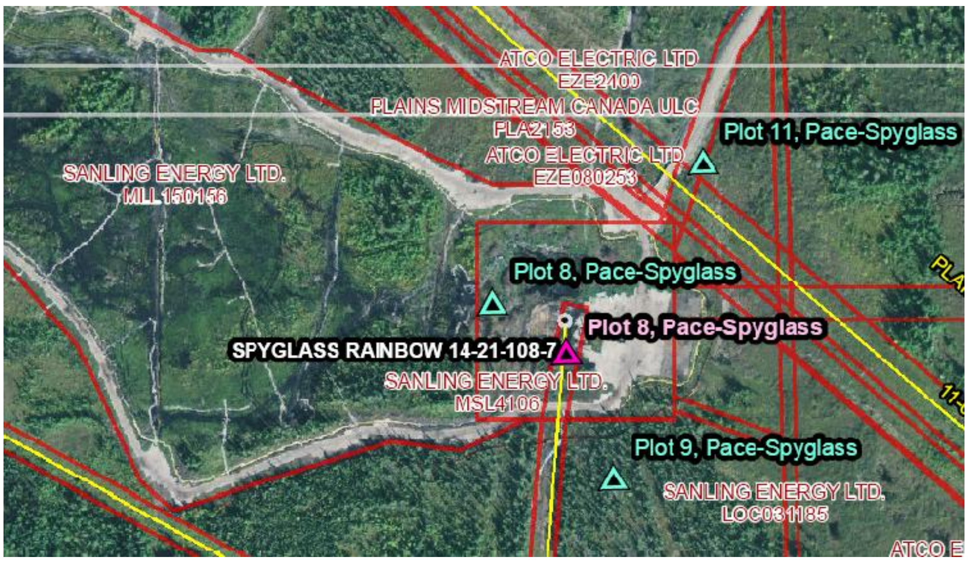


Figure e. Pace-Spyglass Plots 8, 9, and 11 (this study, turquoise symbols; magenta symbol is the AER location for the spill). Note the landscape damage evident after clean-up operations. Image courtesy of Dene Tha First Nation.

Figure f. Amber Site, A1 and A2 (this study, turquoise symbols; magenta symbol is the inaccurate AER location for the site). Image courtesy of Dene Tha First Nation.

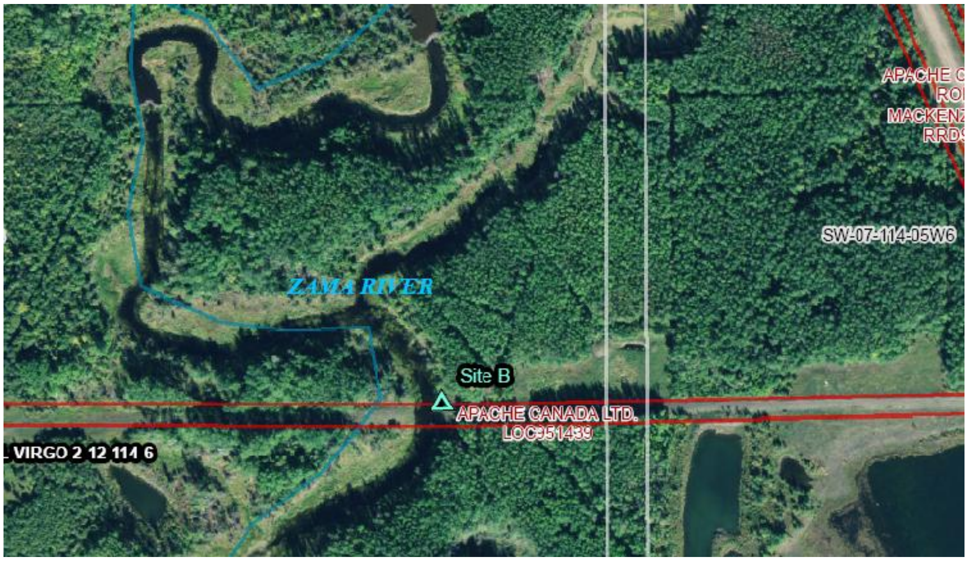


Figure g. Site B historic oil spill observation site. No AER spill records were found for the source well (see Web 2.5q, r). Image courtesy of Dene Tha First Nation.

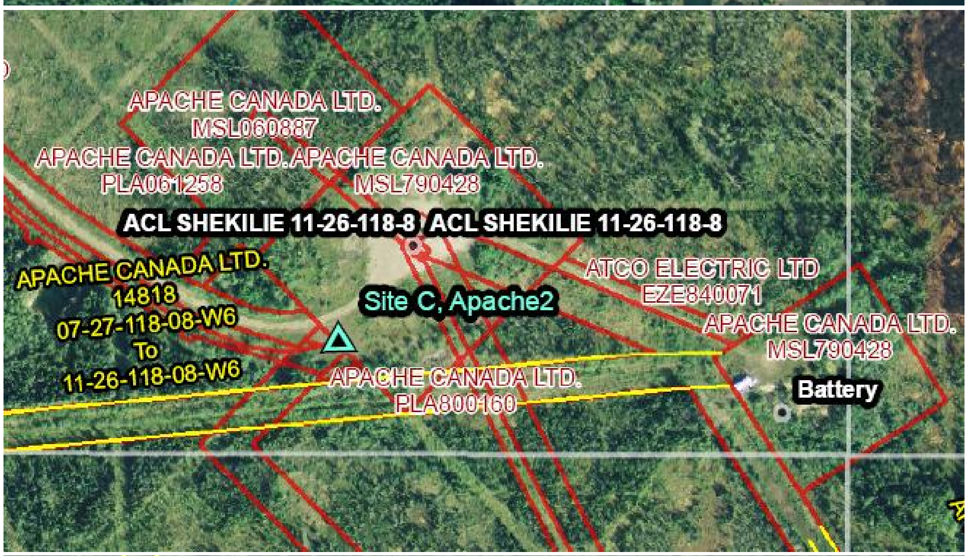


Figure h. Site C, 11-26 Apache spill site. Image pre-dates the spill. Image courtesy of Dene Tha First Nation.

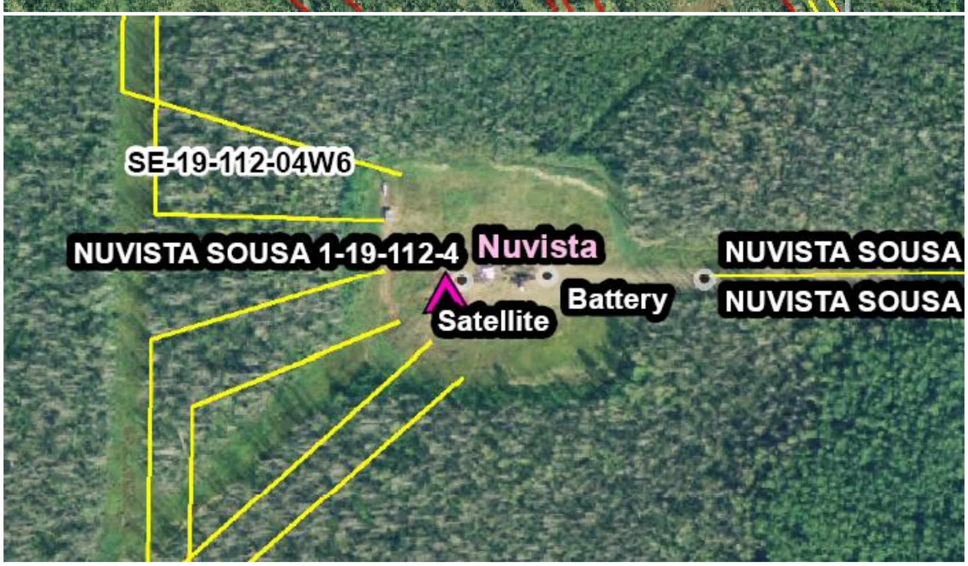


Figure i. Nuvista spill site. Image predates the spill. Image courtesy of Dene Tha First Nation.

Web 2.5. Ground-level and low-level aerial views of the sites.

Figure a. Barnwell saline spill Plot 1, 20 July 2016. Plot center is the pink-flagged pigtail stake highlighted with red octagon symbol. View to north. The ROW and Plot 2 lie near upper right. Plot 3 (control) is located in forest out of view to left. Excavation took place in March 2016. Soil has been exposed for about four months; total vegetation cover on 20 July was trace (< 1 %).

Figure b. Barnwell ROW Plot 2, 20 July 2016. Plot center is the pink-flagged pigtail stake. View to NNW along to the ROW. Total vegetation cover on 20 July was 72 %.

Figure c. Barnwell control Plot 3, 20 July 2016. Plot center is the pink-flagged pigtail stake. View to SSW. Total vegetation cover on 20 July was 118 %.

Figure d. Apache 15-09 saline spill Plot 4, 21 July 2016. Plot center is the pink-flagged pigtail stake. View to NE. Fieldworkers from Northern Alberta Institute of Technology in the background. The saline spill took place in June 2013. Total vegetation cover on 21 July 2016, >/= 3 growing seasons after disturbance, was 5 %. The effects of soil contamination upon the vegetation are evident.

Figure e. Apache 15-09 control Plot 5, 21 June 2016. Plot center is the pink-flagged pigtail stake. View to NW. Total vegetation cover on 21 July was 71 %. This remnant natural control is surrounded by energy disturbance.

Figure f. BP Zama saline spill Plot 6, 21 June 2016. Plot center is the pink-flagged pigtail stake. View to ~ SE along the disturbed pipeline ROW. The Apache Sour Gas Plant “14-12-116-6-W6” is behind the camera and across the road. The site has received multiple saline spills and disturbances over the years.

Figure g. The same BP Zama saline spill Plot 6 on 21 July 2016. Plot center is the pink-flagged pigtail stake. View to ~ SE along the disturbed ROW. The plot was heavily-disturbed by machinery after the June 2016 visit. Total vegetation cover, reduced by recent disturbance, was 19 %.

Figure h. BP Zama control Plot 10, 21 July 2016. Plot center is the pink-flagged pigtail stake. View to ~ SW across the disturbed ROW. Plot 6 and the Apache Sour Gas Plant “14-12-116-6-W6” are out of view to right. Light-toned *Hordeum jubatum* in mid-distance mark the saline linear disturbance. Total vegetation cover was 83 %.

Figure i. Beaver Pond oil spill location (Plot 7) on 24 August 2003, prior to the spill.

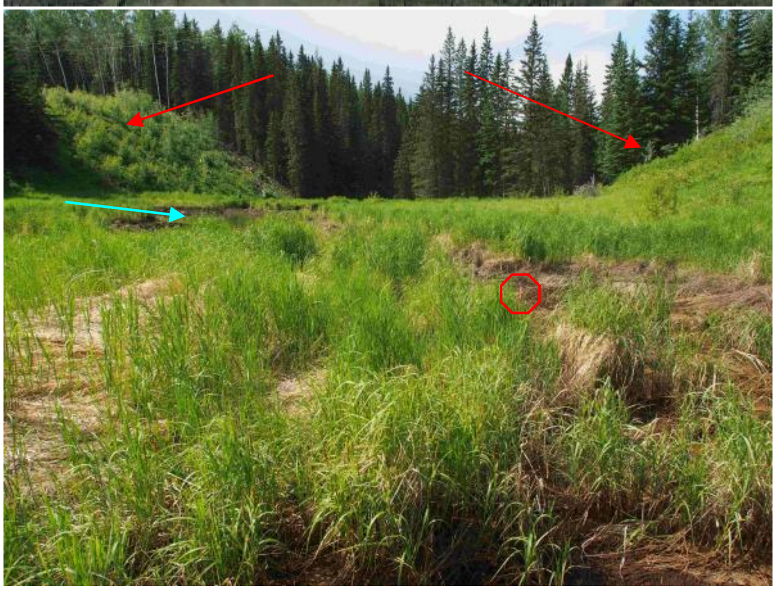


Figure j. Beaver Pond oil spill Plot 7, 21 June 2016. Plot center is at the pink flag. The slope break on the left and right, indicated by the red arrows, is the corridor of the abandoned pipeline and a present power line. A creek flows left to right (indicated by blue arrow) between the slope break and Plot 7. Because AER spill documentation was lacking, this plot was not revisited in July 2016. Approximate total cover on 21 June was 41 %.

Figure k. Pace-Spyglass oil spill Plot 8, 21 June 2016. Plot center is the pink-flagged pigtail stake. View to WNW across the drainage downstream of the spill site. Note the yellow booms intended to contain waterborne oil. The spill source (well head) is located off the image to left. Total vegetation cover, five growing seasons after the spill, on 22 July 2016, was 106 %. Plot 8 is a mixed marsh as a result of combined spill and excavation disturbance. The surrounding area is a bog-fen peatland.

Figure l. Pace-Spyglass bog control Plot 9, 21 June 2016. Plot center is the pink-flagged pigtail stake. View to N across plot center. Note the orange storm fence; this marks the edge of the oil spill containment activities. The spill site is out of view to north. Total vegetation cover on 22 July 2016 was 183 %.

Figure m. Pace-Spyglass marsh-fen transition control Plot 11, 22 July 2016. I am standing at plot center. View to east from road. A high tension powerline, oriented NW-SE, is out of view to right. The spill site is out of view to south. Total vegetation cover on 22 July 2016 was 116 %. Study of airphotos taken soon after the spill in 2012 indicates that this area was disturbed by wheeled vehicles during the spill response.

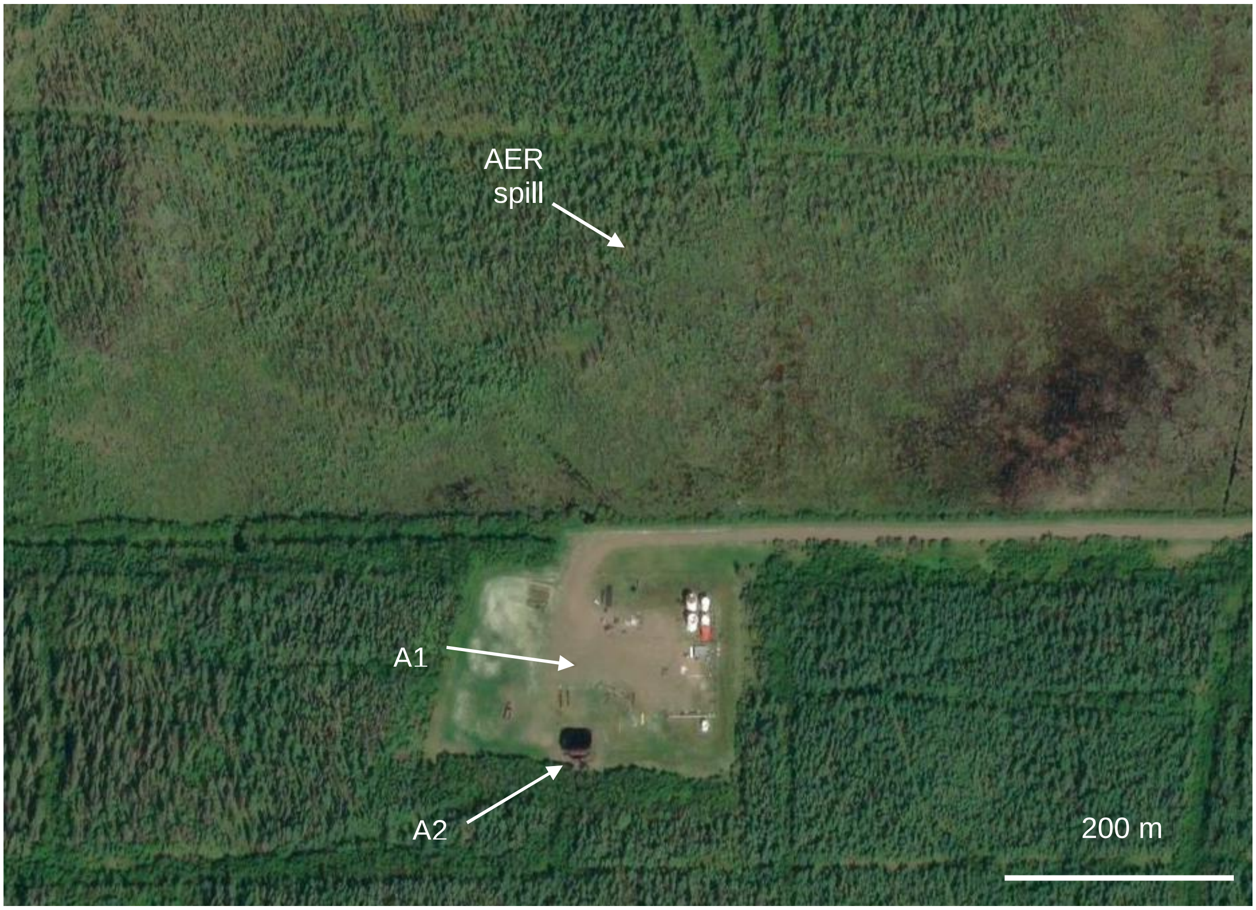


Figure n. Site A, Amber battery and oil spill location with the study plots noted. This is the “Bone Yard”. The site “AER spill” is the erroneous spill location linked to this battery site according to AER. The A2 arrow points to the black oil waste pit and associated oil spill. Image date unknown, from World Image.

Figure o. The Amber site A1 battery. 21 July 2016. The soil here was extremely hard, either through loss of soil structure via salinization or through heavy equipment use, or both. Note the high cover of foxtail barley. The site has a long and complex disturbance history (for background, see Web 8.2).

Figure p. The Amber site A2 oil spill. 21 July 2016. Soil sample (circled) taken from surface (0-5 cm) next to pool of oil that is located 2-3 m outside of oil sump pit. The depressions in the contaminated soil are wood bison tracks.

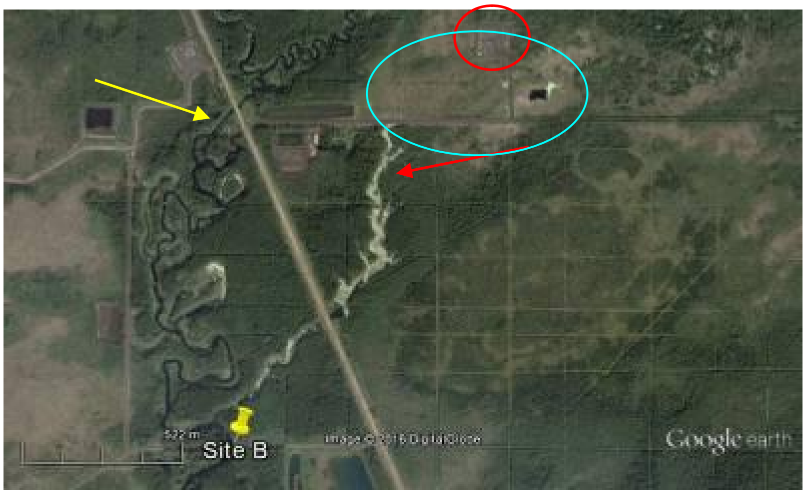


Figure q. Old Man (Zama) Creek observation Site B, downstream and southwest of a major oil spill from the early 1970s missing from AER records. Dene Tha people on site at the time observed the spill emanating from a well site and stated that the oil flowed down the light-toned unnamed creek tributary (red arrow) and into Old Man Creek just north of the Site B (thumbtack). There is an abandoned well site (red circle) at 58º 53’ 29.49” N, 118º 50’ 00.21” W (AER: 14-07-114-05W6). The creek valley near the abandoned well has been obliterated (turquoise ellipse). The yellow arrow points to channelization of Old Man Creek and infilling of former alluvial channels. It is not known when or why this engineering took place. Image 24 August 2003.

Figure r. Site B observation point. The early 1970s oil spill (missing from AER records) took place northeast of here. Oil flowed down the unnamed creek (red arrow) and into Old Man (Zama) Creek. 21 July 2016.

Figure s. Apache2 11-26 saline spill location, Site C. (a) prior to the spill; (b) after the spill and excavation. Image dates are unknown. Note the extensive damage to the area's wetlands.

Figure t. Part of the disturbed area at the Site C Apache2 11-26 saline spill. Sign reads: "Apache Reclaimed Area Do Not Disturb". 21 July 2016. Two soil samples were taken here in September 2016. Three growing seasons after the spill, the joint occurrences of Nuttall's salt-meadow grass and foxtail barley confirm saline soil.

Figure u. View to southeast at the newly-excavated pond at the Apache2 11-26 saline spill. 21 July 2016. Water sample taken, in September 2016. The reddish grass in the distance is the disturbance-adapted tickle grass (*Agrostis scabra*).

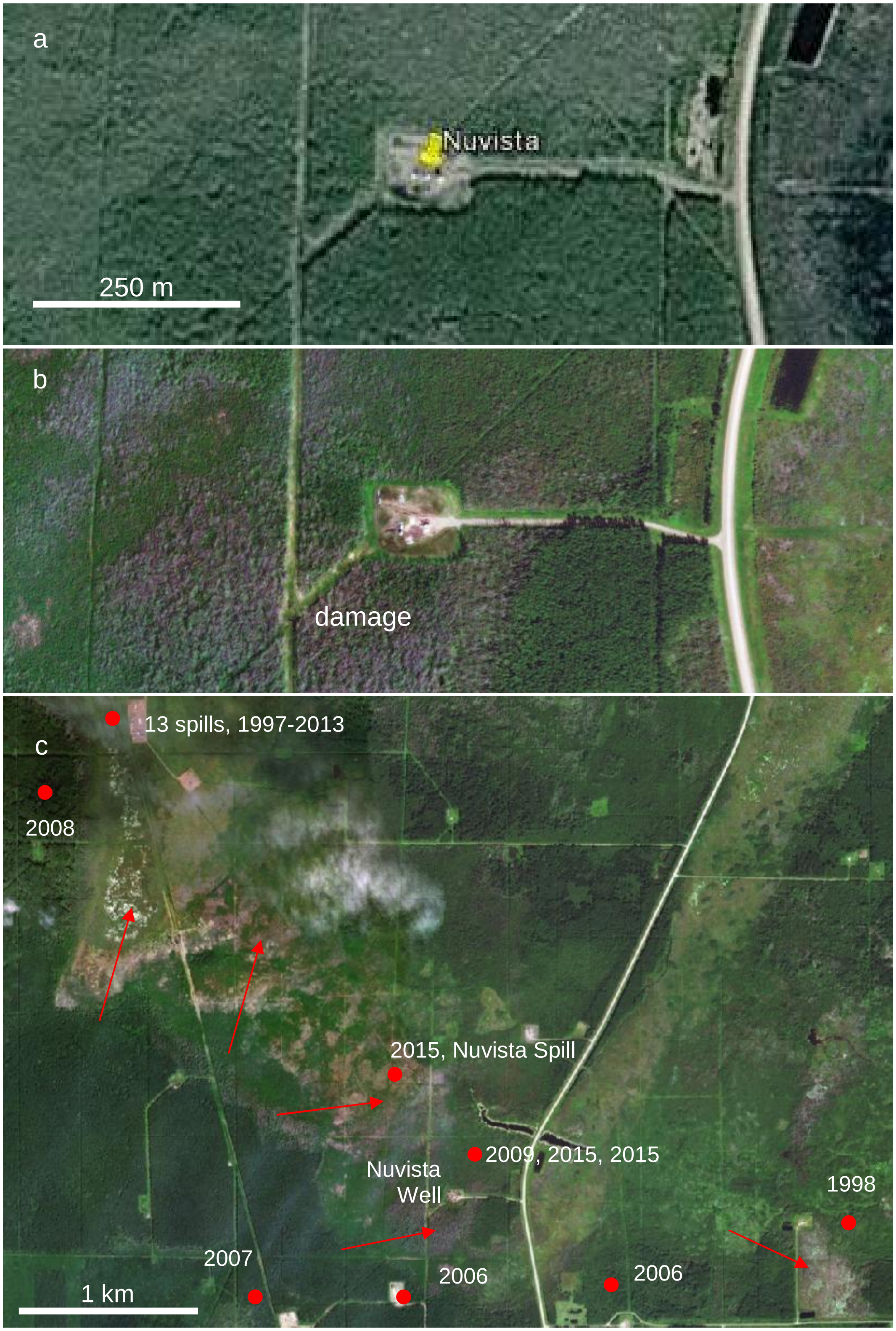


Figure v. The Nuvista well area illustrates a complex history of spills and wetland damage. (a) The well area prior to the spill. (b) The well area some time later. Note the damage to vegetation near the well which may be from another spill. (c) The broader area showing eight AER spill locations (red dots, with years of spills) and a total of 22 spills and extensive areas of unhealthy wetland vegetation as indicated by reddish browns, grays, and mottling (red arrows). The location given for the Nuvista spill lies 700 m northwest of the Nuvista well. The impacts of these spills, roads, pipelines, wells, batteries, and seismic lines have not been investigated.
Image dates are unknown. (a) from Google Earth, (b, c) from Government of the Northwest Territories, Spatial Data Warehouse, World Image.

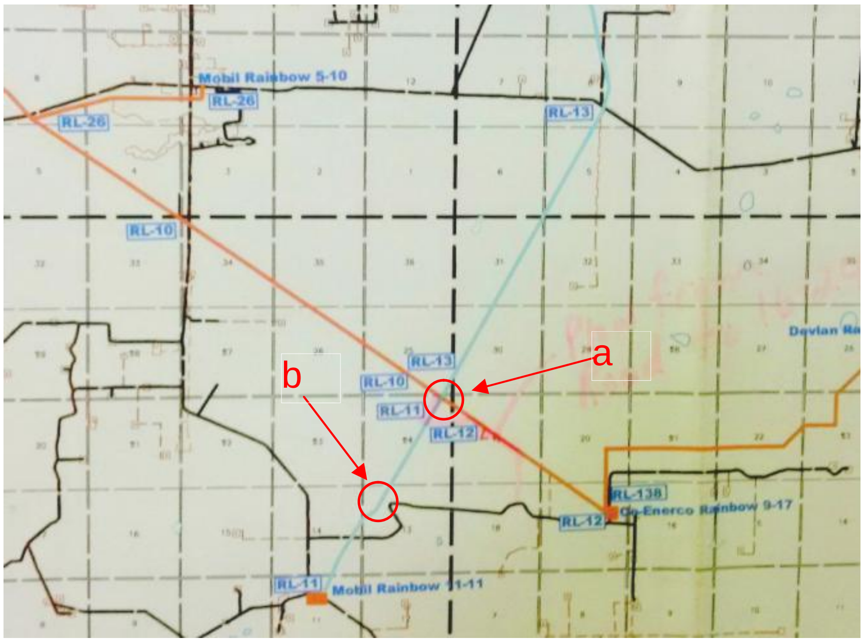
Web 2.6. The Beaver Pond oil spill: A known spill for which the AER has no record.

Despite a concerted effort to find this spill in the regulator's data, no spill records were found for either the site in the Beaver Pond valley (Plot 7) at the pipeline crossing (NW 13-109-06-W6), or for the crossing of pipelines RL-13(RL-11) and RL-10 (NE 24-109-06-W6). The regulator did not explain why no oil spill records exist for these areas.

The following table provides spill information for a crude oil group battery located 4.5 km east of the Beaver Pond spill from 1981 to 2007, sorted by date, volumes in m^3. The Beaver Pond site (Plot 7) is located at NW 13-109-06-W6 (Web 2.5i); the facility is located at 09-17-109-05-W6. The only incident that might be associated with the Beaver Pond spill is set in red font, but the location of the spill is incorrect. Possibly the Beaver Pond spill was never entered into the AER database. In response to the FOIP request, the regulator responded that no records exist.

Incident Number	Incident Date	Incident Complete Date	Source	Failure Type	Release Clean-up Date	Substance Released	Volume Released	Volume Recovered
19810524	6/13/1981	6/16/1981	Crude Oil Group Battery	Equipment Failure	6/16/1981	Crude Oil	32	32
19810933	11/5/1981	10/12/1982	Crude Oil Group Battery	Equipment Failure	10/12/1982	Salt/ Produced Water	11	10
19821029	11/5/1982	11/18/1982	Crude Oil Group Battery	Vandalism / Damage Others	11/18/1982	Crude Oil	8	8
19861457	11/6/1986	8/24/1987	Crude Oil Group Battery	Tank Overflow	8/24/1987	Crude Oil	90	90
19861540	11/25/1986	8/24/1987	Crude Oil Group Battery	Separator	8/24/1987	Crude Oil	32	31
19870860	7/2/1987	8/24/1987	Crude Oil Group Battery	Pump Failure	8/24/1987	Crude Oil	20	20
19880513	3/22/1988	8/15/1988	Crude Oil Group Battery	Operator Error	8/15/1988	Salt/ Produced Water	13	11
19930050	1/5/1993	7/11/1995	Custom Treating Facility	Tank Leak	7/11/1995	Crude Oil	6	5
19941351	5/11/1994	6/28/1994	Crude Oil Group Battery	Equipment Failure	6/28/1994	Salt/ Produced Water	10	8
19992459	11/14/1999	11/15/1999	Crude Oil Group Battery	Equipment Failure	11/15/1999	Salt/ Produced Water	10	10
20000063	1/4/2000	1/25/2000	Crude Oil Group Battery	Equipment Failure	1/25/2000	Salt/ Produced Water	142	0
20001885	7/29/2000	7/31/2000	Crude Oil Group Battery	Pump Failure	7/31/2000	Salt/ Produced Water	4	0
20011595	6/6/2001	6/6/2001	Crude Oil Group Battery	Equipment Failure	6/6/2001	Crude Oil	4	4
20011935	7/17/2001	7/30/2001	Crude Oil Group Battery	Equipment Failure	7/30/2001	Salt/ Produced Water	150	150
20012737	10/27/2001	10/28/2001	Crude Oil Group Battery	Hi Level Switch	10/28/2001	Crude Oil	1	1
20012737	continued--					Salt/ Produced Water	8	8
20013151	12/2/2001	12/3/2001	Water Pipeline	Corrosion Internal	12/3/2001	Salt/ Produced Water	10	10
20030269	1/28/2003	2/1/2003	Water Pipeline	Corrosion Internal	2/1/2003	Salt/ Produced Water	19.8	19.8
20030269	continued--					Crude Oil	0.2	0.2
20040177	1/13/2004	10/8/2004	Crude Oil Group Battery	Equipment Failure	1/13/2004	Salt/ Produced Water	50	50
20040235	1/23/2004	2/26/2004	Crude Oil Group Battery	Line Failure	1/23/2004	Salt/ Produced Water	10	10
20050209	1/19/2005	1/24/2005	Crude Oil Group Battery	Line Failure	1/20/2005	Salt/ Produced Water	1	1
20053000	12/10/2005	2/21/2006	Crude Oil Group Battery	Pump Failure	12/12/2005	Gas Production (Raw)	100	
20053000	continued--					Salt/ Produced Water	10	10
20060455	2/19/2006	12/6/2006	Oil Well	Equipment Failure	2/21/2006	Salt/ Produced Water	14	14

20060685	3/13/2006	4/20/2006	Crude Oil Pipeline	Operator Error	3/15/2006	Crude Oil		10	10
20070620	3/3/2007	3/27/2007	Crude Oil Group Battery	Hi Level Switch	3/3/2007	Fresh Water		11	11
20070620	continued--					Gas Production (Raw)	10,000		
20070620	continued--					Salt/ Produced Water		2	2
20072334	9/26/2007	12/19/2007	Crude Oil Group Battery	Equipment Failure	9/28/2007	Salt/ Produced Water		120	



According to the Dene Tha, the crude oil leak was discovered at (a) with subsequent oil release into the Beaver Pond valley at (b). Map courtesy of B. Metchooyeah, DTFN.

Web 2.7. Additional information on the fieldwork and laboratory methods in northwestern Alberta

Fieldwork

The objectives of the northwestern Alberta fieldwork were to provide environmental data to compare to the AER FIS data for the spills and to assess the condition of sites of concern to the Dene Tha First Nation. Vegetation at the sites included weedy meadow, marsh, fen, bog, conifer forest, and saline barren. Data were gathered to determine whether contaminants remained on site after spill clean-up operations and whether the spill had affected floristic and vegetation composition. At each affected site, and a companion control site, soil and water samples were gathered to determine concentrations of total hydrocarbons and salinity indicators. The composition and cover of vascular and non-vascular plant species were determined at each affected and control site. Animal occurrences and human activities were documented at the sites.

Fieldwork was conducted 20-22 June and 20-22 July 2016. A crew of three (K. Timoney, and the Dene Tha members, B. Metchooyeah, W. Danais) conducted the first round of fieldwork. A crew of four (Timoney, A. Robinson, Metchooyeah, Danais) conducted the second round of fieldwork. Additionally, Dene Tha members G. Didzena accompanied the crew at Sites B and C and J. Chonkolay and N. Chonkolay accompanied the crew at the Pace-Spyglass spill (Plot 8).

We first conducted a reconnaissance survey of spill sites of concern to the Dene Tha First Nation at which we took notes and photographs, established spill and control study plots, and collected soil samples. Based on the laboratory results of the soil samples, our second round of fieldwork involved detailed biological work at the study sites. Additional soil and water samples were gathered by Danais in late August 2016.

Each site was described in relation to geographic location, soil, landform, parent material, drainage, topography, site history, and vegetation. Fieldwork indicated that the footprint of industrial disturbance extended beyond documented spill sites where human activities have affected the environment to varying degrees as a result of soil disturbance, vehicle traffic, seeding, and other intentional activities. Because of this complex disturbance gradient, the industrial sites were subdivided into two site types: those in which a FIS-documented spill of either crude oil or saline water took place, and, generically-disturbed sites in which industrial activities had altered the site but the type(s) and history of the disturbance(s) were undocumented by the regulator.

Categorization into site types resulted in three generically-disturbed sites (Plot 2, Site A1, Site C), six spill sites (Plots 1, 4, 6, 7, 8, Site A2), and five natural control sites (Plots 3, 5, 9, 10, and 11) for which vegetation and soils/water chemistry data were gathered. Study plots, marked by labelled and flagged metal pigtail stakes, measured 0.01 or 0.03 ha (depending on homogeneity of the vegetation) and were either circular or rectangular in shape (depending on the shape of the landform). At each plot, a list of the plant species (flowering plants, lichens, mosses, liverworts) and their percent cover was prepared. Plant specimens were vouchered for later laboratory confirmation as needed. Specimens were confirmed at the University of Alberta Herbarium if required. Photographs and notes were taken at each plot.

A soil surface sample (0-10 cm depth) was analyzed for petroleum hydrocarbon (F1-F4) and salinity (anions, cations, pH, conductivity). Water samples were gathered at two ponds created in the aftermath of saline spills (Plot 4 and Site C) and analyzed for standard water quality indicators. Additional chemistry data on other spill sites were provided by the Dene Tha First Nation.

The natural “undisturbed” sites, given their proximity to industrial activities, should not be seen as entirely free of human influences. Such influences could include off-road vehicle traffic (Plot 11, near Pace-Spyglass oil spill Plot 8), creation of an isolated, small, “natural” vegetation patch surrounded by anthropogenic landscape (Plot 5, near Apache saline spill Plot 4), and semi-natural vegetation on the margin of a pipeline right-of-way (ROW) with a complex disturbance history chosen as the most appropriate comparison for a nearby heavily-impacted site (Plot 10 compared to BP Zama saline spill Plot 6). The need to place natural controls adjacent to affected sites to facilitate direct comparisons meant that “natural” and “undisturbed” were relative terms. Industrially-disturbed sites lie on a continuum from predominantly contaminant disturbance (spilled materials) to predominantly physical-biological disturbance (heavy machinery compaction, excavation, species introduction).

Laboratory Methods

Maxxam Analytics (Edmonton, CALA-certified) conducted the soil assays for benzene, toluene, ethylbenzene, and xylene (BTEX) and F1-F4 hydrocarbons (Canadian Council of Ministers of the Environment, CCME, Tier 1). A silica gel clean-up was employed to remove biogenic hydrocarbons. Concentrations were reported in mg/kg; % recovery of standard surrogates was determined to ensure that concentration data were within acceptable limits. Hydrocarbon chromatograms, which are plots of hydrocarbon concentrations in relation to the number of carbon atoms in the molecules, were produced for F1 and F2-F4 fractions.

The Natural Resources Analytical Laboratory, Department of Renewable Resources, University of Alberta (CALA-certified) conducted the soil assays (saturation paste extraction method) and water assays. Soluble soil chloride, calcium, magnesium, sodium, potassium, sulfate, nitrate, electrical conductivity, and pH ($CaCl_2$) were determined. During clean-up operations at the two Apache saline spills, ponds were created through excavation.

In order to evaluate water quality in those ponds, water samples were analyzed at the Natural Resources Analytical Laboratory (University of Alberta) for a suite of standard water quality parameters including pH, electrical conductivity, sodium, chloride, macro- and micronutrients, and metals.

Analytical Methods

Floristic attributes (native vs. exotic; weedy vs. non-weedy habit; and plant group (vascular, bryophyte, lichen)) were assigned before the analysis. Soil concentrations were determined for a variety of hydrocarbons, chloride, calcium, magnesium, sodium, potassium, sulfate, nitrate, along with electrical conductivity, and pH. Water attributes included pH, electrical conductivity, sodium, chloride, macro- and micronutrients, and a suite of metals. Vegetation and soils data were analyzed by a host of methods (in PC-Ord; see McCune and Mefford 2011) such as non-metric multidimensional scaling (NMS) ordinations, indicator species analysis (ISA), cluster analysis, and row-column summarization (see the glossary and McCune and Grace (2002)).

Laboratory analyses for North-central and Northeastern Alberta, Canol Road, and Rumsey Block are described in Purdy et al. (2005), Kershaw et al. (2013), and Elsinger (2009). In order to make these datasets directly comparable, their data were analyzed by the same techniques that were used for the northwestern Alberta data.

Web 2.7.1 A Demonstration of the Analytical Methods

Science provides a means to query the world's complexity, a set of tools to describe objective reality. To make sense of the world, scientists try to detect patterns and relationships. Modern analytical tools are truly a wonder and for ecologists, ordination and classification are chief among them. The power of these methods is that they can detect meaningful relationships hidden in large amounts of data. They allow us to construct a picture based on information. Not only that, they can tell us how much information our picture explains and conversely how much information remains unexplained.

Both ordination and classification arrange items by the degree of similarity in their characteristics. Items that lie close together are similar; those that lie far apart are dissimilar. To demonstrate how these methods work with a real-world example, I tabulated crude oil and saline spill data from ten energy companies (Web 2.7.2). For illustration purposes, I added "Meancorp" whose attributes were defined from the means (averages) of the six attributes, "Mincorp" whose spill attribute values were assigned to be slightly lower (or better), and "Maxcorp" whose attribute values were assigned to be slightly higher (or worse) than the values observed for the ten real companies.

Husky, Imperial, and CNRL were responsible for most spills. Chevron and BP reported the largest spill volumes. ExxonMobil reported the lowest recovered volumes and lowest % recovery. The delay between the spill and the clean-up was highest for Chevron and was also above average for BP. The proportion of spills that flowed off lease sites was highest for ExxonMobil and lowest for CNRL.

We can make a picture of these data by ranking the values for the spill attributes and conducting an NMS ordination (Web 2.7.3) and a cluster analysis (Web 2.7.4). The ordination provides a picture of the relationships among the energy companies. Companies that lie near one another have similar reported spill records. At a glance, we can see the similarities and dissimilarities between the companies based on data from 13,978 spills and six attributes. "Meancorp"is located in roughly the middle of the two axes and "Mincorp" and "Maxcorp"define the ends of axis 1. Axis 1 is the stronger of the two axes and is significantly correlated with spill recovery efficiency (higher % recovery to the left), percent of spills that flow off the lease site (lower % flowing off lease to left), and median recovery volume (higher volumes to the left).

If we assume that the regulator's data are reliable, each cluster group represents companies with similar spill-related behavior. Apache, Conoco-Phillips, CNRL, and Devon form the largest group characterized by high recovery volumes and high % recovery. "Mincorp" is a unique group representing a best-case scenario for spill attributes. BP, “Meancorp”, and Chevron comprise a third group. Exxon Mobil and “Maxcorp” comprise a fourth group characterized by a high proportion of spills that flowed off the lease sites. Encana, Husky, and Imperial comprise a fifth group.

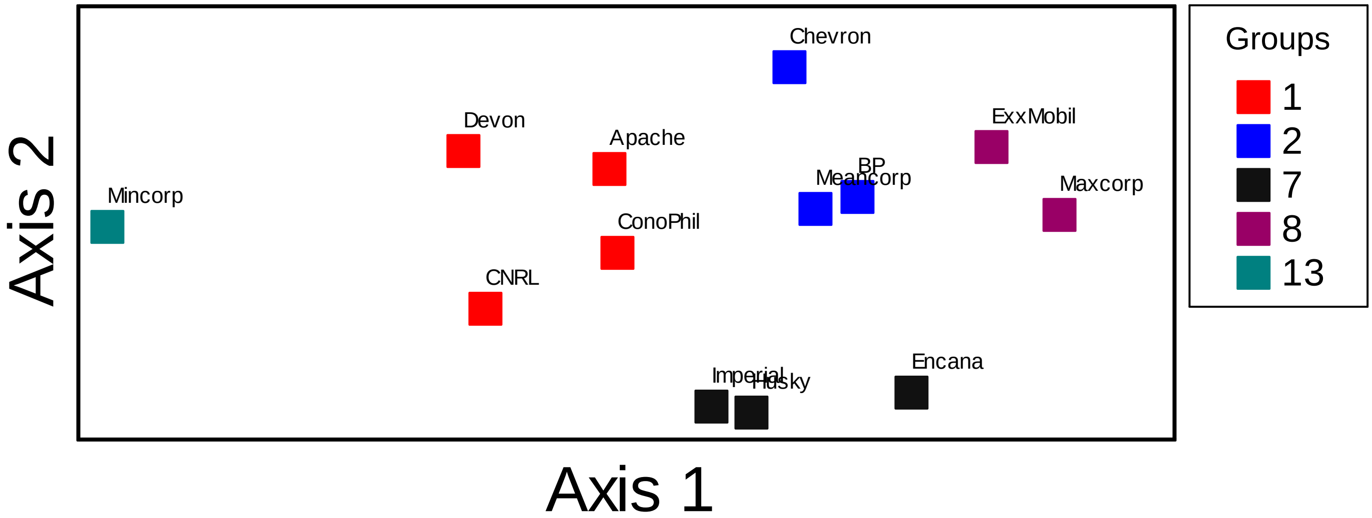
The methods provide an objective assessment of the reported data, but do the data accurately describe reality? That question takes us to a deeper level of study and down a rabbit hole. Are the company differences real or are they due to differences in reporting practices? ExxonMobil’s low spill recovery and high proportion of spills flowing off lease suggest that ExxonMobil is doing a poor job. But spill recoveries of 100 % (i.e., perfect), are not attainable in real world conditions. The truth may be that ExxonMobil’s spill recovery and flow off lease data may be more empirical, and more honest, than the data from the other companies.

We could add attributes in an effort to better understand the similarities and differences between the companies. If we examined total spill volume, we would find that BP and Imperial were responsible for the largest reported total volumes for primary spills of crude oil and saline water (114,744 m^3 and 93,947 m^3 respectively). We could add the proportion of spills for which wildlife/habitat effects were noted and find that Apache and Encana reported the highest rate of effects (2.3 and 1.9 % of spills, respectively) whereas BP, Chevron, and Exxon Mobil reported no wildlife effects at their spills. But we have to be cautious whenever we attempt to reach conclusions. The absence of wildlife/habitat effects for BP, Chevron, and Exxon Mobil is in large part due to missing data: most spills for these companies lack data for wildlife/habitat effects. Moreover, neither the wildlife/habitat effects data nor the reported spill volumes are credible as I show in the main text. Often the data don’t describe the environmental situation for spills; instead they describe the industry and regulatory culture that gave rise to the data.

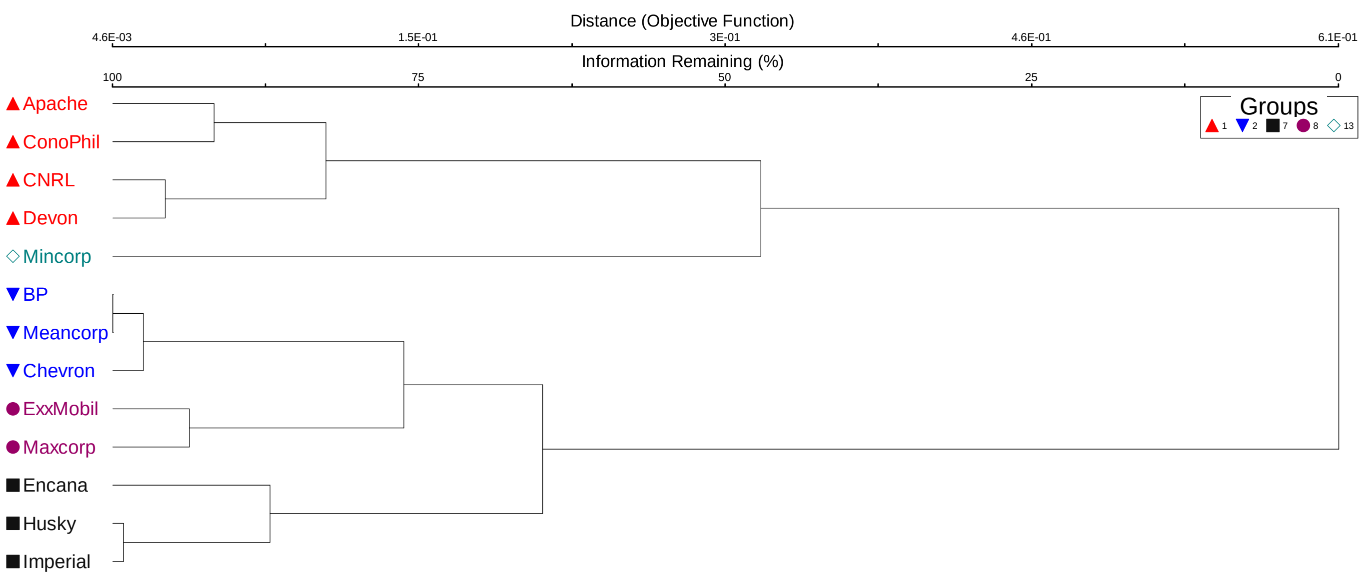
Nothing is ever simple with the AER’s data. It’s long been known that self-reported data are problematic. Therefore I use a variety of methods to assess the data on the journey down the rabbit hole and back into the light. I compare the regulator’s industry-reported data with credible scientific data and subject the data to statistical techniques designed to detect patterns or biased or invalid data.

Web 2.7.2. Spill attributes from the AER FIS database derived from 13,978 primary spills of crude oil or saline water from ten companies. Groups were identified by cluster analysis. “Mincorp”, “Maxcorp” and “Meancorp” were added for illustration purposes.

Company	Spills (n)	Median Spill Volume (m^3)	Median Recovery Volume (m^3)	% Median Recovery	Median Delay between incident and clean-up (days)	% of Spills that flowed off the lease	Cluster Group
Apache Canada Ltd	722	3	3	100	2	49.3	1
BP Canada Energy Company	1948	4	1.7	90	8	61.5	2
Canadian Natural Resources Ltd	2204	3	3	100	1	39.9	1
Chevron Canada Ltd	576	5	2	91.7	31	59.7	2
ConocoPhillips Canada Resources Corp.	652	2	1.4	100	2	46.2	1
Devon Canada Corp.	606	3	3	100	1	44.2	1
Encana Corp.	1619	2	1	85.7	1	51.8	7
ExxonMobil Canada Energy	940	3	0.5	40	2	70.4	8
Husky Oil Operations Ltd	2382	2	1	93.3	2	48.5	7
Imperial Oil Resources Ltd	2329	2	1	100	5	47.5	7
“Mincorp”	500	1	3.5	105	0	35	13
“Maxcorp”	2400	6	0	35	32	75	8
“Meancorp”	1398	2.9	1.8	90.1	5.5	51.9	2



Web 2.7.3. NMS ordination of major energy companies arranged according to six ranked attributes for crude oil and saline water primary spills. We know that the arrangement of the companies conveys information because the two axes are statistically-significant at $p = 0.004$, and 0.008, respectively. The five groups identified by cluster analysis are color-coded.



Web 2.7.4. Cluster diagram of energy companies based on six ranked spill attributes. From left to right, the branches of the classification tree link groups of decreasing similarity. Five groups are identified. These objectively-defined groups form clusters in the ordination (Figure Web 2.7a).

Web 2.8. Example of a FIS record listing the attributes provided for each spill

I first acquired FIS data from investigative journalist Leslie Young for the period January 1975-2013 (pers. comm., June 2013); Global News (2013)). Later, the Alberta Wilderness Association provided me with data for the period 1975-February 2017. After FIS data became available online, I acquired the data for the period 1975 to July 2019.

The left column lists the attributes and the right column lists the value of each attribute from a typical FIS record. Compare this record with the regulator's online reporting in Web 15.2.

Attribute	Example Value
Incident	20110619
IncidentType	Release
Location	12-11-040-24W4
IncidentLSD	12
IncidentSection	11
IncidentTownship	40
IncidentRange	24
IncidentMeridian	4
LicenceNumber	21756
LicenceType	Pipeline Licence
IncidentDate	14-Mar-11
IncidentMonth	3
IncidentDay	14
IncidentYear	2011
IncidentNotificationDate	14-Mar-11
IncidentCompleteDate	12-May-11
Source	Multiphase Pipeline
CauseCategory	Equipment Failure
CauseType	External corrosion
FailureType	Corrosion External
StrikeArea	CLIVE
FieldCentre	Red Deer
LicenseeID	0X0P
LicenseeName	Santonia Energy Inc.
InjuryCount	0
FatalityCount	0
Jurisdiction	Freehold Private Lands
ReleaseOffsite	Yes
SensitiveArea	No
PublicAffected	No affect/Normal Notification
EnvironmentAffected	Air/Land
WildlifeLivestockAffected	No affect
AreaAffected	100 square meters or less
PublicEvacuatedCount	0
ReleaseCleanupDate	15-Mar-11
PipelineLicenceSegmentID	112147
PipelineLicenceLineNo	4
PipeDamageType	Leak

PipeTestFailure	No
PipelineOutsideDiameter(mm)	60.3
PipeGrade	B
PipeWallThickness(mm)	3.91
Substance Released1	Crude Oil
Volume Released1	0.1
Volume Recovered1	0.1
Volume Unit1	m^3
Substance Released2	Salt/Produced Water
Volume Released2	0.2
Volume Recovered2	0.2
Volume Unit2	m^3
Substance Released3	Waste
Volume Released3	0
Volume Recovered3	1
Volume Unit3	m^3
Substance Released4	Air
Volume Released4	0.1
Volume Recovered4	0
Volume Unit4	10^3m3

Web 2.9. North-central and Northeastern Alberta

The sites, distributed from south of Edmonton to the Alberta-Northwest Territories border, were sampled in 2000 and 2001 (Purdy et al. 2005). There were 75 natural vegetation plots and 32 fossil fuel industry reclaimed vegetation plots distributed across 11 sites along moisture and salinity gradients. Plots included emergent marsh, wet meadow, dry meadow, and shrub communities. The data analyzed here included a plant species matrix of 165 plant taxa in 107 plots and a soil quality matrix of 18 soil attributes in 107 plots. The soil attributes included pH, sodium absorption ratio, and electrical conductivity, and concentrations of calcium, magnesium, potassium, sodium, chloride, and sulfate. The data broaden the geographic scope of the field sites and allow us to determine how industry activities have affected vegetation and soil chemistry elsewhere in Alberta.

Web 2.10. Canol Road, Northwest Territories

During World War II, the Canol No. 1 pipeline was constructed in order to carry crude oil south to refineries. A 10 cm diameter above-ground pipe carried crude oil at a rate of about 687 m^3/day. A portion of the pipeline, abandoned in June 1945, was studied by Kershaw et al. (2013). During the period 1947-1953, there was salvage of pipe and machinery; there was no reclamation or mitigation in the area studied. As much as 27,680 m^3 of crude oil were potentially spilled. An estimated volume of 9865 m^3 of crude oil was left in pipelines and pump station surge tanks. Spills occurred as early as November-December 1942 and as late as 1944. For simplicity, the year of spill was set as 1942.

Data from this long-term study of crude oil spills along the Canol Road (courtesy of Dr. Peter Kershaw) provided insight into the long-term effects of crude oil spills in an alpine environment. Vegetation sampling was conducted at the spill sites 35, 55, and 70 years post-spill. The 2012 data (70 years post-spill) comprised 225 plots reporting the percent cover of 116 plant taxa and cover types in three community types: emergent deciduous shrub tundra (135 plots), decumbent shrub tundra (60 plots), and sedge meadow tundra (30 plots) in two treatments: natural controls and crude oil spills (Kershaw et al. 2013). The smell of crude oil was still detectable at the alpine spill sites when sampled in 2012 (L. Kershaw, pers. comm., 9 Feb 2018). Below treeline, the smell of oil was no longer detectable at spill sites, suggesting that the soil microflora and climate conditions above treeline may still inhibit microbial breakdown of the crude oil.

Web 2.11. Rumsey Block, South-central Alberta

Data from a study (Elsinger 2009) of the world's largest remaining tract of native aspen parkland – plains rough fescue landscape were provided courtesy of Mae Elsinger. The Rumsey Block (183 km^2) lies at the transition between the central parkland natural region to the north and the northern fescue natural region to the south. This area of hummocky moraine supports a diverse assemblage of plants, vegetation, and animals. Hydrocarbon exploitation in the area began in the 1970s and continues today while the prospect of coal bed methane development has appeared on the horizon. Tireless work by concerned citizens over the decades has helped to minimize the impacts of agriculture and the fossil fuel industry on this ecologically important area.

In an effort to assist in managing the Rumsey Block's ecological diversity, Elsinger (2009) conducted a comparative study of the vegetation and soils of 17 pipeline ROWs and 36 well sites with the adjacent undisturbed upland native grasslands. Fieldwork was conducted in 2006 when the cover of vascular plant species (69 total species, 58 native, 11 exotic) was determined in ten plots at each site accompanied by soil measurements and soil collection for subsequent laboratory analyses. Soil, site, and vegetation data from the Rumsey Block study were analyzed to provide an overview of species assemblages, species richness, total plant cover, and soil attributes at pipelines, well sites, and controls. These data provide insight into the effects of fossil fuel industry disturbances independent of the effects of spills.

Web 2.12. The Alberta Energy Regulator FIS spill and other data files.

The strengths of the AER's database include the large number of spills; the large number of attributes for each spill; its capacity to provide quantification of spill rates with regard to substance, source, region, time, volume spilled, and volume recovered; and the insight that the data provide into the ecological knowledge and culture of the regulator. Weaknesses of the database include inaccurate spill locations; the lack of empirical evidence to support the data; that spill volume and recovery volumes proved to be influenced by human bias and were unsupported by science; that there are a large number of missing spills; and that attributes such as environment type, sensitive area, size of area affected, and wildlife habitat impacts proved to be underestimates or were poorly-defined, undefined, blank, or inconsistently applied. These weaknesses were not immediately apparent; they were uncovered during analyses and point to significant environmental and social liabilities.

Analytical methods used to evaluate the regulator's data included graphing, mapping, tabulation, tests for differences (Mann-Whitney, Kolmogorov-Smirnov, and chi-square), Benford analysis, and correlation.

Web 2.13. Notes on the map of spills for Alberta, Saskatchewan, North Dakota, and Montana (book Figure 2.3)

The map plots the occurrence of all recorded upstream production spills in Alberta (1975-2019), North Dakota (2006-2014), and Montana (1997-2019). The map for Saskatchewan spills is incomplete. Although there were 19,511 spills reported (1990-2018), I couldn't obtain geographic location data for non-pipeline spills prior to 2000 and for non-pipeline spills 2016-2018. Figure 2.3 does not plot National Energy Board spills.

The map in *Hidden Scourge* is most useful as a guide to the broad geographic patterns in spill occurrence.

Maps of upstream production spills provide a minimum estimate of the number and geographic extent of spills for four reasons: (1) More spills occur than are reported. (2) Sites receive multiple spills, so what looks like a single spill can actually represent dozens of spills. (3) Many thousands of spills occurred prior to commencement of records. (4) Spills continue to occur every day in all jurisdictions; a map of spills is out of date before the ink dries. For more detailed spill maps for each jurisdiction along with maps of all Alberta industrial wells, please see the file: "Spills Maps" in this information package.

Web 3. Statistical summaries of spills in Alberta, Saskatchewan, and North Dakota

Web 3.1. Alberta fossil fuel industry primary spills reported by substance spilled in the Alberta Energy Regulator FIS (Field Inspection System) database, from 1 January 1975 to 6 February 2017 and to 30 June 2019, change over the intervening 28 months, sorted by substance.[a]

Dataset Substance	to Feb 2017 Spills (n)	to June 2019 Spills (n)	Change [e] (n)	Dataset Substance	to Feb 2017 Spills (n)	to June 2019 Spills (n)	Change [e] (n)
acid	112	126	14	hydrogen sulphide	108	269	161
acid gas	92	96	4	hydrotest fluids (methanol)	209	222	13
air	140	145	5	KCl (potassium chloride)	1	1	0
ammonia	3	3	0	kerosene	17	20	3
bitumen slurry	53	157	104	leachate	2	4	2
boiler blowdown water	81	92	11	lime sludge	11	15	4
brackish water	9	21	12	liquid petroleum gas	24	25	1
butane	6	10	4	liquid waste	17	26	9
carbon dioxide	20	24	4	lubricants	130	148	18
cement	43	44	1	methane	12	13	1
chemicals	466	531	65	methanol	90	133	43
chlorides	5	6	1	nitrogen	85	130	45
chlorine	1	3	2	oily sludge	79	83	4
condensate	1563	1658	95	ozone depleting substance [c]	1	2	1
contaminated surface water	323	788	465	pentanes plus [d]	5	5	0
corrosion inhibited water	39	49	10	polymer	0	2	2
crude bitumen	1206	1264	58	process water	1113	1421	308
crude oil	24,948	25,403	455	produced sand	61	63	2
diesel oil	275	310	35	production gas (marketable)	3483	3546	63
dilbit	7	17	10	production gas (raw)	7641	7992	351
diluent	20	33	13	propane	41	46	5
drilling mud (hydrocarbon based)	239	256	17	rags (oily)	1	1	0
drilling mud (water based)	1121	1489	368	salt (inorganic)	7	8	1
emulsifiers	48	49	1	salt/produced water	15,803	16,175	372
ethane	11	13	2	sewage	4	20	16
field blank (unknown substance)	1688	2046	358	solvent	14	16	2
frac oil	205	205	0	steam	10	18	8
frac sand	16	18	2	steam condensate	42	70	28
frac water	290	301	11	sulfur	83	105	22
fresh water [b]	5623	6106	483	sulfur dioxide	8	29	21
fuel gas	169	184	15	sweetening agent	20	26	6
gasoline	17	19	2	synthetic crude oil	79	80	1
gel chemicals	29	29	0	tailings	235	321	86
glycol	129	144	15	total hydrocarbons	24	179	155
gypsum	1	6	5	transformer oil	3	13	10
heating oil	22	25	3	used oil	63	79	16
heavy metals	0	1	1	waste	1526	1954	428
hydrogen	16	44	28				

[a] There were 103,669 total substance releases, composed of 74,975 primary, 21,232 secondary, 5770 tertiary, and 1692 quaternary spills. The 75 *ad hoc* substance categories are presented verbatim as reported by the AER. Some categories are ambiguous, such as “chemicals”, or overlap with other categories such as “hydrotest fluids (methanol)” vs. “methanol”. A

more consistent classification of spill substances would be helpful, but it would require access to records that are unavailable outside the regulator. The lack of quality control in the reporting of substances introduces needless uncertainty. See the glossary for more information.

[b] "fresh water" spills contained 43 other named substances; in these complex "fresh water" spills, the most common secondary substances were salt/produced water, waste, raw production gas, and crude oil

[c] spills of ozone-depleting substances are relatively common in Alberta Environment's EMS database (see Timoney and Lee 2013)

[d] "pentanes plus" is a mix of hydrocarbons containing molecules with 5 or more carbons; they are a synonym for "condensate"

[e] For several substances, the number of spills increased significantly between Feb 2017 and June 2019. For example, bitumen slurry, contaminated surface water, unnamed substances (blank records), hydrogen sulphide, process water, tailings, and total hydrocarbons. Why this is so is unclear but the increases could be due to either or both an increased number of incidents or changes in bookkeeping.

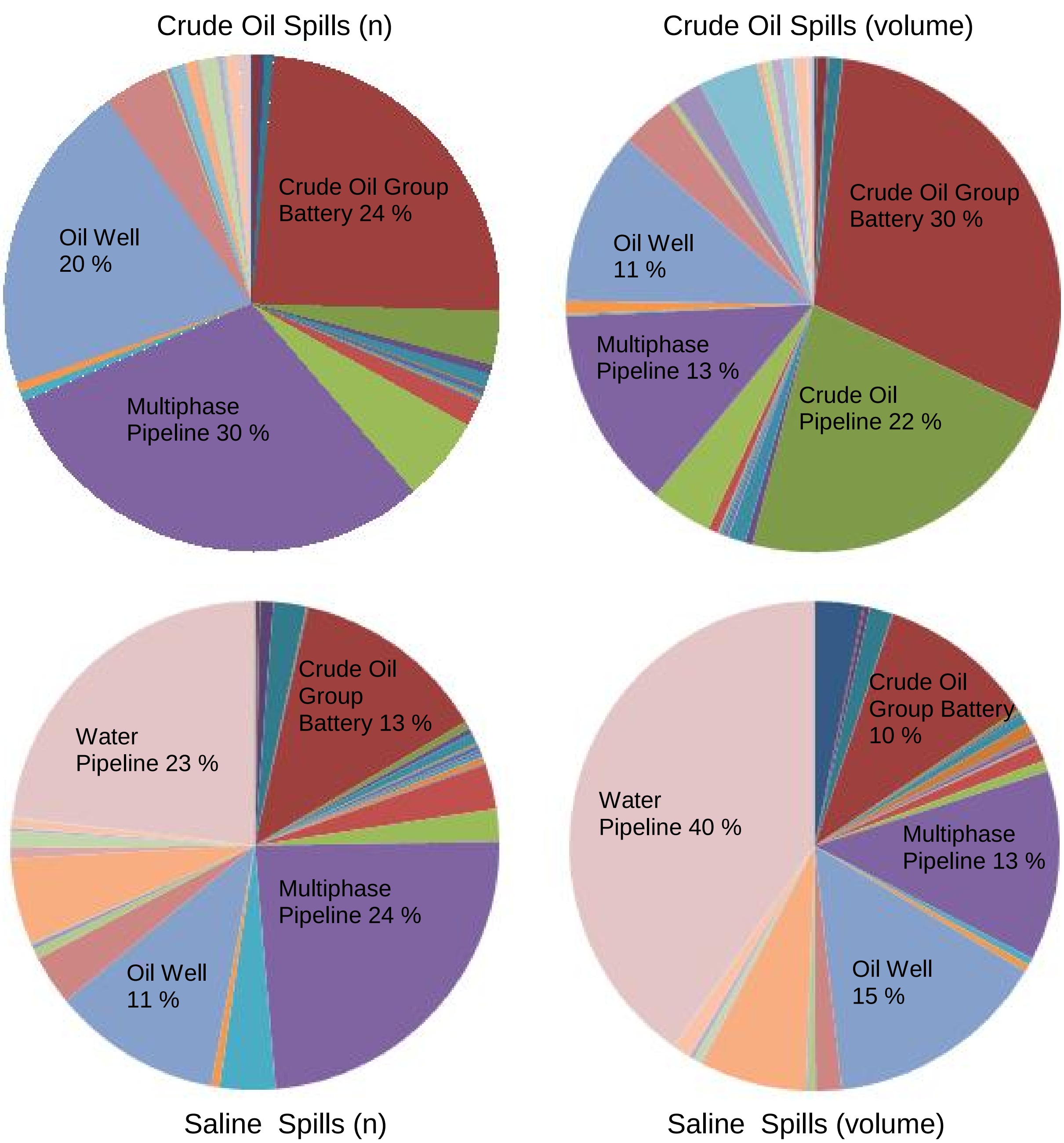
Web 3.2. Frequency and release volume of Alberta crude oil and saline spills by source of spill, 1 January 1975 to 30 June 2019 as reported in the Alberta Energy Regulator FIS database.

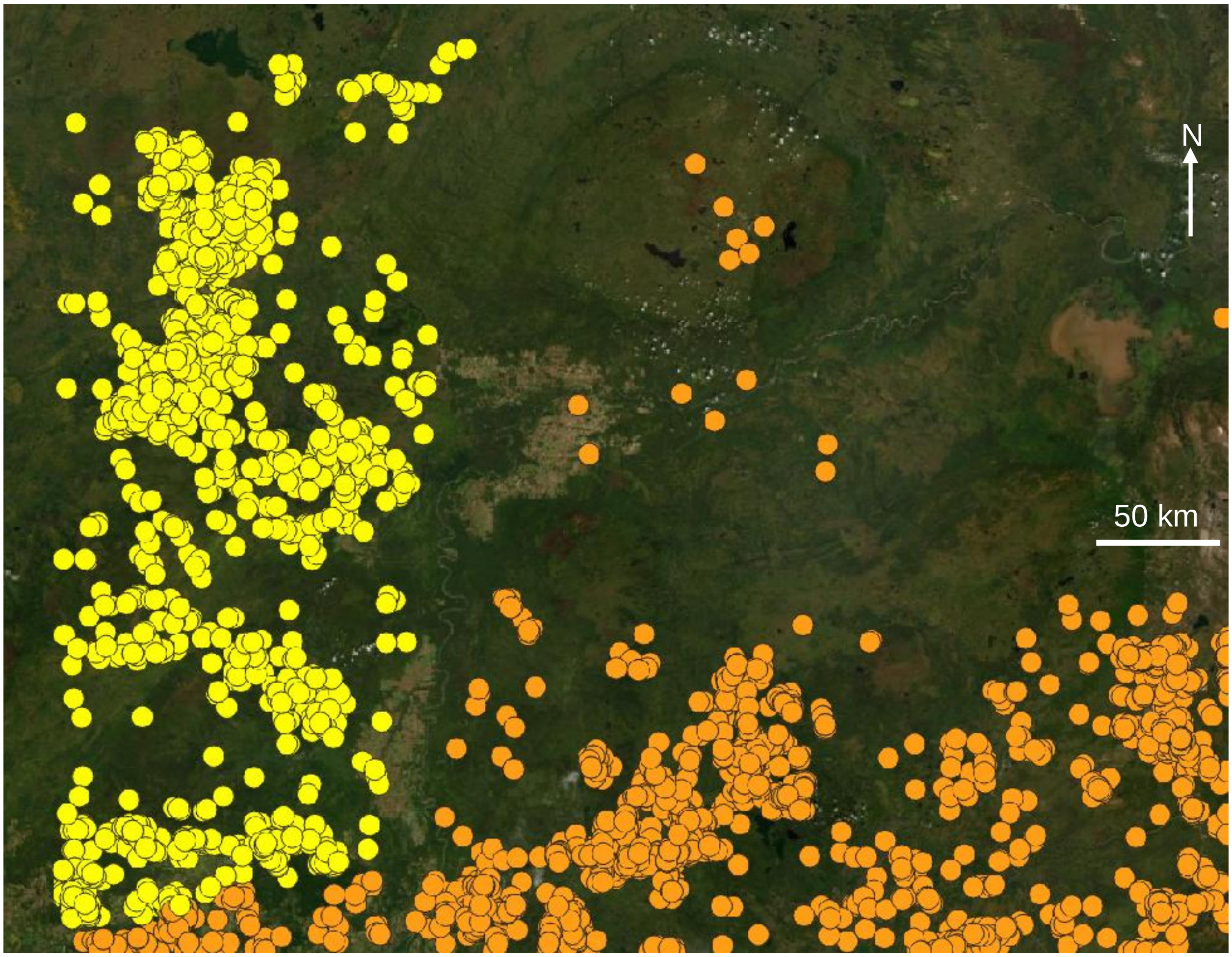
See Web 3.2.1.

Source of Spill	Crude Oil Spills (n)	Crude Oil Volume (m^3)	Saline Spills (n)	Saline Volume (m^3)
abandoned well	40	675	49	31078
blank “source” data field	102	1864	41	1133
CBM (coal bed methane) gas well	0	0	7	41
compressor station	102	311	231	3080
crude bitumen group battery	169	2636	583	14880
crude bitumen paper battery	4	37.1	12	154
crude bitumen single battery	16	100	21	266
crude oil group battery	7296	87770	3508	101246
crude oil pipeline	1063	63743	127	2294
crude oil single battery	190	1447	103	1539
custom treating facility	271	3321	188	6495
drilling well	26	138	37	8464
gas plant fraction sour	1	3	11	1035
gas plant straddle	0	0	1	28
gas plant sulphur recovery	41	438	45	2366
gas plant sweet	86	667	83	740
gas plant acid gas flaring/injection	65	543	89	1155
gas proration effluent battery	56	250	109	899
gas single battery	24	95	27	237
gas well	502	1871	798	10967
miscellaneous	1676	11733	576	7219
multiphase pipeline	9059	38486	6427	122214
natural gas pipeline	191	390	988	4625
oil sands plant	173	2538	145	4699
oil well	6182	32920	3008	142932
oil/bitumen satellite	1266	10404	884	16704
other injection / disposal	50	1083	184	4332
other pipeline	66	5671	71	639
pump station	276	11386	31	1109
service well	223	919	1541	68411
shale gas well	2	10.1	3	742
sour gas pipeline	62	269	180	773
suspended well	381	1411	301	4422
sweet drilling well	79	2207	50	3405
tank farm / oil terminals	79	2111	15	160
unknown	257	2574	159	11237
waste plant	19	194	21	269
water pipeline	233	952	6218	392211

Comments: Overall, pipelines (of all kinds) are responsible for 35.2 % of crude oil spills, 37.6 % of crude oil spill volume, 52.1 % of saline spills, and 54.8 % of saline spill volume.

Web 3.2.1. The predominant sources of crude oil and saline spills in Alberta.





Web 3.3. Primary spills (2910 spills, yellow dots) in the territory of the Dene Tha First Nation in northwestern Alberta as of June 2019.
Orange dots are primary spills outside of the Dene Tha First Nation territory.

Web 3.4. Top 15 companies responsible for crude oil and saline spills in Alberta, sorted by number of spills and volume of spills in relation to spills from all companies.*

Crude Oil Spills				Saline Spills			
N	**Company**	**Volume (m^3)**	**Company**	**N**	**Company**	**Volume (m^3)**	**Company**
1899	Imperial	26728	BP	2023	Husky	129678	Imperial
1830	Husky	16933	Imperial	1800	CNRL	97155	BP
1641	CNRL	13314	Husky	1608	Imperial	50549	CNRL
1347	Encana	12374	CNRL	1384	Encana	49489	Encana
1254	Obsidian	8090	Encana	1295	Obsidian	46693	Repsol
1109	BP	6293	Chevron	1222	BP	40974	Husky
884	Petro-Canada	5735	Gulf	906	ExxonMobil	37781	Chevron
728	Repsol	5453	Obsidian	792	Repsol	34407	Obsidian
700	ConocoPhillips	5347	Repsol	646	Paramount	29342	ExxonMobil
616	Renaissance	5287	Petro-Canada	608	Renaissance	26451	Paramount
606	Paramount	5156	Anadarko	565	ConocoPhillips	17114	Gulf
562	ExxonMobil	4419	ExxonMobil	499	Petro-Canada	15282	Shell
510	Anadarko	4111	ConocoPhillips	395	Chevron	13599	ConocoPhillips
478	Chevron	3167	Unknown	365	Shell	13462	Petro-Canada
406	Unknown	3102	Paramount	358	Anadarko	13169	Renaissance
14570	Total of Top 15	125510	Total of Top 15	14466	Total of Top 15	615145	Total of Top 15
30329	All Companies	291164	All Companies	26872	All Companies	983378	All Companies
48.0	Top 15 Companies (%)	43.1	Top 15 Companies (%)	53.8	Top 15 Companies (%)	62.6	Top 15 Companies (%)

* see Web 6.20 for details; values for 1975-2019

Web 3.5. Top 15 companies responsible for crude oil and saline spills in Saskatchewan, sorted by number of spills and volume of spills in relation to spills from all companies. *

Crude Oil Spills				Saline Spills			
N	**Company**	**Volume (m^3)**	**Company**	**N**	**Company**	**Volume (m^3)**	**Company**
1757	Husky Oil	11120	Husky Oil	1583	Husky Oil	26303	Husky Oil
815	CNRL	6787	CNRL	955	CNRL	19752	Nexen
751	Crescent Point	5326	Enbridge	859	Nexen	19255	Crescent Point
458	Wascana Energy	4721	Nexen	779	Crescent Point	17069	CNRL
412	Nexen	4395	Wascana Energy	574	Repsol	13925	Wascana Energy
398	Obsidian	4340	Baytex	506	Wascana Energy	13447	Petro-Canada
383	Repsol	3512	Crescent Point	479	Obsidian	11822	CNR Petro Resources
378	Baytex	2219	Obsidian	319	Baytex	11619	Repsol
268	Penn West	1863	CNR Petro Resources	303	Saskatchewan Oil and Gas	10933	Saskatchewan Oil and Gas
215	Saskatchewan Oil and Gas	1725	Repsol	281	CNR Petro Resources	10694	Obsidian
197	Enbridge	1579	Penn West	268	Pan Canadian Petroleum	9976	NAL
193	CNR Petro Resources	1430	Saskatchewan Oil and Gas	235	Penn West	8835	Cona Resources
181	NAL	1079	Koch	218	NAL	6571	Penn West
98	Cona Resources	1070	Murphy	158	Cona Resources	4487	Paramount
93	CS Resources	1056	Cona Resources	157	Pemoco	4473	Pan Canadian Petroleum
6597	Total of Top 15	52222	Total of Top 15	7674	Total of Top 15	189161	Total of Top 15
11644	All Companies	88733	All Companies	12592	All Companies	299803	All Companies
56.7	Top 15 Companies (%)	58.9	Top 15 Companies (%)	60.9	Top 15 Companies (%)	63.1	Top 15 Companies (%)

* values for 1990-2018

Web 3.6. Top 15 companies responsible for crude oil and saline spills in North Dakota, sorted by number of spills and volume of spills in relation to spills from all companies. *

Crude Oil Spills				Saline Spills			
N	**Company**	**Volume (m^3)**	**Company**	**N**	**Company**	**Volume (m^3)**	**Company**
508	Continental Resources	3466	Tesoro	378	Continental Resources	4371	Arrow
488	Hess Corporation	2412	Continental Resources	273	SM Energy	4335	Zenergy
290	Whiting Oil & Gas	1758	BNSF	239	Hess Corporation	3872	Denbury Onshore
262	EOG Resources	662	Whiting Oil & Gas	204	Whiting Oil & Gas	2991	Continental Resources
202	SM Energy	660	Enbridge Energy	134	Encore Energy	1937	Petro Harvester
172	ExxonMobil/XTO	540	Denbury Onshore	126	Oxy	1693	Whiting Oil & Gas
168	ConocoPhillips/Burlington Resources	522	Hess Corporation	118	Denbury Onshore	1491	Oasis Petroleum
160	Encore Energy	489	Petro-Hunt	99	ConocoPhillips/Burlington Resources	1427	SM Energy
152	Oasis Petroleum	448	Oasis Petroleum	94	Petro-Hunt	1321	Encore Energy
121	Denbury Onshore	443	SM Energy	93	Kodiak Oil & Gas	1070	Hess Corporation
119	WPX	423	Newfield Production Company	92	EOG Resources	1002	Petro-Hunt
109	Oxy	419	Encore Energy	72	Zenergy	955	Citation Oil & Gas
105	Petro-Hunt	376	Slawson Exploration	68	ExxonMobil/XTO	936	Kodiak Oil & Gas
104	HRC Operating	344	Citation Oil & Gas	67	Oasis Petroleum	634	Marathon Oil
95	Citation Oil & Gas	338	Murex	65	Citation Oil & Gas	622	Mbi
3055	Total of Top 15	13300	Total of Top 15	2122	Total of Top 15	28657	Total of Top 15
4853	All Companies	20596	All Companies	3354	All Companies	41567	All Companies
63.0	Top 15 Companies (%)	64.6	Top 15 Companies (%)	63.3	Top 15 Companies (%)	68.9	Top 15 Companies (%)

* values for 2006 to 13 October 2014; there was no adequate way to pro-rate the values to end of 2014 (see Web 6.18.4)

Web 4. Quantifying the effects of spills

Web 4.1. Canada-wide standards for acceptable concentrations of petroleum hydrocarbons in soil. Values in mg/kg, from CCME (2008a).

Land Use	Soil Texture [a]	F1 [b]	F2	F3	F4
Agricultural	Coarse	30[c]	150	300	2800
Agricultural	Fine	210 (170)[d]	150	1300[e]	5600
Residential/ Parkland	Coarse	30[c]	150	300	2800
Residential/ Parkland	Fine	210 (170)[d]	150	1300[e]	5600
Commercial	Coarse	320 (240)[d]	260	1700	3300
Commercial	Fine	320 (170)[d]	260 (230)[d]	2500	6600
Industrial	Coarse	320 (240)[d]	260	1700	3300
Industrial	Fine	320 (170)[d]	260 (230)[d]	2500	6600

[a] coarse soil defined as median grain size > 75 µm, fine soil median grain size ≤ 75 µm; For wildlands, Alberta has opted to apply the agricultural land use guidelines; for wildland organic soils, it applies the coarse soil texture guidelines (Dinwoodie, pers. comm., 2 August 2016)

[b] F1 C6-C10, F2 C11-C16, F3 C17-34, F4 C35+

[c] assumes contamination near residence

[d] where applicable for protection of potable groundwater

[e] based on acute exposure to three plant species and three invertebrates, 25th percentile effects level for “nominal” exposure (CCME 2008b); when the same effects levels was used for the three invertebrates, and for the “initial” realized exposure level, the acceptable level for F3 was 250 mg/kg

Web 4.2. Comments on CCME petroleum hydrocarbon guidelines

I wrote the Canadian Council of Ministers of the Environment to enquire about the lack of natural habitat and organic soil guidelines for petroleum hydrocarbons. On behalf of CCME, Dinwoodie (pers. comm., Alberta Environment and Parks, 2 August 2016) explained that, in the absence of such guidelines, Alberta has adopted the same ecological guidelines for natural areas as for agricultural land use. He explained that Alberta allows "the application of coarse-textured CWS PHC guidelines to organic soil. PHC will sorb readily to organic soil, yet the mobility of dissolved components may be similar to coarse textured soils. In the absence of toxicity and fate and behaviour data specifically for organic soils, application of coarse textured guidelines offers a practical alternative to no guidelines at all."

A single "acceptable" concentration for an F1-F4 fraction can never serve as a Canada-wide standard. Biological sensitivity to contaminants is a function of exposure duration, hydrocarbon concentration, constituents of the hydrocarbon fraction, species exposed, genetics, paths of exposure, ecosystem processes, rhizosphere, mycorrhizal relationships, and underlying stressors such as climate change, other pollutants, or disease.

A more protective approach would be to apply guidelines that protect the most sensitive species in an ecosystem under chronic exposure. Microcosm and mesocosm studies of real world ecosystems will be required to develop petroleum hydrocarbon guidelines that are truly protective. In the meantime, empirical data on community composition at control sites and at spills of known duration and concentration might be useful to determine safe levels of soil petroleum hydrocarbons.

Despite the shortcomings of CCME hydrocarbon guidelines, they form the basis for the regulatory environment. In Alberta, the CCME acute exposure guidelines have been applied for assessment and remediation at contaminated sites since 2001, most commonly at upstream oil and gas facilities and petroleum storage tank sites (CCME 2014). Given that the guidelines are used to determine whether a site requires remediation, use of acute exposure guidelines is not defensible. If a site is not remediated, the ecosystem and its species are exposed to chronic, not acute, exposure.

Currently, the guidelines might do more harm than good in that they lend an aura of regulatory compliance to activities that are harmful to ecosystems. Concerns about the appropriateness of the guidelines appear in some publications (e.g., ECASG 2006), indicating that environmental protection is not being served by short-term growth, yield, and reproduction-related guidelines and that socio-economic considerations (costs to industry) have played a large role in defining the guidelines.

The standards don't consider natural ecosystems; instead, they report standards for agricultural, residential/parkland (e.g., municipal parks), commercial, and industrial lands. There are no standards for the soils in which most petroleum spills occur in Alberta.

The standards focus on protection of human health, rather than protection of ecosystems. They provide little guidance as to what levels of petroleum hydrocarbons are protective of ecosystem structure, function, vegetation, habitat, and species. This is a major impediment to use of the standards despite the fact that the standards were purportedly developed to be "sufficiently protective when applied at the vast majority of terrestrial sites within Canada where PHC releases might be encountered" (CCME 2008b).

Little or no consideration was given to mammals and birds, which was believed "acceptable for PHC release sites as most PHC are readily metabolized by vertebrates, modified into a more readily excretable form, and thus do not tend to accumulate in tissues."

A key protocol used in defining acceptable PHC levels was the 25th percentile effect level for a species/endpoint for agricultural and residential/parkland use and the 50th percentile of this distribution for commercial and industrial use. In other words, for agricultural and residential/parkland, a PHC level is acceptable when 25% of the population experiences an acute effect. Depending on the species used, and the duration of exposure, such an "acceptable" level might result in complete mortality for sensitive organisms under chronic exposure. This deficiency was recognized (CCME 2008b): "This means that at the guideline level, effects may be seen in sensitive species/endpoints. For instance earthworm reproduction may be affected at the guideline level." The lack of protection was considered acceptable given "the objective of retaining overall soil ecosystem function while considering the socio-economic costs of remediating soil to a particular level."

A guideline for cattle daily ingestion of drinking water was set at 230 mg/L petroleum hydrocarbons. It's doubtful that such a level of daily chronic exposure would be acceptable for moose, bison, caribou, and other wildlife and for traditional users dependent on those animals.

Data on species responses to petroleum hydrocarbons are scant. For example, "no specific studies have been undertaken of the toxicity to soil invertebrates or plants of the PHC CWS Fraction 4" (CCME 2008b). For the F3 fraction, the guidelines relied upon data from only three plant species, two of which are agricultural species: *Medicago sativa* (alfalfa, 8-26 day tests), *Hordeum vulgare* (barley, 6-14 day tests), and one of which is a native grass *Agrophyron* (*sic, Agropyron) dasystachyum* (northern wheatgrass, 8-25 day tests) [now known as *Elymus lanceolatus*].

Similarly, F3 guidelines relied upon acute exposure data for only three invertebrates: *Onychiuris folsomi* (springtail, 7-36 day tests), *Eisenia fetida* (earthworm, 14-57 day tests) and *Lumbricus terrestris* (earthworm, 14 day tests) (CCME 2008b). Responses of the plant species used growth indices such as root and shoot length and weight. Responses of invertebrates used indices such as fecundity, number of juveniles, and adult mortality.

The paucity of species and the use of only short-term exposure data undermine the utility of the F2 standards. Although CCME (2008b) discussed "chronic" or "'definitive'" exposure, the discussion was based on extrapolation from acute exposure.

F3 acceptable levels are based on mean short-term responses of three plant and three invertebrate species. More protective levels would be defined if only invertebrate data were used.

Similar methods (short-term exposure, same three plant and three invertebrate species) were used to define acceptable F2 and F1 exposure levels.

Surrogate ecotoxicity data were used to complement the PHC exposure data (CCME 2008b). Unfortunately, similar short-term exposures were used on only a small number of experimental subjects (e.g., *Eisenia fetida* (earthworm), *Lactuca sativa* (lettuce), and *Raphanus sativa* (radish). This deficiency was recognized by CCME (2008b): "Exposure period is of critical importance for the effects endpoint. The F3 fraction was progressively more toxic with an increase in exposure time for both soil invertebrate and plant toxicity tests."

Additional data were considered that examined short-term F2 and F3 exposures to *Zea mays* (corn), *Festuca rubra* (red fescue), *Eisenia andrei* (earthworm), grasshoppers, carabid beetles, other beetles, spiders, harvestmen, ants, and mites (species names not provided). It's unclear if these data resulted in modification of exposure guidelines.

Web 4.2.1 The Confounding Effect of Biogenic Hydrocarbons

The application of Canada-wide standards for soil petroleum hydrocarbons can be confounded by biogenic hydrocarbons. Biogenic hydrocarbons (mainly F3, but also F2 and F4) are ubiquitous in ecosystems. They are synthesized by plants, bacteria, algae, and animals as alkanes, sterols, sterones, fatty acids, fatty alcohols, waxes, and wax esters. Peat, manure, and straw can contain appreciable amounts of biogenic hydrocarbons, e.g., 2200 to 4000 mg/kg F3 (Kelly-Hooper and Dixon, n.d.).

Because standard assay methods don't differentiate petroleum from biogenic hydrocarbons, biogenic hydrocarbons can cause false exceedences of CCME standards. Fortunately, there are other criteria that can be used to differentiate biogenic from petrogenic hydrocarbons. Biogenic hydrocarbons are dominated by odd-numbered carbon chains whereas petrogenic hydrocarbons have an equal distribution of even- and odd-numbered chains. Additionally, (a) the presence of alkylated PAHs, hopanes, steranes, and terpanes can be used to identify petrogenic hydrocarbons (Kelly-Hooper and Dixon, n.d.); (b) a high ratio (>/= 0.10) of F2:F3b hydrocarbons indicate petroleum contamination; and (c) clean samples should contain no detectable F2 hydrocarbons (Kelly-Hooper, n.d.).

Web 4.3. Moosehorn and Swan Rivers spill

According to the company, 397 m^3 of crude oil were recovered. The AER record for the spill states that 477 m^3 of crude oil were spilled and 397 m^3 were recovered. Although the crude oil flowed offsite from a seepage slope into the Moosehorn River, the regulator did not consider either the seepage slope or the river to be ecologically sensitive (more on ecological sensitivity in Chapter 7). The AER provided no data on wildlife effects or the areal extent of the spill. A combination of external corrosion and underground seepage that resulted in sagging of the corroded pipeline probably caused the pipeline rupture and spill (Bishop 1976). The AER attributed the spill to "earth movement" but provided no other information. The location for the spill provided by the regulator was misplaced 460 m to the northwest of the actual spill.

Bishop noted that the June 1975 event was not the first oil spill into the Moosehorn and Swan River stating that "there have in fact been many others". The regulator has no record of any such spills prior to June 1975. I summarize development-driven decline of breeding bird populations in the Swan River area in Chapter 14.

Web 4.4. House River spill

About 238 m^3 of hydrocarbons flowed into the river, 207 m^3 were reportedly recovered; 970 m^3 were spilled onto land, and 191 m^3 were reportedly recovered. The total spill volume remaining after clean-up on land and in water was estimated at 811 m^3, corresponding to a recovery efficiency of 33 %. The HBT Agra (1992) report estimated that about 1.3 ha of land were affected by the spill, that hydrocarbons had penetrated at least 0.8 m into the soil, that hydrocarbons were migrating horizontally through the soil, and that soil hydrocarbon concentrations ranged from non-detectable to >10,000 mg/kg (43 of the soil samples were quantified at > 10,000 mg/kg, the maximum value quantifiable by the method used).

The spill demonstrates poor record-keeping by the regulator. The regulator stated that the spilled material was synthetic crude oil (not naphtha/diesel). Although the spill was directly into the House River, the AER did not consider the river a sensitive area. The record did not state whether the public or wildlife/livestock had been affected, nor did it specify the areal extent of the spill (data fields were blank). AER's failure to provide accurate information on the spill is egregious given the existence of the post-spill report by August 1992 and the AER release clean-up date of 17 March 1994, indicating that the record keeping post-dated the spill report.

Web 4.5. Wabamun Lake spill

One source estimated the spill volume at 1299 m^3, 701 m^3 of which were recovered, yielding a recovery rate of 54% (Boufadel et al. 2015). Another source estimated the spill volume at 800.5 m^3 (Pimblett and Mitton 2015). A large proportion of the residual oil will persist even under optimum conditions for microbial breakdown (Hollebone et al. 2011).

The common great bulrush (softstem bulrush) emergent marshes of Wabamun Lake are critical to the health of the lake and serve as important bird and fish habitat and nurseries. These bulrush marshes were extensively damaged in the wake of the oil spill, more by the attempts to recover oil than by the oil spill itself (Thormann and Bayley 2008). First the plants were cut at their bases or just below the waterline and removed from the marsh. Then the sediments were subjected to high-pressure flushing and vacuuming. Flushing and vacuuming degraded the marshes and resulted in impaired regrowth of the bulrushes. Reduction in plant growth, rhizome density, and seed germination were greater in deeper water. For future spills, the authors recommended against using high pressure flushing and vacuuming or any other treatment that significantly disturbs lacustrine marsh sediment.

An animal care first responder recalls the spill: “Many aquatic birds were affected by the oil spill at Wabamun Lake. The lake is home to one of only a few breeding areas for western grebes in Alberta and they were at the height of their nesting and raising young. Western and the more common red-necked grebes are entirely aquatic birds – they do not come out onto land except for a brief time to sit on a nest and incubate their eggs. When the oil spill occurred, hundreds of birds lost their lives. Fortunately, a small number of birds were salvaged and supported until they could be cleaned and released elsewhere. However, the disruption to the breeding cycle was devastating. Recovery from the damage done to this colony would take years” (K. Blomme, pers. comm., 8 May 2019).

The social and economic effects of the spill have not been determined. A scientist familiar with the spill observed: “Last time I looked (2016), there was still a consumption advisory for pike from the lake for women and children. The Paul First Nation was seriously affected” (name withheld, pers. comm., 21 March 2019).

Web 4.6. Pine River spill

Of the 952 m^3 spilled, 448 m^3 entered the Pine River; 82 % of the oil was reportedly recovered. No water samples were taken to determine hydrocarbon concentrations in the river. Similarly, there was insufficient study of both the sub-lethal effects and the long-term population effects of the spill. Of the estimated 15,000 to 27,900 fishes killed directly by the spill, most were mountain whitefish, followed by slimy sculpin, burbot, bull trout, rainbow trout, and arctic grayling.

Changes to the stream channel and its habitat were catastrophic and irreparable (Sumners 2001). Alteration of a 115 m long backchannel resulted in the abandonment of an oxbow that had provided fish habitat and food. Bank armoring and removal of riparian vegetation and logjams destroyed floodplain habitat. The contractor also failed to construct the recommended fish habitat features. The removal of logjams and woody structure from the river channel was done without consultation or authorization from the Department of Fisheries and Oceans and the BC Ministry of the Environment. Unauthorized removal of a logjam resulted in rerouting of the Pine River away from its 3.4 km long Lemoray Meander. The new, steep gradient 1.6 km long channel that formed was unstable and resulted in mass erosion of soil, vegetation, gravel, and sand that was deposited downstream in spawning habitat. There was no investigation to determine the impact of this human-caused avulsion. The use of heavy machinery within the river channel also caused habitat damage, which was permitted by the regulatory authorities in order to finish operations before winter. Poor records were kept during the clean-up. In short, the spill response was disastrous.

Incidentally, the August 2000 spill was not the first at this location. A spill on 18 August 1994 released 30 m^3 of gasoline and 24 m^3 of diesel oil that killed an undetermined number of fish (150 mature fish and 1000 juvenile fish were found dead).

Web 4.7. United States inland spills into water

Near Spartansburg, South Carolina, fuel oil spills in May and June of 1979 damaged vegetation and killed fish and wildlife (NTSB 2004). A 1980 pipeline spill of fuel oil near Manassas, Virginia, damaged vegetation and killed approximately 5000 fish and an indeterminate number of waterfowl and small animals (NTSB 2004). After a Romeoville, Illinois 2010 spill of heavy crude oil from Enbridge's Line 6A pipeline, 32 dead animals were found. An additional 141 turtles and frogs were treated and released. Damages, including environmental remediation costs, totaled about US $46.6 million (NTSB 2013).

Disposal of saline wastewater in injection wells in West Virginia caused elevated conductivity, sodium, chloride, barium, bromide, strontium, and lithium concentrations in surface waters downstream of the wastewater disposal site. Sediments had elevated levels of radium and bioavailable iron (Akob et al. 2016). Wastewater injection damaged the stream and altered the chemistry of nearby ecosystems with impacts to the microbiota and measurable increases in endocrine disruptors.

Development of four natural gas wells in Knox County, Kentucky released fracking fluids into Acorn Fork, which created toxic conditions in the habitat of the threatened blackside dace (Papoulias and Velasco 2013). Release of fracking fluids acidified the stream and increased its conductivity to a toxic 35,000 µS/cm which killed or stressed fish, invertebrates, and wildlife. Creek chub and green sunfish were collected a month after fracking in lieu of unavailable blackside dace. Fish exposed to affected river waters showed signs of stress and a high incidence of gill lesions consistent with exposure to acidic water and toxic concentrations of metals such as aluminum and iron. Abrupt and persistent changes in river water quality resulted in conditions that could have been deleterious to blackside dace health and survival.

A large 2015 pipeline spill of 11,400 m^3 of saline wastewater into Blacktail Creek, North Dakota caused major chemical changes (Cozzarelli et al. 2017) (Web 4.7.1). The spill, with a salt concentration about nine times that of sea water, raised concentrations of sodium, chloride, bromide, strontium, boron, lithium, ammonium, and hydrocarbons in water and sediments. Boron and strontium concentrations and radium activity reached up to 15 times the background levels in sediment. Fishes experienced interference with their estrogen metabolism and their survival was strongly reduced. Only 2.5 % of fishes survived 7.1 km downstream of the spill compared to 89 % survival upstream of the spill. Sediments accumulated radium, barium, and other contaminants with the potential for long-term harm to aquatic life. The biological and chemical effects of the saline spill constituted an "environmental signature". In a related study, waters receiving Bakken brine spills revealed a chemical signature of elevated concentrations of sodium, chloride, bromide, selenium, vanadium, lead, and ammonium; sediments had elevated radium (Lauer et al. 2016).

Web 4.7.1. Clean-up of the saline pipeline spill into Blacktail Creek involved impounding the water and pumping it out of the creek followed by excavation. Credit: US Environmental Protection Agency (see Allison and Mandler 2018).

On 17 January 2015, the Poplar Pipeline operated by Bridger Pipeline LLC spilled approximately 114 to 191 m^3 of Bakken crude oil into the Yellowstone River ~ 11 km upstream of Glendive, Montana (Montana DEQ 2015). The oil flowed downstream under the winter ice cover, which prevented most clean-up and caused exceedances of Montana surface water quality standards in the Yellowstone River. Oil remained visible as a sheen for at least 95 km downstream of the spill and visible on shorelines until at least early April 2015. The State of Montana and the Department of the Interior "determined that the oil may have caused injuries to natural resources, including fish (including the federally listed endangered pallid sturgeon) and other aquatic organisms, birds (including migratory birds), wildlife, surface water and riverine aquatic habitat and supported biota, terrestrial habitat, shoreline habitat and supported biota adjacent to the river, and the services provided by these natural resources."

The volume of crude oil recovered was not determined with precision because recovery volumes included oil and water. Although the spill was considered a major incident, it's worth bearing in mind that, at minimum, 284 crude oil spills on record in the Alberta FIS database as of 30 June 2019 released more than 114 m^3 (the often-stated volume of the Yellowstone River spill).

4.7.2 Kalamazoo River Spill Monitoring

The July 2010 Enbridge pipeline spill of Cold Lake blend heavy crude oil near Marshall, Michigan into wetlands, Talmadge Creek, and the Kalamazoo River is one of the better-documented spills in the United States. The spill harmed animals and vegetation and caused loss of ecological services such as provision of fisheries and recreation. An August 2010 fish health assessment found skin lesions and eye, fin, and ventral hemorrhages. Common white suckers and common shiners suffered liver and kidney congestion. The smallmouth bass population declined in the Kalamazoo River. PAHs and residual oil in heavily oiled sites posed chronic risks to animals that live in sediments. Species diversity of mussels was reduced. Much of the vegetation along the Kalamazoo River floodplain was damaged by oil (Stratus Consulting 2012). In one 15 km long reach, three-fourths of the vegetation was coated in oil. Enbridge reported a total release of 3195 m^3 (NTSB 2012); other estimates place the spill volume as substantially larger (USFWS et al. 2015).

Web 4.8 Examples of documentation of spill effects in Alberta

Web 4.8.1 Trilogy Resources spill

One important aspect of the US Fish and Wildlife Service study (Web 4.7.2) was that it was a cooperative effort with First Nations and various branches of government. The thorough, joint effort and wide dissemination of the results after the Kalamazoo spill stand in contrast to the perfunctory nature of most Alberta spill studies. For example, after a spill of 50 m^3 crude oil and 50 m^3 saline water into an Alberta wetland on 6 October 2016, Trilogy Resources reported two dead birds were found covered in oil– a woodpecker and a 'small sparrow like bird'. No other impacts to wildlife were reported (Linnitt 2016). The regulator reported that there was no effect on wildlife, despite the fact that there was release offsite into an organic wetland and the spill footprint was 100-1000 m^2. The regulator's superficial effects monitoring is not credible. Web 4.8.1 summarizes another Alberta spill impact report that would not pass peer review yet was accepted by the regulator.

Web 4.8.2 Spills near Edmonton

The regulator's record for the Bruderheim spill is enigmatic. At the location given by the researchers, there were two spills of crude oil in 1982, one of 1 m^3 and one of 2 m^3, but neither site was a crude oil group battery. There were, however, three crude oil spills at nearby crude oil batteries at three different locations. Using the regulator's FIS records, it can be difficult to reconstruct history from even well-documented spills.

Web 4.8.3. Example of findings from an Alberta post-spill impact report

A wetland impact report was filed by Canadian Natural Resources Ltd (CNRL) in January 2014 in response to an Environmental Protection Order (EPO-2013-33/NR) issued by Alberta Environment and Sustainable Resource Development in relation to the release to surface of bitumen at the CNRL Primrose operations. The impact report (Matrix Solutions Inc. 2013, see below) filed by CNRL follow did not provide sufficient credible evidence to assess environmental impacts. Why do I believe this to be true? Read on.

A single nomenclatural source for vascular plants was not provided, even though this is standard practice in vegetation science. Instead, the report provided several plant guides, most of which were outdated, applied to other regions, or were non-standard for use in Alberta. No standard nomenclatural references were provided for bryophytes.

The vegetation plots did not provide a sufficient description of the flora necessary to evaluate the impacts of the spill. The plot data did not list common and expected shallow aquatic wetland and poor fen plants such as *Drepanocladus aduncus* and *Smilacina trifolia* (yet did list a *Smilacina trifolia* look-alike, non-wetland, plant *Maianthemum canadense*). No data were provided for liverworts and lichens.

The species list reported taxa such as “Salix spp.” and “bryophyte sp.” which indicate a lack of familiarity with the flora.

Although the plant species list was depauperate in expected taxa, several of the taxa listed were uncommon to rare in Alberta such as *Sparganium fluctuans*. Although it’s possible for common species to be absent and rare or uncommon species to be present, such results are unlikely. When wetland vegetation types are reportedly composed of uncharacteristic species (e.g., *Maianthemum canadense*), are lacking in the common characteristic species (e.g., *Drepanocladus aduncus*, *Smilacina trifolia*), and contain provincially rare species (e.g., *Sparganium fluctuans*), the vegetation types are either never-before described rare communities or are mistakenly described.

The list of 122 bird taxa reported for the 9-21 bitumen release site includes 19 species classified as “sensitive” in Alberta and two species federally-listed under COSEWIC (barn swallow, rusty blackbird). If 15.6 % of the bird species were classified as sensitive, this high proportion would present conservation concerns given the ongoing bitumen releases and cleanup activities. However, the source for this list was cited as “Canadian Natural Resources Limited (2013)”, which was missing from the literature cited.

The bird list reported taxa such as “American pipet” (*sic*), “gull sp.”, and “woodpecker sp.” which suggest unfamiliarity with the fauna.

The mammal list reported Canada lynx (sensitive in Alberta) and woodland caribou (at risk in Alberta, threatened under COSEWIC, and Schedule 1 species under SARA). Again, this would be significant, but the source for this list was “Canadian Natural (2013)”, which was also missing from the literature cited.

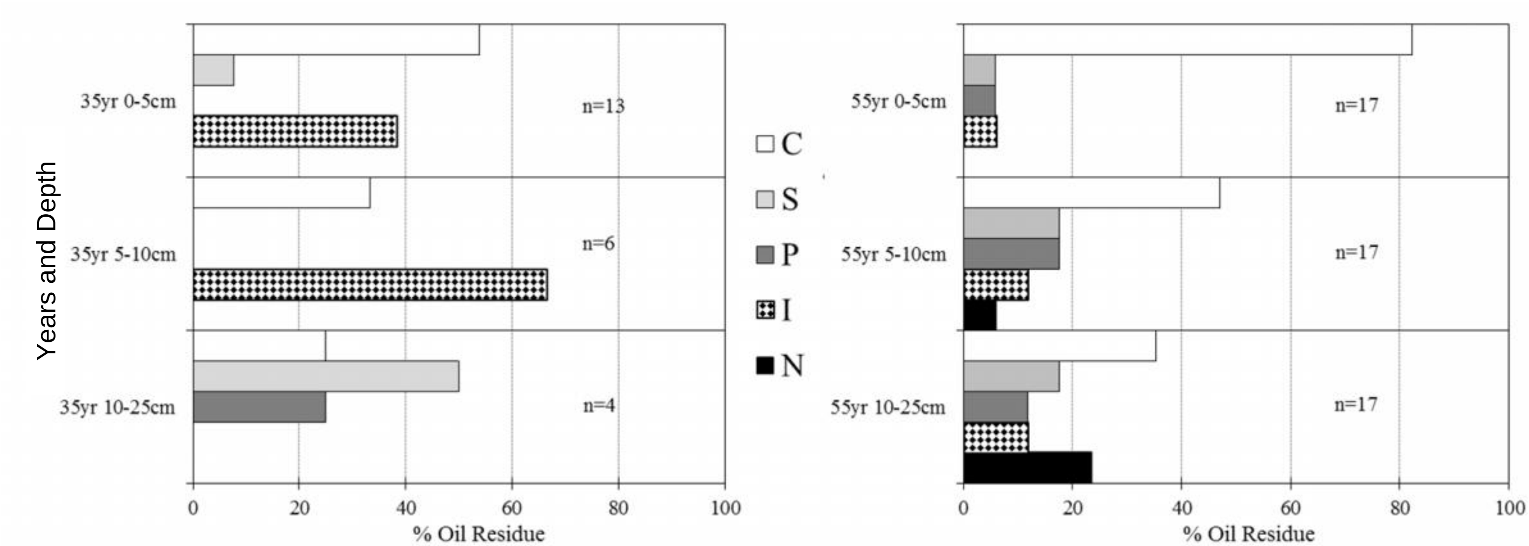
The mammal list reported taxa such as “deer sp.”, “east chipmunk” (*sic*), and “vole sp.” which suggest unfamiliarity with the fauna.

Common and expected mammal species such as northern bog lemming, deer mouse, dusky shrew, and porcupine were missing from the list.

The wetland impact summary report would not pass peer review with regard to the flora and fauna. CNRL did not provide credible ecological and biological information to the regulator.

Web 4.9. Canol Road spills

The researchers mapped the areal extent of the spills roughly 30 years post-spill and quantified the residual hydrocarbon contamination over time. Partial degradation of the crude oil took place over time; breakdown rate of the crude oil decreased with soil depth. After 55 years, soil contamination remained at all depths; at depths of 10-25 cm, roughly 24 % of the crude oil showed no sign of degradation (Web 4.9.1).



(a) 35 years (b) 55 years

Web 4.9.1. Crude oil remaining in the soil after (a) 35 years and (b) 55 years in the Canol Road pipeline study area (Kershaw et al., n.d.). Key: C (white): complete utilization of n-alkanes; S (light gray): selective metabolism of C6-C19 n-alkanes; P (medium gray): partial removal, n-alkane peak discernible; I (checkered): only isoprenoids remaining; N (black): no degradation of crude oil.

Web 4.10. Oil Spills in Alaska

Most moss and lichen species died within one year of an experimental application of Prudhoe Bay crude oil to Alaskan tundra. Northern white mountain avens, the dominant species on dry soils, was also killed (Walker et al. 1978). Water sedge, narrowleaf cotton grass, arctic willow, and snow willow showed some recovery. Diesel oil, applied at the same rate, was more toxic than crude oil; all species other than the aquatic moss *Scorpidium scorpioides* were killed. The survival of this aquatic moss was attributed to standing water, which caused the oil to float and not contact the submersed moss. The researchers cautioned that the effects of the spill could become more pronounced over time.

Species that have appeared to recover from a spill after one year may later die, such as the wet tundra grass *Dupontia fisheri* at Barrow, Alaska and dwarf shrub - bog cranberry vegetation at Norman Wells, Northwest Territories. Conversely some species that appear dead may later recover.

The scientists also provided an oil spill recovery value for a 1977 release of crude oil from the Prudhoe Bay pipeline near Franklin Bluffs, Alaska. They stated that 286 m^3 of crude oil were spilled onto the tundra and that an estimated 223 m^3 were recovered, a recovery efficiency of 78 %.

Vegetation at two black spruce forest sites in interior Alaska was studied 15 and 20 years after crude oil was experimentally applied as low-volume sprays or high-volume point spills (Racine 1994). Spray spills were less damaging than were point-source spills. Point spills created areas of surface oil saturation with dead vegetation and little sign of recovery. The oil spread below-ground with little or no apparent effect on the shallowly rooted vegetation outside the spill footprint. Winter spills on frozen soil created a greater area of surface oil, and therefore their effects were more extensive. After 15 years on soils saturated with oil, only sheathed cotton grass survived. At sites with surface crude oil, black spruce mortality was high, with no evidence of long-term recovery.

Web 4.11. Oklahoma tall grass prairie spill

Soil microbial and nematode abundance and activity and species composition and plant community composition and diversity were all sensitive to a crude oil spill in an Oklahoma tall grass prairie (Sublette et al. 2006). Both the nematode and bacterial communities provided a sensitive and low cost measure of ecosystem impacts. Populations of Actinobacteria and Acidobacteria were reduced at oil-contaminated sites while Firmicutes and γ Proteobacteria increased at oil-contaminated sites. The effects on soil bacteria at brine-contaminated sites were similar to those at oil-contaminated sites but were more extreme. Bacterial groups that increased were those able to respond rapidly to an influx of readily degraded hydrocarbons and may have been salt tolerant. Application of nitrogen fertilizer assisted in bacterial recovery after oil contamination but was less effective at brine contaminated sites.

Web 5. Quantifying other fossil fuel industry effects

Web 5.1 Every Spill is a Story Waiting to be Told: A Complex Disturbance History at a Pipeline ROW and 40-Year Old Crude Oil Spill in Chrenek Estates, Sherwood Park, Alberta

A complex disturbance history creates a complex disturbance footprint. But because we private citizens have little or no access to credible information, it can be difficult to piece together that history, especially if that spill took place 40 years ago. Fortunately I unearthed sufficient information about the Chrenek Estates spill to demonstrate how an industrial landscape produces a disturbance signature.

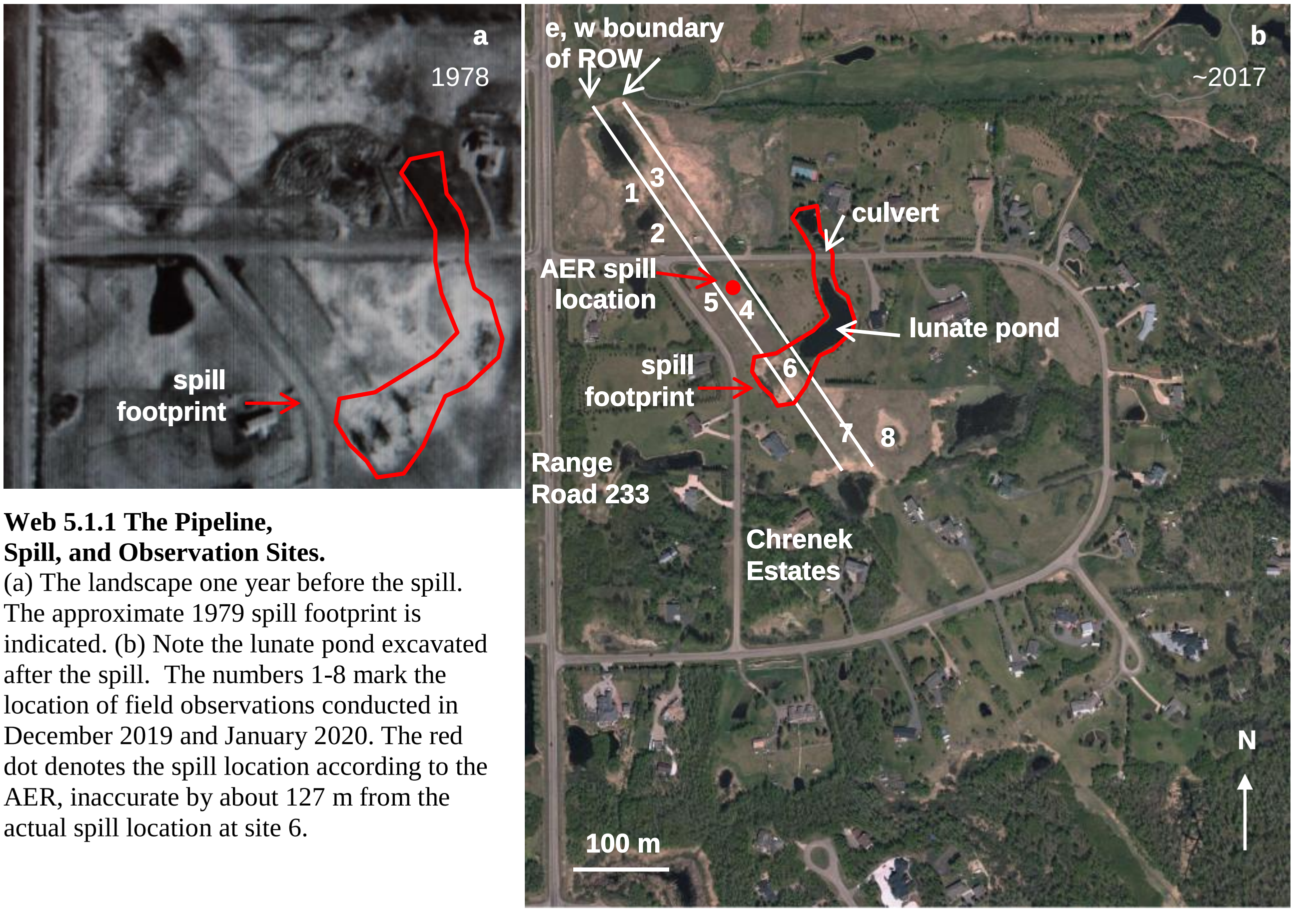
On 4 July 1979, somewhere between 840 m^3 (AER incident 19790565) or 1590 m^3 of crude oil (according to the Edmonton Journal of 21 July 1979, page B5) were spilled from an Interprovincial Pipeline Company high-pressure pipeline in Chrenek Estates south of Sherwood Park (Web 5.1.1). The Edmonton Journal stated the crude oil was released into a slough and that most of the oil was removed by conventional methods while the remaining oil was burned as a "black smudge stained the skies". The AER record indicates that there was release off-site (meaning off the pipeline ROW), and that the area was not sensitive. Strangely, the AER record states that no recovery of crude oil took place and that the release was into flowing water, but there is and never has been flowing water at the site. The AER location for the spill is displaced about 127 to the northwest of the actual spill location. As expected, the AER spill record does not stand up to scrutiny.

From study of airphotos and imagery gathered over the decades, I observed that prior to the spill, the native vegetation had already been damaged by pipeline construction, then, after the spill and over the years, the area was subjected to excavation and contouring with heavy machinery, reclamation, regular pipeline maintenance, vehicle traffic, and nearby residential subdivision.

After knocking on doors over several days I found an eyewitness to the spill. The informant, who has lived in the subdivision for 42 years, was directly impacted by the spill. At the time, he owned two lots, both of which received crude oil. He told me that officials arrived on his doorstep on the day of the spill and told him to extinguish all pilot lights because the hydrocarbon vapors in the area posed a fire hazard. He described how oil from the pipeline break pooled in a low-lying area (indicated in Web 5.1.1) then flowed east then north into his wetland slough. The growing spill then flowed north through a culvert under the Chrenek Estates road and accumulated in a fish pond on the informant's property. Pumps and tanker trucks were used continuously for three days to remove the free fluid. Then, over the course of the next year, contaminated soil was excavated and trucked away. The excavations created the lunate-shaped pond in Web 5.1.1b. The present owners of the lot that received the bulk of the spill were unaware of the spill until I informed them in January 2020.

Within the ROW and the spill footprint, the dominant plant community 40-years later is an exotic meadow dominated by reed canary grass along with alsike clover, sweet-clover, alfalfa, sow-thistle, and smooth brome. Reed canary grass and common cattail cover the wetter sites (Web 5.1.2, 5.1.3a). Within the pipeline ROW but outside the spill footprint we find a similar reed canary grass exotic meadow but also other exotics such as crested wheat grass, red fescue, and common plantain (Web 5.1.3b). Beyond the spill and the ROW, weedy and exotic species remain present but native species such as awned sedge, pussy willow, Bebb's willow, red-osier dogwood, prickly rose, water hemlock, buckbrush, saskatoon, bog orchid, and broad-leaved water-plantain mark the transition to remnants of semi-natural vegetation on uplands and in wetland depressions (Web 5.1.3c).

Both within and outside the spill footprint there's an unmistakable disturbance signature. Forty years after the spill, the area within the spill footprint remains more affected than the pipeline ROW but there's no clear vegetation boundary; it's a disturbance gradient whose vegetation is composed of the usual suspects found at spills and other industry disturbances. Beyond the spill and the pipeline ROW the vegetation is a mosaic of vegetation in various states of disturbance ranging from exotic monocultures to semi-natural grass and shrub communities.



Web 5.1.1 The Pipeline, Spill, and Observation Sites.
(a) The landscape one year before the spill. The approximate 1979 spill footprint is indicated. (b) Note the lunate pond excavated after the spill. The numbers 1-8 mark the location of field observations conducted in December 2019 and January 2020. The red dot denotes the spill location according to the AER, inaccurate by about 127 m from the actual spill location at site 6.

Web 5.1.2 Plant Species Observed Within and Outside the Pipeline ROW and the 40-Year Old Crude Oil Spill Footprint. Bolded species are the dominants.

Species Name	Common Name
Site 1, north of road, outside ROW, outside spill, 24 Dec 2019	
Amelanchier alnifolia	saskatoon
Bromus inermis	Smooth Brome
Carex atherodes	Awned Sedge
Cornus stolonifera	Red-osier Dogwood
Epilobium angustifolium	Fireweed
Festuca rubra	Red Fescue
Melilotus	Sweet-clover
Phalaris arundinacea	Reed Canary Grass
Plantago major	Common Plantain
Rosa acicularis	Prickly Rose
Salix discolor	Pussy Willow
Solidago canadensis	Canada goldenrod
Symphoricarpos occidentalis	Buckbrush
Symphyotrichum lanceolatum var. *hesperium*	Willow Aster
Trifolium hybridum	Alsike Clover
Typha latifolia	Common Cattail
Vicia americana	American Vetch
Site 2, north of road, outside ROW, outside spill, near road edge, 24 Dec 2019; to the Site 1 species, add:	
Elytrigia repens var. *repens*	Quack Grass
Platanthera	Bog Orchid
Poa pratensis	Kentucky Blue-grass
Populus balsamifera	Balsam poplar
Populus tremuloides	Trembling Aspen
Shepherdia canadensis	Buffaloberry
Site 3, north of road, within ROW, outside spill, 24 Dec 2019	
Phalaris arundinacea	Reed Canary Grass
Trifolium hybridum	Alsike Clover
Typha latifolia	Common Cattail
Site 4, south of road, within ROW, outside spill, 25 Dec 2019	
Agropyron cristatum	Crested Wheat-grass
Melilotus	Sweet-clover
Phalaris arundinacea	Reed Canary Grass
Trifolium hybridum	Alsike Clover
Site 5, south of road, edge of ROW, outside spill, 25 Dec 2019	
Bromus inermis	Smooth Brome
Cirsium arvense	Canada Thistle
Geum	Yellow Avens
Phalaris arundinacea	Reed Canary Grass
Salix cf. ***pentandra***	Bayleaf Willow (planted)
Symphyotrichum lanceolatum var. *hesperium*	Willow Aster
Symphoricarpos occidentalis	Buckbrush
Site 6, south of road, within ROW, within spill footprint, 28 Dec 2019	
Bromus inermis	Smooth Brome
Medicago sativa	Alfalfa
Melilotus	Sweet-clover
Phalaris arundinacea	Reed Canary Grass
Potentilla	Cinquefoil
Sonchus uliginousus	Smooth Perennial Sow-thistle
Trifolium hybridum	Alsike Clover

Site 7, south of road, edge of ROW, outside spill on low upland ridge, 28 Dec 2019	
Achillea millefolium	Common Yarrow
Aster conspicuus	Showy Aster
Bromus inermis	Smooth Brome
Cirsium arvense	Canada Thistle
Cornus stolonifera	Red-osier Dogwood
Phalaris arundinacea	Reed Canary Grass
Rosa acicularis	Prickly Rose
Salix bebbiana	Bebb's Willow
Salix discolor	Pussy Willow
Symphyotrichum lanceolatum var. *hesperium*	Willow Aster
Symphoricarpos occidentalis	Buckbrush
Site 8, south of road, outside ROW, outside spill, in pond, 28 Dec 2019	
Alisma plantago-aquatica	Broad-leaved Water-plantain
Beckmannia syzigachne	Slough Grass
Carex atherodes	Awned Sedge
Cicuta	Water-Hemlock
Phalaris arundinacea	Reed Canary Grass
Rumex occidentalis	Western Dock
Typha latifolia	Common Cattail

Web 5.1.3. The vegetation today. (a) 40-years after the crude oil spill, at the site of the spill's origin, the vegetation is dominated by reed canary grass, sweet-clover, Alsike clover, and alfalfa. 28 Dec 2019, site 6. (b) On the pipeline ROW but north of the spill footprint, the vegetation is dominated here by reed canary grass and sweet-clover along with common cattail in wetter areas. 25 Dec 2019, site 3. (c) West of the ROW, this patch of semi-natural shrubland is dominated by buckbrush, prickly rose, pussy willow, and reed canary grass along with a mixture of other native and exotic species. 5 Jan 2020, site 1.

Web 5.2. A brief review of the impacts of pipelines, well sites, and other land uses

In this section I summarize the results of relevant studies on the effects of pipelines, wells, and other industrial land uses.

Web 5.2.1. United States

Hydrocarbon exploitation in the Powder River Basin of Wyoming has resulted in persistent changes in soil chemistry and plant composition (Bergquist et al. 2007). Well pads and produced water discharge sites exhibit increased conductivity and sodium concentrations, an increased number of invasive plant species, and a decreased number of native plant species.

More than 65 years after abandonment of land impacted by oil operations in Oklahoma, a three-dimensional plume of high salinity groundwater (5000 to 30,000 mg/L of total dissolved solids) was detected (Kharaka and Dorsey 2005). The plume had the same chemical and isotopic signature of the produced water disposed of at the site. Large amounts of salts and hydrocarbons remained in the local rocks and groundwater after more than 65 years of natural attenuation. Fossil fuel production had resulted in long-term damage to groundwater.

Leakage from underground fuel storage tanks has been examined more closely in the United States than in Canada. Out of an estimated 2.5-3 million registered underground storage tanks in the United States, about 400,000 have leaked or are leaking and have contaminated about 15-24 million m^3 of subsoil (Testa and Jacobs 2014). This estimate is conservative because it does not include unregistered tanks and underground fuel releases.

Web 5.2.2. Southern and Central Alberta

Vegetation and soil effects remained evident 10 to 26 years after pipeline construction near Princess in south-central Alberta (Naeth 1993). Relative to undisturbed prairie, a ten-year-old pipeline ROW had significantly more bare ground, more exotic and weedy species, lower species diversity, and fewer native plant species. Soil salts continued to migrate downward through the soil profile after 10 years. On a 26-year-old ROW, vegetation remained different from that of undisturbed prairie.

Soils disturbed by oil well drilling, surface mining of coal and bitumen sands, spills, and pipeline construction differ from undisturbed soils in southern and central Alberta (Rowell and Florence 1993). Disturbed soils differ from natural soils in their conductivity, organic carbon, phosphorus, cation exchange capacity, and measures of nutrient cycling.

Industry sites differ in their soils and vegetation from undisturbed sites on pipeline ROWs and reclaimed well sites in the Rumsey Block of central Alberta (Elsinger 2009). Industry sites that left sod and topsoil intact were the most similar to undisturbed sites. Site construction and revegetation methods and cattle grazing pressure influenced vegetation responses. Stripping of topsoil caused the largest impacts. There was no evidence of convergence of industrial and undisturbed sites over time; the industrial sites were impaired indefinitely.

Natural colonization by native species created a more diverse plant community than did using seed mixes. Almost all reclaimed well pads and pipelines subjected to topsoil removal or ditch witching and reclaimed with native or non-native species mixtures exhibited a disturbance signature. The signature was characterized by increased soil density and soil compaction; elevated calcium, magnesium, potassium, sodium, pH, and conductivity; increased exotic rhizomatous grasses, exotic tufted grasses, exotic perennial forbs, and increased abundance of undesirable plant species such as quack grass, smooth brome, and Kentucky bluegrass; decreased levels of organic carbon and nitrogen; and reduced native prairie plant species, especially of native perennial forbs, sedges, and plains rough fescue. I analyze original data from this study in Chapter 10.

The Express Pipeline carries crude oil in a 434 km long pipeline along a 20 m wide ROW from Hardisty, Alberta to the Montana border at Wildhorse. Kinder Morgan’s regulatory commitment was to establish species that would undergo succession to native prairie plant communities. Revegetation efforts represented a best-case scenario of state of the art practices. To achieve the goal of restoration, disturbance was minimized, native seed mixes were developed, and specialized seeding equipment and erosion controls were used. Three treatments were used: seeding with cultivars developed from native grasses, natural recovery, and controls. A study of attempted restoration on the Kinder Morgan Express Pipeline in the dry mixed-grass region of southern Alberta made important observations (Gramineae Services Ltd 2013).

After 14 years, some sites were improving in health, some were not changing, and others were declining in health. Almost none of the sites recovered to conditions similar to undisturbed controls. Natural recovery produced more natural plant assemblages than did seeding with cultivars whose aggressive growth inhibited establishment of other native species. At many sites, exotic sheep fescue became the dominant species. Drought, grazing by cattle, and overwinter storage of topsoil hampered vegetation recovery. Impaired vegetation health prior to disturbance and the presence of exotic perennials also undermined vegetation recovery. After 14 years, relative to controls, the pipeline ROW exhibited more bare soil and still lacked the normal native prairie ground layer of mosses, lichens, and prairie selaginella. The study concluded with a sobering recommendation: Long-term monitoring is needed to determine <u>if it is possible</u> to restore to native vegetation communities after disturbance, and if so, in what situations and over what period of time.

A study of the soils at 25 Alberta oil and gas well sites certified as reclaimed between 1964 and 2011 in the region between Calgary and the Alberta-United States border concluded that the soils remained impaired relative to natural controls (Janz et al. 2019). The researchers sampled sites in 2015 on low risk landscapes where natural conditions favored successful reclamation (in essence, they intentionally biased their sampling to sites where reclamation success would be most likely). Persistent impairment was evident based on changes in soil pH, bulk density, and total organic carbon and a reduced land capability rating even though the sites received annual agricultural inputs and management. In the couched parlance of science, the researchers concluded that the “long-term legacy effects” were significant and “not well aligned with intended provincial outcomes.” In plain language, in spite of ideal natural soil conditions, active management, and certified reclaimed status, after decades the soils remained significantly impaired and did not meet with the expectations and hopes of society. The authors noted that since 1963, about 100,000 oil and gas well sites in Alberta have been officially certified as reclaimed.

Web 5.2.3. Multi-region Studies

When I compared vegetation and environment at 417 natural and industrially-affected mineral wetland plots in the boreal plains, prairie, and taiga plains ecozones of western Canada, I found that industrial wetlands adjacent to bitumen exploitation were impaired (Timoney 2015). Impairment was characterized by reduced native plant species richness; elevated weed species richness and cover; reduced vegetation biomass, density, and stature; reduced diversity of vegetation types; elevated concentrations of contaminants and salts in water and sediments; reduced organic matter in sediments; steeper slope profiles with a narrower shallow and biologically productive littoral zone; reduced concentrations of macronutrients; disconnections in water flow; reduced wetland areal extent; and increased habitat fragmentation. Industrially-affected wetlands were surrounded by a greater proportion of disturbed landscape that contributed contaminants to the wetlands and posed risks to wildlife.

Plant indicators of process-affected wetlands included water sedge and widgeon-grass; those of wetlands indirectly-affected by tailings and bitumen mining operations included small bottle sedge, creeping spike-rush, spiked water-milfoil, and the alga stonewort. Process-affected wetlands had the highest concentrations of conductivity, chloride, sulfate, sodium, iron, alkalinity, naphthenic acids, and boron. The combination of reduced fertility, low organic carbon content in sediments, high conductivity and related parameters, and compact sediments undermined the prospects for recovery. Post-disturbance wetlands had not been restored to their pre-disturbance state nor were these wetlands on a trajectory towards a pre-disturbance state. I observed wholesale failure of wetland reclamation following bitumen mining and a growing legacy of impaired wetlands in a damaged landscape.

Vegetation and soils at 48 abandoned well sites aged 7 to 48 years after being certified reclaimed differed from natural controls in the grassland, boreal, and foothills natural regions of Alberta (Huggard 2016). None of the well sites demonstrated full recovery to control conditions. Some of the oldest certified reclaimed well sites had the lowest recovery scores because they were subjected to “severe rehabilitation”, a euphemism for severe soil and site disturbance. Bare ground, and total non-native plant species richness and cover were consistently higher at reclaimed sites than at controls. Reclaimed sites had reduced total plant cover, species richness, and diversity. In forested areas, reclaimed sites had reduced tree basal area and downed woody material. Soil density, conductivity, and nitrogen, and species composition showed little or no recovery over the 48-year period, indicating permanent impairment.

Web 5.2.4. Boreal Studies

The Swan Hills oilfield in north-central Alberta has been in production since the mid-1950s and is operated by Devon Canada on behalf of more than 20 production companies. Risk assessment identified 210 contaminated sites such as flare pits where oily waste and produced water were disposed; leaks from storage tanks at battery sites; and pipeline breaks where crude oil and saline water were spilled (Dance et al. 2015). Contaminants included BTEX, aromatic compounds and PAHs, and a wide range of other hydrocarbons; the metals aluminum, arsenic, barium, cadmium, copper, and zinc; and saline produced water. The assessment recommended removal of obviously contaminated soil or free product within pits or spill areas. Significantly, the plan excluded excavation of discolored soils and lenses of hydrocarbon-contaminated soil <30 cm thick, which could leave up to 3000 m^3 of hydrocarbon-contaminated soil per hectare. The plan would leave residual contamination that exceeds regulatory criteria; remediation was to rely upon natural attenuation.

In the Chipewyan Lake area of northeastern Alberta, plant communities at four reclamation certified abandoned well sites were dominated by exotics such as smooth brome and alsike clover (Figure 5.1a,b; Timoney 2011). A gas pipeline ROW was dominated by the exotics red fescue, alsike clover, alfalfa, timothy, and smooth brome (Figure 5.1c). Near a gas well abandoned in 1983, 26 years after abandonment, disturbed soil persisted as a semi-barren gray clay (Figure 5.1d,e). No AER record was found of a spill or dumping of drilling waste at the site. These observations corroborate two consistent themes: a persistent vegetation signature at industry sites and spills missing from the AER record.

Can impacts be prevented or minimized by better industrial practices and a more effective regulator? Researchers examined whether advanced mitigation measures along Enbridge's Norman Wells to Zama pipeline were sufficient to reduce the risk of exotic plant species introduction along the pipeline ROW (Cody et al. 2000). Despite advanced mitigation measures, they observed 34 exotic plant species along the pipeline, 15 of which were new to the flora of the Northwest Territories. Two of the exotics, creeping foxtail and hard fescue, were also observed at the BP Zama spill and pipeline sites (see Chapter 10) which are adjacent to the southern terminus of the Norman Wells to Zama pipeline (Figure 5.2).

Web 5.3. A brief review of the impacts of seismic lines

In this section we survey the effects of an often overlooked industry disturbance by reviewing the results from eight studies.

Seismic lines cause numerous impacts that are influenced by climate, soils, permafrost, pre-disturbance vegetation, distance to nearest roads, and other factors (Table 5.1). Conventional seismic lines (6-10 m wide) cause shifted species assemblages, deforestation, and dissect and fragment the landscape (Dabros et al. 2018). Fragmentation, in turn, harms biodiversity and ecosystem processes and is a major factor in the decline of endangered woodland caribou. Some of the most seriously degraded landscapes are found in the Dene Tha territory of northwestern Alberta where the cumulative effects of seismic lines, pipelines, wells, facilities, spills, logging, and increasing wildfires have transformed the landscape beyond recognition and contributed to the decline of woodland caribou. These effects have been observed wherever the industry operates. Here we survey several recent studies.

The vegetation on 20-30 year old seismic lines at two upland tundra sites differed from that of adjacent reference tundra in the low arctic Mackenzie River Delta (Kemper and Macdonald 2009). There were persistent differences in plant community composition between seismic lines and reference tundra. Shrub and graminoid cover increased and lichen cover decreased on the seismic lines relative to undisturbed tundra. Seismic lines were indicated by increased cover of bog birch and polar grass. The persistent effects on plant community composition applied to at least 90% of the seismic lines.

Thirty-five years after they were cut, only 8 % of seismic lines had recovered their woody plants in three forest types in the boreal plains of Alberta (Lee and Boutin 2006). Most seismic lines (65 %) remained in a non-forested state dominated by low forbs. After 35 years, one-fourth of the seismic lines had been converted to off-road vehicle access routes.

Regeneration of trees on seismic lines in former forests in northeastern Alberta is lowest on wet soils, on wide seismic lines, and on those nearest to roads (van Rensen et al. 2015). Terrain wetness and the presence of fen wetlands exerts the strongest negative effect on tree regeneration. The wettest sites failed to recover to tree vegetation even after 50 years. About one-third of linear disturbances will remain unregenerated to trees and cause persistent habitat fragmentation.

Study of 351 seismic lines in west-central and northwestern Alberta demonstrated that seismic lines favored an assemblage of disturbance-adapted species such as sedges, fireweed, horsetails, peavine, and clovers. *Rhododendron* and bog cranberry were more abundant on the edges of seismic lines, and alders, willows, and birches were more abundant on the centers and edges of seismic lines (Finnegan et al. 2018). All-terrain vehicle use increased the abundance of fireweed. Decades after construction of the seismic lines, understory vegetation differed from that of interior forest.

Seismic lines in Alberta, Saskatchewan, British Columbia, and the Northwest Territories favored the occurrence of 16 exotic and weedy plant species (Bayne et al. 2011). These undesirable species were scentless chamomile, Canada thistle, foxtail barley, pineappleweed, black medick (*Medicago lupulina*), alfalfa, annual hawk's-beard, hemp-nettle, timothy, common plantain, perennial sow-thistle, common chickweed, common dandelion, stinkweed, sweet-clovers, and clovers. Annual hawk's-beard and common dandelion invaded forest interiors off the seismic lines.

Modern “low impact” seismic lines are becoming increasingly widespread in western Canada. They are narrower (~1.75-3 m wide) than earlier seismic lines and are constructed with lightweight equipment that minimizes soil disturbance, but their high density and potential edge effects make their impacts greater than anticipated. In a typical high-density seismic disturbance, such as in the Chipewyan Lake area (see Chapter 14, Figure 14.2), seismic lines are spaced ~120 m apart east-west and ~75 m apart north-south, which yields the shockingly high line density of 90 km/km^2. In such areas, interior habitat, that is, habitat unaffected by seismic lines, is obliterated.

Three to four year-old “low impact” seismic lines in upland coniferous forests of north-central Alberta differed strongly from controls (Dabros et al. 2017). Herb species richness was reduced from the seismic line edge up to 15 m into the adjacent forest. Bryophyte and lichen species richness and cover were reduced on seismic lines and their edges relative to those in the interior forest. Much of the vegetation change was driven by changes in soil temperature, soil moisture, and light conditions. Species richness rose with increased distance from seismic lines (Web 5.3.1). The assumption that the effects of seismic lines, in particular “low impact” seismic lines, are restricted to the seismic lines is invalid. Seismic lines affect plant assemblages, species richness, and the physical environment well beyond the seismic lines proper.

Web 5.3.1. “Low impact” seismic lines affect species composition and species richness

Data on plant species occurrence in one-m^2 plots relative to seismic line position in low impact seismic lines in northwestern Alberta allow us to determine if these seismic lines influence plant community composition and species richness (Web 5.3.1.1). I analyzed the data using indicator species analysis and grouped 330 plots into three location classes (center and edge of seismic lines; transitional: 1, 2, 5 m distant; and interior: 15, 25, and 75 m distant from seismic lines).

Plant species richness is lowest in the centers of seismic lines and increases over the 75 m gradient from the seismic lines into the interior forest. That “low impact” seismic lines should have such a large spatial effect on species richness is remarkable.

Location affected cover types and species assemblages. Seismic lines were indicated by dead wood, wood slash, and humus cover types (all $p < 0.05$). Transitional locations were indicated by stair-step moss ($p = 0.06$) and studded leather lichen ($p = 0.07$). Interior locations were indicated by palmate-leaved coltsfoot, prickly rose, dwarf birch, peat moss, cloudberry, dewberry, and three-seeded sedge (all $p < 0.05$).

In sum, “low impact” seismic lines affected plant species composition and plant species richness increased from seismic line centers to interior forest. The data demonstrate how the ecological footprint of human disturbances can greatly exceed the strictly-defined spatial footprint

Web 5.3.1.1 Plant species richness in one-m^2 plots relative to seismic line position in low impact seismic lines in northwestern Alberta. Data from Dabros et al. (2017).

Seismic Line Position	Mean Species Richness	Species Richness s.d.	Richness Difference (% of max)	n
Center	6.3	2.1	-35.5	22
Edge	7.1	1.9	-27.9	44
1 m	7.5	1.9	-23.3	44
2 m	7.9	2.2	-19.3	44
5 m	8.2	2.0	-16.5	44
15 m	8.3	2.2	-14.9	44
25 m	9.6	2.2	-2.1	44
75 m	9.8	3.4	---	44

Web 6. Further examination of the AER's spill data

Web 6.1. Responses of the AER to questions about the Apache 15-09 saline spill

This major spill was plagued by lack of information, misinformation, and discrepancies. Timoney and Lee (2013) documented information provided by the regulator, the company, and the media. The following evidence illustrates how industry and the regulator fall short in their responsibilities to provide accurate and timely information.

On 9 June 2013, CBC (2013) reported: "Officials with the Alberta government and the Natural Resources Conservation Board (NRCB) [ERCB?] are investigating after a spill near Zama City in northern Alberta. The spill, which consisted of an emulsion of water, oil and other chemicals, was reported to the province by Apache Corporation on June 1 [2013]. The pipeline has been shut down and the managing company is now working on containment. Both the Alberta Environment Support and Emergency Response Team and NRCB are working with Apache to assess the situation and ensure containment of the emulsion waters. 'At this point, we're still monitoring wetlands and water bodies near the break so I don't have information on impact on wetlands and water bodies are,'[sic] said Nikki Booth, who speaks for the province. 'But we do know at this point in time there's no indication there's been any impact to the Zama river.' It's not yet clear how much emulsion water spilled or what caused the incident."

The spill was reportedly discovered during an aircraft flyover and consisted of saline produced water from a well. Although the ERCB (2013b) news release indicated that the pipeline spill was located about 20 km northeast of Zama City, that information was incorrect. Timoney and Lee (2013) communicated to ERCB that a spill location 20 km northeast of Zama City was unlikely given the pipeline distribution in the area. ERCB later contacted us with a corrected location about 20 km southwest of Zama City, i.e., 40 km southwest of the location that the regulator provided to the public.

On 14 June 2013, Apache Corporation (2013) provided a news release update, excerpted below:

Q: "What happened in Zama? On Saturday, June 1, Apache Canada reported a release of produced water from a pipeline in the area of our Zama operations. Crews have shut-in the affected water injection pipeline, contained the spill and begun clean-up and remediation operations. Approximately 9,500 cubic meters of produced water were released. There is no danger to the public."

It's significant that Apache uses the phrase "reported a release" on 1 June, rather than the release occurred on 1 June. The release began on 5 May 2013. The actual release volume was estimated to be 15,363 m^3.

Q: "Why did this happen? A third-party expert will be conducting a root-cause analysis of the pipe. While our priority right now is remediation and restoration, we are investigating the cause and will develop a solution to prevent a similar incident."

Two weeks after reporting the spill, the company did not know the cause of the spill. According to ERCB (now, AER) records, Apache was at that time responsible for 304 other spills of saline produced water. The company's statement that it will develop a solution to prevent a similar incident is not supported by Apache's record.

Q: "How can we expect Apache to operate safely and as good stewards of the environment in the future? Apache has a long history of outstanding operational performance and environmental stewardship. The cause of the leak is under investigation, and we expect to identify it."

The "long history of outstanding operational performance and environmental stewardship" included 954 pipeline incidents in the spill database attributed to Apache Canada Ltd and Apache Corporation between 1975 and February 2013 in Alberta. That history included 372 spills of crude oil and 304 spills of salt/produced water. In the Zama area, there were 87 spills attributed to Apache in the database up to February 2013.

Q: "How much oil was leaked? There was only a trace amount of oil in the produced water.
The oil has been removed from the ground."

"Only a trace amount" is vague. The ERCB indicated that the spill contained 200 ppm of oil or roughly two m^3 of oil in the spill. Without verification of the cleanup, the statement that the oil has been removed from the ground is not credible. Soil analyses accessed under FOIP revealed significant amounts of hydrocarbons in the soil distributed over a large area (AER 2017b).

Q: "How long will clean up take? We have a plan in place to ensure that any environmental impacts are minimized. Wildlife, aquatic and vegetation studies are underway by an extensive environmental remediation team and analytics are being compiled. Water sampling and monitoring is conducted daily and collection of the produced water is well underway. A fleet of specialized equipment has been deployed to support these environmental remediation efforts. Apache continues to work closely with the Energy Resources Conversation Board (ERCB) and Alberta Environment and Sustainable Resource Development (AESRD) on site."

The company declined to answer its question. Why would the company pose a question and then not answer it? As for the studies, documents released under FOIP in 2017 revealed significant environmental impacts as of summer 2013. Despite my request, no post-2013 data on water, soil, wildlife, and vegetation data were provided.

Q: "What's the worst case scenario? We believe we've seen it. We are working on clean-up and remediation now. The Zama River has not been impacted and there is no risk to the public. No injuries have been associated with this incident."

Without independent verification of facts, vague assurances serve little purpose other than public relations.

As reported, the 2013 Apache incident is consistent with the pattern observed in the incidents documented in this study, viz., important remaining unknowns and lax reporting, as follows:

<u>Lax reporting</u>

Eleven days after being made aware of the spill, the regulator announced (on 12 June 2013, ERCB 2013b) that approximately 9.48 million L had been spilled over an estimated 42 hectares. The actual saline release volume was later estimated as 15,363 m^3. An ERCB spokesperson, Bob Curran, said that the regulators did not learn the volume of the spill until Tuesday, 11 June 2013. He added, "At the outset we were unaware that it was of this extent or volume... If we had known that up-front we would have made the announcement at that time. Once it was determined that the volumes were at this level we immediately moved to issue a news release" (Canadian Press 2013). It's also significant, given the public's right to accurate and timely information, that the location of the spill as provided by ERCB was approximately 40 km away from the true location of the spill.

Vanderklippe (2013) wrote: "Neither Apache nor the Alberta government initially disclosed the spill, which was only made public after someone reported it to a TV station late last week ... Bob Curran, a spokesman for the ERCB, defended the late release of information, saying it took 10 days to determine the size of the spill. 'The second we knew the volumes, we put out a news release,' he said. Asked how it could take so long to determine the severity of a large spill, he said Wednesday: 'We didn't know it was over 42 hectares. We found that out last night.'" Did the ERCB contact the media because it had learned of the large volume of the spill or because someone had reported the incident to a television station?

Both industry and the ERCB bear responsibility for this failure to report in a timely manner to the public. A government spokesperson disagreed via email with this assessment (J. Potter, pers. comm., 10 June 2013): "Albertans and First Nations in the area of the spill were notified of the situation immediately, as is required by regulation." That response raised further questions.

Timoney and Lee then asked: "What proportion of the people were notified? 100%? How were they notified... email, door to door, radio announcements, telephone, community leaders only?" And "how is 'area of the spill' defined? Is it a set radius from a spill, some other quantitative measure, or up to the discretion of the regulator?" The government spokesperson (J. Potter, pers. comm., 11 June 2013) replied: "polluters are required to report releases to persons who may be directly affected by the release. Depending on the type of release, ESRD may also notify the municipality directly and/or other government agencies as necessary." In short, the AER did not answer the questions.

Potter directed Timoney and Lee to ERCB Directive 071, whose notification policy is intended to minimize acute risks to public safety during an emergency event. ERCB's notification policy is not intended to serve the public's right to know what incidents take place on public lands. Questions about disclosure remain, such as: Why is there no requirement for the general public and the media to be notified? Why should industry be entrusted to contact all affected parties in a timely manner? Is it not the regulator's responsibility to protect the public interest?

In a 17 June 2013 commentary in The Globe and Mail "Alberta regulator falls short on disclosure", Jones (2013) noted that the new Alberta Energy Regulator (formerly the ERCB) has a new name and that "after sitting on the news of a recent spill for 12 days, it apparently also needs new policies about transparency." The commentary compared the pipeline spill disclosure policy of the National Energy Board (NEB) with that of the ERCB. It noted that a federal jurisdiction Kinder Morgan pipeline spill of 1.9 m^3 was reported by the NEB to the public the day after the spill whereas the Alberta jurisdiction Hay-Zama spill of 9500 m^3 [actual volume 15,363 m^3] was not reported by the regulator to the public until 12 days had passed. Jones (2013) observed that the Alberta Energy Regulator "claims that it decides when it learns of a spill whether to issue a bulletin based on the incident's public and environmental impact." Ken Hughes, Alberta Energy Minister, was quoted as trusting the regulator to decide when to disclose spill information based "on a process of established science and protocol."

What science? What the minister did not reveal is that ERCB Directive 071 pertains to acute exposure to hazardous substances (such as poisonous gases) in the immediate vicinity of an incident. Directive 071 is mute and irrelevant to the issue of the public's right to be informed.

Summary: How Apache and the AER Handled the 15-09 Saline Spill

The reporting was characterized by misinformation. Apache reported a spill volume of 30 m^3 of produced water on 1 June 2013; on 12 June 2013, 11 days after reporting the spill, Apache reported a spill volume of 9480 m^3 (AER 2015). AER FIS data (first released to me in January 2016) stated a release of 2.0 m^3 crude oil with volume recovered left blank and a release of 9500 m^3 of salt/produced water and 70 m^3 recovered. According to Canadian Press (2015), the spilling took place over 27 days. The AER FIS data stated that the incident took place on 1 June 2013, that there was "no affect" on wildlife or livestock, and that the area affected was "over 1000 square meters".

However, the regulator was aware that the spill occurred on or before 5 May 2013; it was aware on 18 October 2013 that the volume of the saline spill was 15,363 m^3; it was aware on 1 June 2013 that the spill area covered 42 ha (AER 2015), 420 times larger than the areal estimate provided to the public; and Apache was fined by AER for damage to the environment (Wagener 2015b). It's therefore difficult to understand how the regulator could inform me in January 2016, more than two years after it was aware of the incident particulars, that the incident took place on 1 June 2013, that the saline spill volume was 9500 m^3, that the affected area was "over 1000 square meters", and that there was "no affect" on wildlife. The regulator provided misinformation.

Incredibly, when Apache operators noted a drop in pipeline pressure (as a result of the pipeline failure), rather than investigating, they attempted to regain normal system pressure by activating a second pump. When this second pump failed to restore system pressure, workers failed to inform the facility engineering manager. No actions were taken until the release came to surface and a hydrogen sulfide odor was detected by an Apache contractor on 1 June 2013 (AER 2015). Although staff was aware for weeks of both the pressure loss and discrepancies in the daily meter logs for volumes at injection wells, no actions were taken. AER (2015) noted that "any prudent and reasonable operator would be aware that one cause of a meter log discrepancy would be a potential pipeline failure".

Despite the large and damaging spill and inadequate spill responses, AER levied a fine of only $16,500 (Wagener 2015b), equivalent to ~ 1/10 of one cent per liter of saline water released to the environment.

Web 6.1.1. Information on the 15-09 Apache spill obtained under FOIP (AER 2017b)

The FOIPed documents stated that monitoring was conducted in 2013, 2014, and 2015, but only 2013 data were provided. Why the later data were not provided to me is unknown. Isn't it against the law to fail to provide documents that the government is obligated to produce? Were the documents lost, never produced, never received by the regulator, or were they withheld? So many questions, so few answers.

A 19 June 2013 AER comment noted "Upland soils and vegatation [sic], as well as wetland areas are impacted with elevated chlorides". Moreover, after remediation, our 2016 soil and pond analyses demonstrated that the remaining soil was high in conductivity and sulphates and that the excavated pond was high in conductivity and sodium and supported little life other than cyanobacteria colonies. The absence of expected macroinvertebrates such as water fleas, snails, and dragonfly larvae in the excavated pond in 2016 speaks to residual contamination.

Surface water and soil chemical data gathered during summer 2013 revealed elevated levels of many analytes. But before we look at the data, here is some context to help understand just how elevated they were. The FOIPed data reported local "background" pond conductivity ranging from ~700 to 1400 µS/cm while background levels for chloride were all below 30 mg/L; the Alberta Environment freshwater protection guideline for chronic chloride exposure is 230 mg/L.

The spill footprint was subdivided into four divisions. Division 1 was the upland surrounding the 15-09 well. This area was impaired by industrial activities before the spill and is an exotic-dominated meadow; 383,011 metric tons of salt-contaminated soil were removed from Division 1 and disposed of at the Tervita Landfill. Divisions 2 was a "muskeg wetland complex" (Figure 12.11 and Web 12.2). This bog-fen complex received the brunt of the toxic discharge and was later excavated to create a pond. Division 3 was reportedly a "large beaver pond", and Division 4 was a "pond/wetland complex". Water flows into the Zama River.

In Division 1, the mean conductivity exceeded a startling 100,000 µS/cm, sufficiently toxic to kill everything it contacted. About 80 % of the water samples reported conductivities over 100,000 µS/cm; almost all chloride concentrations exceeded the laboratory's ability to measure them and were reported as some value > 6000 mg/L.

In Division 2, conductivity and chloride concentrations remained highly elevated. Conductivity values ranged from 828 to 106,000 µS/cm and typically exceeded 5000 µS/cm. Chloride ranged widely but most locations recorded values from 2 to 30 times the freshwater protection guideline.

In Division 3, conductivity and chloride concentrations remained elevated. Conductivity values ranged from 2200 to >4000 μS/cm and typically exceeded 3500 μS/cm. At most locations, chloride values ranged from 3 to 40 times the freshwater protection guideline.

In Division 4, conductivity and chloride concentrations fell into two groups, those with elevated levels and those with background levels. In the affected areas, conductivity ranged as high as 6000 μS/cm and chloride concentrations were 2 to 4 times the freshwater protection guideline. Elsewhere, conductivity ranged from about 500 to 2000 μS/cm and chloride concentrations ranged from below to two times the freshwater protection guideline. Even in the “unaffected” Division 4, there were effects on water chemistry. Some areas with an elevated chemical spill signature were located more than 2 km from the 15-09 well, indicating that the affected area exceeded the 42 ha in the court document.

Apache reported daily wildlife contaminant exposures in 2013. These included: on 1 July, among other species observed, two “mice”; on 4 July 2013, 282 bison; on 31 July 2013, boreal chorus frogs and wood frogs, “squirrel”, and nine bird species, one of which was a “swamp swallow” (a non-existent species).

From monitoring conducted during June and July 2013 alone, Apache reported finding the following dead animals: 382 wood frogs, an American bittern, a mallard, a spruce grouse, and a ruffed grouse. A 5 July document contained a photograph of a bucket of 178 dead tadpoles recovered from Division 2 and listed 11 bird species, wood frogs, boreal chorus frog, and black bear. A 7 July document listed 11 bird species, wood frogs, and “squirrel”. An 8 July document listed 13 bird species, wood frogs and boreal chorus frogs, “squirrel”, and “hare”.

As part of the administrative penalty of $16,500, the regulator stated: “Apache released 15 363 cubic meters of produced water with a concentration of 79 000 milligrams/litre of chlorides into the environment that may have cause [sic] an adverse effect, and failed to take all reasonable measures to repair, remedy and confine the effects of the produced water” (Wagener 2015b).

It’s difficult to comprehend the volume and toxicity of this event. We have a smattering of documents but little in the way of credible monitoring. Book Figures 12.10-11 provide a glimpse of the affected area. The death of vegetation was detected on satellite imagery (Plate 12.3b). Failed reclamation due to contaminated soil is shown in Plate PS1. See also Web 2.5, Figure d.

Web 6.2. Notes on crude oil spill rates and recovery rates

Of the 24,948 crude oil primary spills (as of 6 February 2017), 42 spills reported a spilled volume of zero. Of the 24,906 crude oil primary spills with volume spilled reported, the total release was 255,286.1 m^3. 18,534 spills reported that oil was recovered, with a total release of 218,847.6 m^3, of which 176,416.2 m^3 were reported recovered. No oil was reported recovered from 5694 primary spills. For 720 primary crude oil primary spills, the volume recovered field was blank.

Spills with zero volume, or with recovered volume unspecified exacerbate the uncertainty of the volume of contaminants remaining in ecosystems. A Suncor pipeline rupture from 1 November 2007 (incident 20072793) illustrates the problem. This was a major spill of crude oil given that the public was notified due to potential hazard (notification is given in only 0.8 % of spills); there was release off site into flowing water; habitat was affected; and the spill area exceeded 1000 m^2. Yet the AER data stated that zero crude oil was released, the volume recovered was left blank, and no other compounds were reported spilled.

In addition to crude oil primary spills, there were 3835 crude oil secondary spills reporting a total volume of 28,203.8 m^3, and 19,082.3 m^3 recovered, 510 crude oil tertiary spills reporting a total volume of 2008.1 m^3 and 1431.5 m^3 recovered, and 71 crude oil quaternary spills reporting a total volume of 214.8 m^3 and 313.6 m^3 recovered.

Inspection of the data indicates that 46 % of crude oil primary spills reported a recovery efficiency of <99.9 %, with a mean recovery efficiency of 35% and a median recovery of 0 %. The discrepancy between median and mean recovery is due to the uncertain nature of recovery volumes in which many spills report recovery volumes exceeding spill volumes, which results in recovery efficiencies exceeding 100 %. Further inspection reveals that 54 % of crude oil primary spills reported an essentially perfect recovery efficiency of ≥ 99.9 %, with a mean recovery of 123.9 % and a median recovery of 100.0 %.

Notes on Crude Oil Spill Recovery Efficiency and Environment Types

AER's Environment Types

"Flowing Water" includes rivers and creeks, but flowing water can also be found in the other two environment categories. A less informative designation than "Air/Land" would be difficult to envision. It includes releases to everything other than flowing water and "muskeg" (below), but it's worse than that because "air/land" includes flowing water and "muskeg". Air/land is what's known as a "garbage can" category... everything gets thrown into it and its information value is nil.

"Muskeg/Stagnant Water" in AER usage connotes peatlands and mineral wetlands such as marshes, wet meadows, and carrs. No competent scientists use the term "muskeg" because its meaning is vague and pejorative. Furthermore, water flows through organic terrain (AER term: "muskeg") and it is therefore misleading to refer to water in organic terrain as "stagnant". No competent scientists use the term "stagnant" for non-flowing water. AER's use of uninformative environment types conveys more information about the regulator than it does about the environment.

The regulator's environment types could be improved by using easily identified classes that convey information such as peatland, mineral wetland, flowing water, lake, conifer forest, deciduous forest, weedy meadow, native grassland, unvegetated, hayfield, and cropland. An AER staff person explained to me that their environment categories lack definitions and methodologies that would ensure they are used consistently (name withheld, pers. comm., 20 May 2017). Informative environment types are important because spill recovery is influenced by environment type (NOAA 1992; Nuka Research and Planning Group 2015).

There were significant changes in the recovery efficiency data when the 2013 and 2017 versions of the same FIS spills database were compared, as follows:

In Muskeg/Stagnant Water, no oil recovery was reported in 27.1 % of spills in the 2013 version of the data or 3.7 % in the 2017 version of the data; in the Air/Land category, no oil recovery was indicated in 24.0 % for 2013 or 23.1 % for 2017; and in Flowing Water, no oil recovery was indicated in 26.5% of spills for 2013 or 34.7 % for 2017.

Changes were also evident in the subset of spills reporting perfect recovery (≥ 99.9 % recovery) as follows:

In the Muskeg/Stagnant Water, there was perfect oil recovery in 53.3 % for 2013 or 62.5 % for 2017; in the Air/Land category, there was perfect oil recovery in 53.4 % for 2013 or 54.7 % for 2017; and in Flowing Water, there was perfect oil recovery in 45.3 % for 2013 or 30.6 % for 2017.

Some of these changes in frequency of particular recovery efficiencies are large given the thousands of spills that they represent. The changes demonstrate active editing of the spills database and the release by the regulator of data whose values were later changed. The regulator does not inform the public of changes to the spills database, nor of the reasons for changes. An onus is therefore placed on the public to not only detect changes in the spills database but also to attempt to explain them; this is not acceptable practice for a regulator.

Is Crude Oil Spill Recovery Efficiency Affected by Lease Location?

The AER reports whether spills remained on lease or flowed off lease; 50.0 % of crude oil primary spills flowed off lease and 50.0 % remained on lease. The median recovery efficiency for primary crude oil spills that remained on lease was 100 % whereas the median off-lease recovery efficiency was 90 %. In 60.0 % of on-lease crude oil spills, recovery efficiency was ≥ 100 %. In comparison, in 44.6 % of off-lease crude oil spills, recovery efficiency was ≥ 100 %. Reported recovery efficiency was higher for on-lease spills than for off-lease spills (Mann-Whitney test, $p < 0.001$).

Is Crude Oil Spill Recovery Efficiency Improving over Time?

Oil recovery efficiency may be increasing over time. The overall rank correlation between year and recovery efficiency was $r = 0.24$ ($p \ll 0.001$). Within each environment category, the rank correlation between year and recovery efficiency was: for Muskeg/Stagnant Water $r = -0.16$ ($p \sim 0.07$); for Flowing Water $r = 0.29$ ($p < 0.001$); and for Air/Land $r = 0.23$ ($p \ll 0.001$). Although recovery efficiency may be rising over time, the relationship with time was weak. If the data were normal in distribution, time would explain only about 6 % of the variation in recovery efficiency in the overall dataset. Given that the oil recovery efficiency values are unempirical, the relationship between recovery efficiency and time could be spurious.

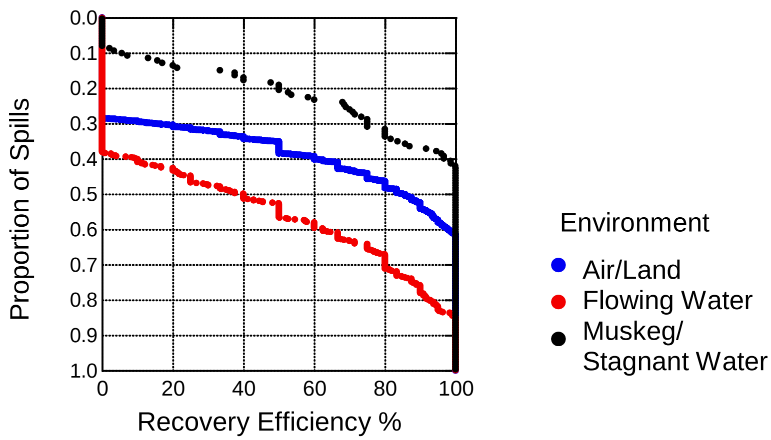
Web 6.3. Summary statistics for crude oil primary spills for various subsets of the data.
The data (current to 6 February 2017) don't include secondary, tertiary, and quaternary crude oil spills. The summary here is meant to describe the structure of the data. For total spills and total volumes current to June 2019, please see Web 6.20.

Dataset/Statistic	**Oil Spilled (m^3)**	**Oil Recovered (m^3)**	**Recovery %**
All Crude Oil Primary Spills			
Mean	10.2	7.3	83.0
Median	2.0	1.0	100
n	24,948	24,228	24,199
Skewness	44	24	1363
Kurtosis	3105	859	19,961
Oil Spilled >/= 1 m^3			
Mean	12.7	8.9	75.0
Median	2.5	2.0	100
n	19,921	19,650	19,650
Skewness	40	22	78
Kurtosis	2499	711	7328
Oil Spilled >/= 5 m^3			
Mean	31.4	21.8	81.7
Median	12.0	9.0	96.9
n	7366	7276	7276
Skewness	25	14	76
Kurtosis	970	292	6271
Oil Spilled >/= 10 m^3			
Mean	46.5	31.5	79.5
Median	20.0	15.0	95.7
n	4596	4558	4558
Skewness	20	12	3
Kurtosis	625	197	91
Oil Spilled >/= 50 m^3			
Mean	173.9	105.6	72.9
Median	80.0	60.0	93.8
n	800	795	795
Skewness	9	5	-1
Kurtosis	129	41	-0.4
Oil Spilled >/= 100 m^3			
Mean	342.8	192.2	67.3
Median	175.0	127.5	90.0
n	312	310	310
Skewness	6	3	-0.8
Kurtosis	58	17	-1.0

Comments: Crude oil spill volumes are non-normal in distribution due to their strong positive skewness (means much greater than medians) and their strong kurtosis ("peakiness") with some volumes far more abundant than would be observed under a normal distribution.

Web 6.4. Example of AER spill volumes and recovery volumes for crude oil primary spills illustrating perfect recovery not attainable under real-world conditions.

Substance	Volume Spilled (m^3)	Volume Recovered (m^3)	Incident Number
Crude Oil	18	18	19810565
Crude Oil	18	18	19810749
Crude Oil	18	18	19810829
Crude Oil	18	18	19830492
Crude Oil	18	18	19850510
Crude Oil	18	18	19861511
Crude Oil	18	18	19870498
Crude Oil	18	18	19870501
Crude Oil	18	18	19890341
Crude Oil	18	18	19890498
Crude Oil	18	18	19890556
Crude Oil	18	18	19901861
Crude Oil	18	18	19901990
Crude Oil	18	18	19910983
Crude Oil	18	18	19931136
Crude Oil	18	18	19931987
Crude Oil	18	18	19941587
Crude Oil	18	18	19941602
Crude Oil	18	18	19941815
Crude Oil	18	18	19943537
Crude Oil	18	18	19952193
Crude Oil	18	18	19960278
Crude Oil	18	18	19970743
Crude Oil	18	18	19970812
Crude Oil	18	18	19972495
Crude Oil	18	18	19973309
Crude Oil	18	18	19973490
Crude Oil	18	18	19980197
Crude Oil	18	18	19991995
Crude Oil	18	18	19992328
Crude Oil	18	18	20001967
Crude Oil	18	18	20002893
Crude Oil	18	18	20021068
Crude Oil	18	18	20022756
Crude Oil	18	18	20032405
Crude Oil	18	18	20040120
Crude Oil	18	18	20040274
Crude Oil	18	18	20040523
Crude Oil	18	18	20051478
Crude Oil	18	18	20051882



Web 6.5. Frequency of spills in relation to reported crude oil recovery rates in three AER environment types.
Air/Land n = 22,591, Flowing Water n = 921, Muskeg/Stagnant Water n = 136.

Web 6.6. Spearman rank correlation between crude oil spill volume and recovery efficiency for various subsets of the data.[a, b]

Dataset	Correlation (Spearman r, n)
All oil spills	-0.028, 24,199
Spill ≥ 1 m^3	0.057, 19,650
Spill ≥ 5 m^3	-0.080, 7276
Spill ≥ 10 m^3	-0.084, 4558
Spill ≥ 50 m^3	-0.140, 795
Spill ≥100 m^3	-0.078, 310

[a] Because the spill volume data were strongly non-normal, the relationship between reported spill volume and recovery efficiency was tested via rank correlations.

[b] If the data were normally-distributed, spill volume would explain zero to 2 % of the variation in recovery efficiency.

Web 6.7. Does spill volume influence crude oil recovery efficiency? A binary approach.

	Spill Volume (m^3) (Recovery = 0 %)	Spill Volume (m^3) (Recovery = 100 %)	Test Result	
Environment	**median, mean, n**	**median, mean, n**	**Mann-Whitney U, p**	**Notes**
Flowing Water	2, 28.6, 320	1, 10.1, 281	5.41×10^4, $p < 0.0001$	smaller spills more often report perfect recovery
Air/Land	1, 4.7, 5228	1, 6.0, 12,242	2.85×10^7, $p << 0.0001$	larger spills more often report perfect recovery
Muskeg / Stagnant Water	0.1, 0.3, 5	2, 20.7, 75	71.5, $p = 0.020$	larger spills more often report perfect recovery

Web 6.8. Notes on the falcon effect for crude oil spill recovery

In Figure 6.6 in the book, the families of arcuate lines formed a mirror image with the line of symmetry at a recovery efficiency of 0.5. Above a recovery efficiency of 0.5, curves suggest increasing recovery efficiency as spill volume increases; below a recovery efficiency of 0.5, curves suggest decreasing recovery efficiency as spill volume increases. This interpretation would be incorrect because the shape of the curves is an artifact of guessing.

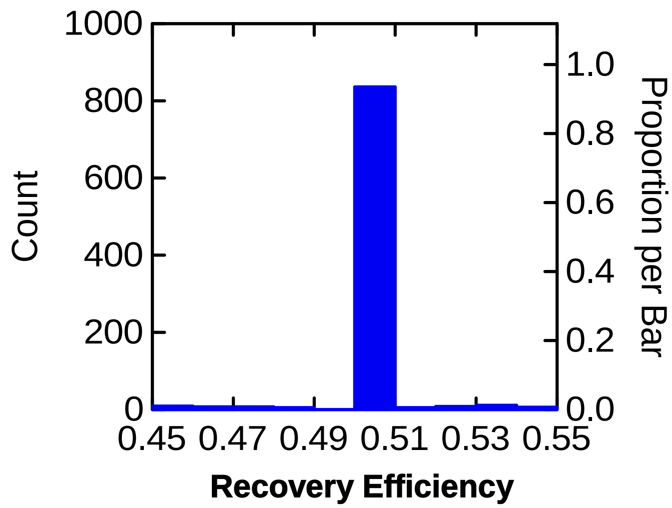
Why would there be families of curves plotting differing efficiencies of cleanup in relation to spill volume? What made the pattern even more curious was the fact that the families of curves plot opposing patterns of differing efficiencies of cleanup with increasing volume. Interspersed with the families of curves, and their mirror image curves, and lying between the horizontal lines of points indicating both zero recovery and perfect recovery are random clouds of points with no discernible pattern. The curves proved to result from humans guessing the recovery volumes from a set of numbers limited to whole number fractions of the spill volume

Higher than expected numbers of spills at convenient "guesstimate" recovery efficiencies result in horizontal lines at recovery efficiencies of zero, one-fourth, one-third, one-half, two-thirds, three-fourths, four-fifths, and one (Figure 6.6 and Web 6.9, 6.10). Were the recovered volumes based on actual measurements, the frequency of particular recovery efficiencies would not reveal marked peaks at ballpark estimates such as "one-half". Such a pattern could not arise if the volumes were measured.

I asked whether the relationship between spill volume and recovery efficiency was changing over time. The crude oil spill data were divided into four time periods with roughly the same number of observations (Web 6.10). The falcon effect was evident in all time periods.

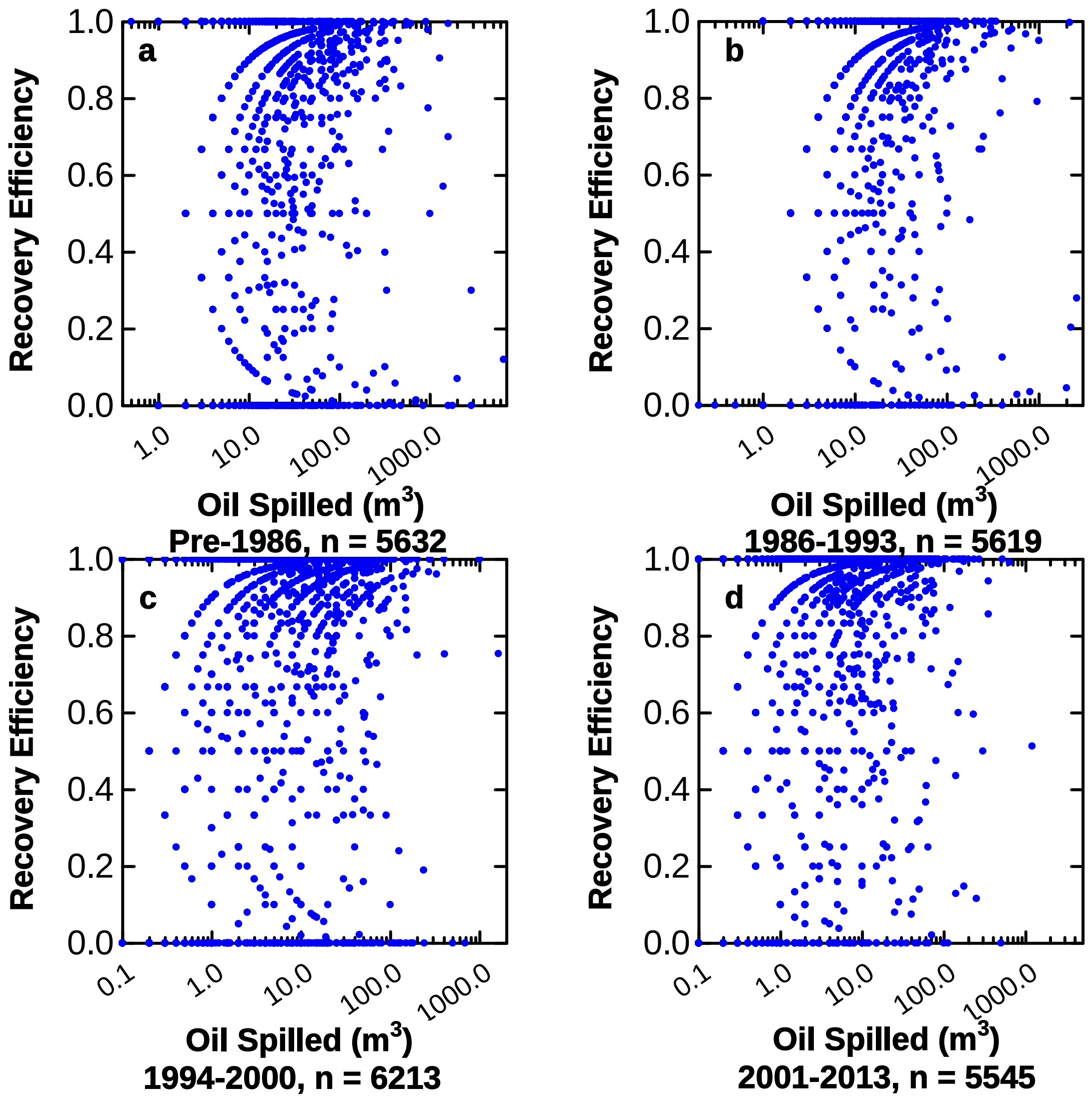
Determining the reason for the families of curves was challenging because what appeared to be single data points were often composed of up to hundreds of spills with the same volume released and the same recovery efficiency. The query was therefore simplified by limiting the data to a single randomly-chosen year (Web 6.10.1). The reason for the falcon effect lay in guessing: recovery volumes were chosen from the set of whole numbers ranging from 0 to the spill volume.

Choosing whole number fractions of the spill volume as the value for the recovery volume produces families of curves whose shapes are constrained by fractions of the spill volume. For example, for spills of 2 m^3, there are only three possible recovery volumes: 0, 1, and 2; for spills of 3 m^3, there are four possible recovery volumes of 0, 1, 2, 3. When this series is expanded over a range of spill volumes, curves emerge depicting recoveries of 0/1, 1/2, 1/3, 2/3, 1/4, 3/4, ..., to 1/1. The three most common guesstimates are, in decreasing order, perfect recovery, zero recovery, and one-half recovery.



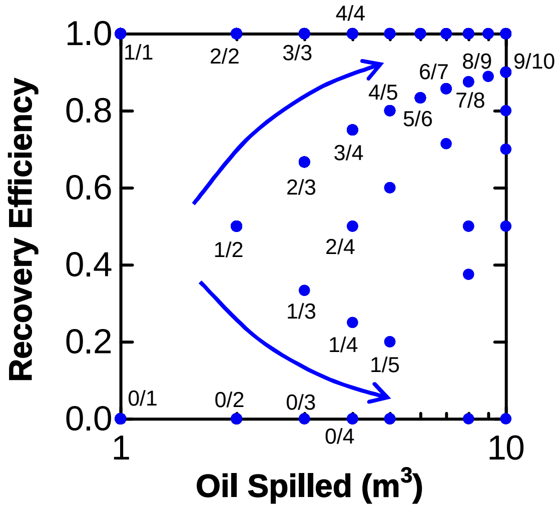
Web 6.9. Frequency of oil recovery efficiencies over the range of 0.45 to 0.55.
The majority of these spills (93.4 %) report a recovery efficiency of exactly one-half of the spilled volume. Higher than expected frequencies of particular recovery efficiencies indicate that the AER crude oil recovery volumes are not measured values but are instead based on human decisions.

Web 6.10. Crude oil recovery and the falcon effect for four time periods.



The "falcon effect" is a persistent feature of AER's data on recovery efficiencies of crude oil spills. The four panels (a, pre-1986; b, 1986-1993; c, 1994-2000, d, 2001-2013) illustrate the same data structures for different time periods. Thousands of data points overlap.

Web 6.10.1. Spill volumes in relation to cleanup efficiency for crude oil spills of 1-10 m^3 from 1990.



The "falcon effect" results from guessing common fractions of the spill volume. This constraint produces the families of smooth curves, two of which are indicated. Some of the common fractions are labelled. Many points overlap; n = 656 spills in this panel.

Web 6.11. Summary statistics for saline primary spills for various subsets of the data.
The data (current to 6 February 2017) don't include secondary, tertiary, and quaternary saline spills. The summary here is meant to describe the structure of the data. For total spills and total volumes current to June 2019, please see Web 6.20.

Dataset/Statistic	Water Spilled (m^3)	Water Recovered (m^3)	Recovery %
All Saline Water Primary Spills			
Mean	41.4	22.2	66.7
Median	5.0	2.0	84.2
n	15,801	15,230	15,215
Skewness	50	39	101
Kurtosis	3156	1945	11,406
Water Spilled >/= 1 m^3			
Mean	46.2	24.5	63.4
Median	6.9	3.0	83.3
n	14,142	13,754	13,754
Skewness	47	37	46
Kurtosis	2828	1760	3071
Water Spilled >/= 5 m^3			
Mean	76.9	40.6	69.0
Median	16.0	10.0	88.9
n	8347	8132	8132
Skewness	36	29	11
Kurtosis	1682	1058	299
Water Spilled >/= 10 m^3			
Mean	101.8	53.5	69.6
Median	25.0	16.0	90.0
n	6159	6001	6001
Skewness	31	25	12
Kurtosis	1248	789	324
Water Spilled >/= 50 m^3			
Mean	278.8	139.1	67.1
Median	100.0	62.5	85.7
n	1939	1877	1877
Skewness	18	14	9
Kurtosis	405	261	199
Water Spilled >/= 100 m^3			
Mean	480.7	228.0	64.2
Median	199.5	103.0	83.3
n	996	960	960
Skewness	13	11	4
Kurtosis	213	139	71

Comments: Saline spill volumes are non-normal in distribution due to their strong positive skewness (means much greater than medians) and their strong kurtosis ("peakiness") with some volumes far more abundant than would be observed under a normal distribution.

Web 6.12. Notes on saline water spill rates and recovery rates

Of the 15,803 saline primary spills, two lacked data for volume spilled. An additional 18 spills reported a volume spilled of zero. Of the 15,801 saline primary spills with volume spilled reported, the total release was 653,787.9 m^3. 10,899 spills reported that saline water was recovered, with a total release of 465,469.6 m^3 and 337,794 m^3 reported recovered. No saline water was reported recovered from 4331 primary spills. For 573 saline primary spills, the volume recovered field was blank.

There were an additional 8314 saline secondary spills reporting a total spilled volume of 211,544.5 m^3 and 120,680.1 m^3 recovered, 1293 saline tertiary spills reporting a total volume of 78,088.9 m^3 and 34,062.7 m^3 recovered, and 299 saline quaternary spills reporting a total volume of 8942.4 m^3 and 6796.1 m^3 recovered.

61.5 % of saline primary spills reported a recovery efficiency of <99.9 %, with a mean recovery efficiency of 36% and a median recovery of 20 %. 38.5 % of saline primary spills reported an essentially perfect recovery efficiency of ≥ 99.9 %, with a mean recovery of 115.4 % and a median recovery of 100.0 %.

Notes on: Is Saline Spill Recovery Efficiency Influenced by the Environment?

As with the crude oil data, there were changes in recovery efficiency in the 2013 and 2017 versions of the AER database, as follows:

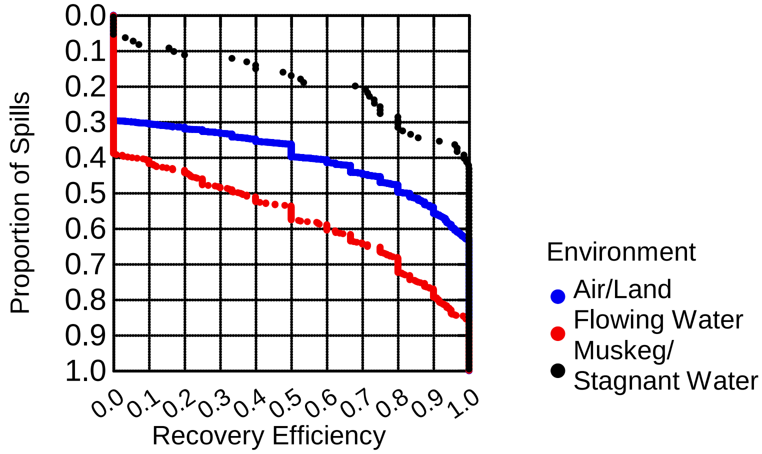
There was no saline water recovery in Muskeg/Stagnant Water, in 5.5 % (2013) or 7.8 % (2017) of spills; in Air/Land, of 29.4 % (2013) or 28.2 % (2017) of spills; and in Flowing Water, of 38.8 % (2013) or 38.1 % (2017) of spills. There was perfect recovery of spilled saline water in Muskeg/Stagnant Water in 60.2 % (2013) or 60.8 % (2017) of spills; in Air/Land, of 37.3 % (2013) or 39.2 % (2017); and in Flowing Water, of 14.6 % (2013) or 15.4 % (2017) of spills. The reasons for these data changes have not been divulged by the regulator.

Is Saline Spill Recovery Efficiency Affected by Lease Location?

The AER reports whether spills remained on lease or flowed off lease; 52.1 % of saline primary spills flowed off lease. The median recovery efficiency for primary saline water spills that remained on lease was 100 % whereas the median off-lease recovery efficiency was 50 %. In 50.3 % of on-lease saline water spills, recovery efficiency was ≥ 100 %. In comparison, in 24.9 % of off-lease saline water spills, recovery efficiency was ≥ 100 %. Reported recovery efficiency was higher for on-lease spills than for off-lease spills (Mann-Whitney test, $p < 0.001$).

Is Saline Spill Recovery Efficiency Improving over Time?

Saline recovery efficiency may be increasing over time. The overall rank correlation between year and recovery efficiency was: $r = 0.405$ (<< 0.001); and within each environment category was: Muskeg/Stagnant Water $r = 0.147$ ($p \sim 0.07$); Flowing Water $r = 0.205$ ($p < 0.001$); and Air/Land $r= 0.405$ ($p << 0.001$). Although saline water recovery efficiency may be rising over time, the relationship with time was weak. Were the data parametric, time would explain about 2 to 16 % of the variation in recovery efficiency. Given the unempirical nature of the recovery data, the relationship between recovery efficiency and time could be spurious.



Web 6.13. Frequency of spills in relation to reported saline water recovery rates in three AER environment types. Air/Land n = 14,182, Flowing Water n = 591, Muskeg/Stagnant Water n = 153.

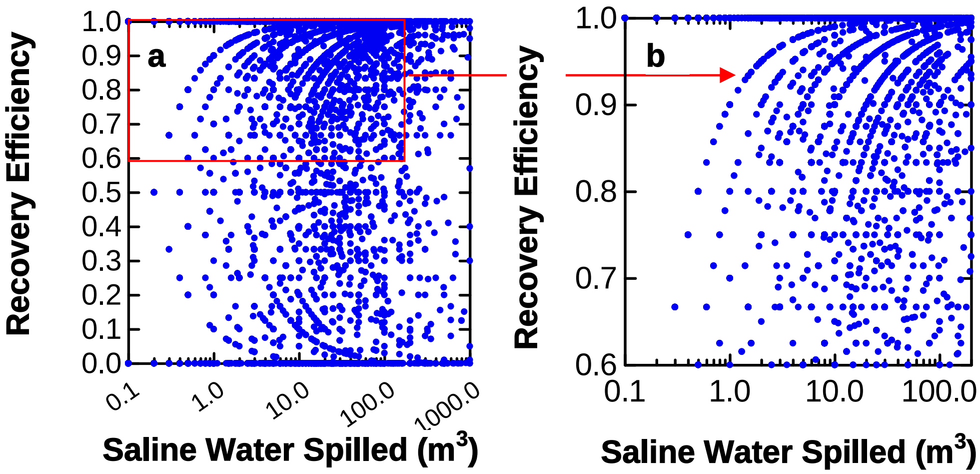
Web 6.14. Spearman correlation between saline water spill volume and recovery efficiency. [a, b]

Dataset/ Statistic	Correlation (Spearman r, n)
All saline spills	0.078, 15,215
Spill ≥ 1 m^3	0.126, 13,754
Spill ≥ 5 m^3	-0.039, 8132
Spill ≥ 10 m^3	-0.060, 6001
Spill ≥ 50 m^3	-0.056, 1877
Spill ≥100 m^3	-0.096, 960

[a,] Because the spill volume data were strongly non-normal, the relationship between reported spill volume and recovery efficiency was tested via rank correlations.

[b] If the data were normally-distributed, saline spill volume would explain zero to 1.6 % of the variation in recovery efficiency.

Comments:
For six different versions of the saline water spill dataset, correlations between spill volume and recovery efficiency ranged from weakly negative to weakly positive.



Web 6.15. The relationship between saline water recovery efficiency and spill volume.
(a) The pattern shown here is for Air/Land saline water spills with recovery of 0-100% and spill volume 0-1000 m^3. (b) The inset highlights the saline recovery/spill volume relationship at spill volumes of 0–200 m^3 and recovery efficiencies from 0.6-1.0. Thousands of data points overlap.

Web 6.16. Does spill volume influence saline water recovery efficiency? A binary approach.

	Spill Volume (m^3) (Recovery = 0 %)	**Spill Volume (m^3) (Recovery = 100 %)**	**Test Result**	**Notes**
Environment	Volume median, mean, n	Volume median, mean, n	Mann-Whitney U, p	
Flowing Water	16, 181.9, 225	25, 168.3, 90	9.50×10^3, $p = 0.394$	no effect of spill volume on recovery
Air/Land	2, 24.9, 4004	4, 18.6, 5417	8.92×10^6, $p << 0.0001$	larger spills more often report perfect recovery
Muskeg / Stagnant Water	9, 22.9, 12	10, 155.8, 83	447.5, $p = 0.571$	no effect of spill volume on recovery

Web 6.17. Rates of no recovery and perfect recovery for saline water and crude oil spills in three AER environment types.

Environment Type / Spill Category	Percent of Saline Spills with 0 % Recovery (n, %)[a]	Percent of Crude Oil Spills with 0 % Recovery (n, %)	Comments
Muskeg/Stagnant Water	12, 7.8 %	5, 3.6 %	saline water more frequent zero recovery than crude oil
Air/Land	4004, 28.2 %	5228, 23.1 %	saline water more frequent zero recovery than crude oil
Flowing Water	225, 38.1 %	320, 34.7 %	saline water more frequent zero recovery than crude oil
	Percent of Saline Spills with ≥ 100 % Recovery	Percent of Crude Oil Spills with ≥ 100 % Recovery	
Muskeg/Stagnant Water	92, 60.1 %	100, 73.5 %	crude oil more frequent perfect recovery than saline water
Air/Land	5563, 39.2 %	12,357, 54.7 %	crude oil more frequent perfect recovery than saline water
Flowing Water	91, 15.4 %	282, 30.6 %	crude oil more frequent perfect recovery than saline water

[a] n and % refer to number of incidents within that spill category and environment type

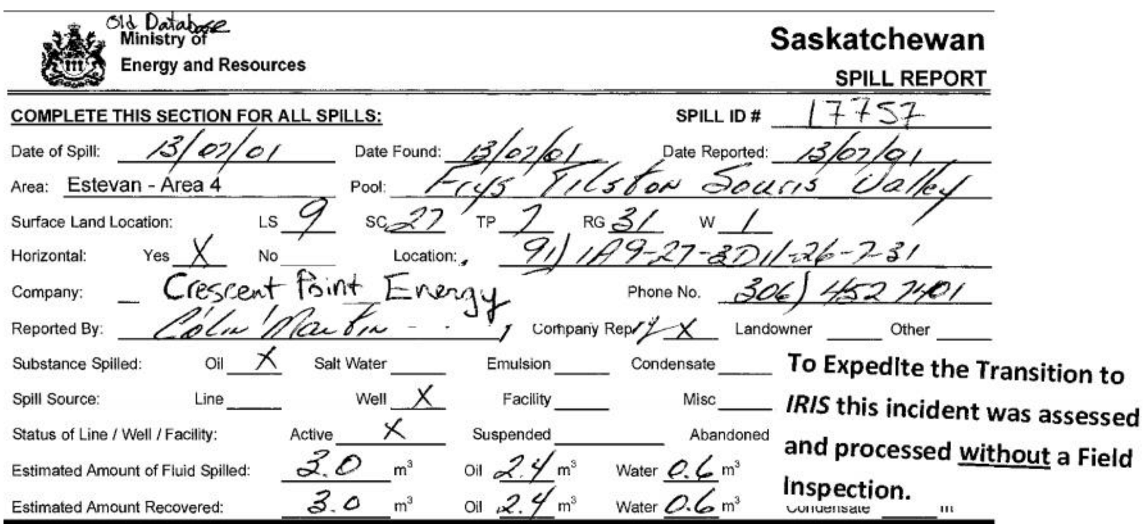
Web 6.18. Comparison data on crude oil and saline spills in Alberta, Saskatchewan, North Dakota, and Montana

The Saskatchewan spill data obtained under Freedom of Information Request from the Ministry of Energy and Resources contain industry-reported information on 19,511 spills. Of those records, there are 12 pre-1991 records, 140 records from 2018 current to 2 April 2018, and 38 records with no occurrence date. I focussed my attention on the years with relatively complete data, 1991-2017. According to the ministry, “water released” in the data pertain to “produced water/salt water”, not fresh water releases (which are not reportable). For brevity, I refer to these spills as saline spills.

The North Dakota spill data cover the period 1 January 2006 to 13 October 2014, were obtained from the North Dakota Department of Health, and were appended to an article from the New York Times (Sontag and Gebeloff 2014). Saline/produced water releases in the data are referred to as “brine”. To download the industry-reported data, see: https://www.nytimes.com/interactive/2014/11/23/us/north-dakota-spill-database.html.

The Montana spill data cover the period from 17 January 1997 to 3 January 2020 and were provided by the Montana Department of Environmental Quality on 22 January 2020. The Montana DEQ Records request number was R000149-012020, 20 January 2020; the data file is: Montana 21 jan 2020 Qry_ComplaintSpillRpt_RecordRequests.xlsx. The data report information on 24,987 releases into the environment of diverse substances including crude oil, produced water, diesel oil, sewage, asbestos, sediment, dust, gas, solid waste, transformer oil, other oil, and manure. After cleaning the data file of duplicate records, the file contained usable information on 970 crude oil spills (107 of which lacked spill volumes) and 881 produced water spills (56 of which lacked spill volumes).

Web 6.18.1 A spill recovery form used in Saskatchewan


Old Database
Ministry of
Energy and Resources

Saskatchewan
SPILL REPORT

COMPLETE THIS SECTION FOR ALL SPILLS: SPILL ID # 17757

Date of Spill: 13/07/01 Date Found: 13/07/01 Date Reported: 13/07/01

Area: Estevan - Area 4 Pool: Frys Bilston Souris Valley

Surface Land Location: LS 9 SC 27 TP 7 RG 31 W 1

Horizontal: Yes X No Location: 91/1A9-27-3D1/2-26-7-31

Company: Crescent Point Energy Phone No. 306) 452 7401

Reported By: Colin Martin Company Rep X Landowner Other

Substance Spilled: Oil X Salt Water Emulsion Condensate

Spill Source: Line Well X Facility Misc

Status of Line / Well / Facility: Active X Suspended Abandoned

Estimated Amount of Fluid Spilled: 3.0 m³ Oil 2.4 m³ Water 0.6 m³

Estimated Amount Recovered: 3.0 m³ Oil 2.4 m³ Water 0.6 m³ Condensate m³

To Expedite the Transition to *IRIS* this incident was assessed and processed without a Field Inspection.

Comments:
This is an example of a government form used to track volumes spilled and recovered after a 2013 oil spill in Saskatchewan (Buffalo Head Environmental Ltd 2013). Note the admission of lack of a field inspection and the perfect correspondence of volumes spilled and recovered without empirical evidence. Note also how for both crude oil and saline water spilled and released the sum of the volumes is an integer. The available data support the conclusion (see below) that Saskatchewan and Alberta experience similar problems with spill data reliability.

Web 6.18.2 Summary statistics for crude oil and saline spills in Saskatchewan, 1991-2017.[a]

Statistic	Oil Spilled (m^3)	Oil Recovered (m^3)	Recovery % [b]
All Crude Oil Spills			
Mean	7.6	5.6	78.9
Median	1.5	1.0	97.5
n	11,644	11,644	11,644
Skewness	30.5	26.2	106.9
Kurtosis	1262.2	1087.0	11,501.5

Statistic	Saline Water Spilled (m^3)	Saline Water Recovered (m^3)	Recovery % [c]
All Saline Water Spills			
Mean	23.8	17.6	117.4
Median	4.8	2.0	86.6
n	12,592	12,592	12,592
Skewness	21.6	28.1	53.4
Kurtosis	660.4	1089.3	2997.5

[a] Data are filtered to oil spilled > 0 m^3 for crude oil spills and water spilled > 0 m^3 for water spills.
[b] If 36 spills with recovery efficiency > 100 % are omitted, mean and median oil recovery efficiency are 68.6 and 97.3 % (n = 11,608).
Mean and median recovery efficiencies for pure crude oil spills are 90.8 and 95.0 % (n=4793). [c] Anomalously high mean recovery efficiency is due to 172 spills with recovery volumes exceeding spill volumes. If these spills are deleted mean and median water recovery efficiency are 61.3 and 85.3 % (n = 12,420).
Mean and median recovery efficiencies for pure saline spills are 79.0 and 80.0 % (n=5741).

Comments:
Data on spills of crude oil and saline water are inherently messy and there is no single way to summarize the data that satisfies all objectives. Here are some summary statistics.
Of the total of 19,511 reported spills in the Saskatchewan data (1991-2017):
89 % (n=17,385) of those spills released either combined crude oil + saline water, crude oil, or saline water;
Of those 17,385 spills of crude oil and/or saline water,
39 % (n=6851) released a combination of crude oil and saline water; of these combined oil/saline spills, spill volumes were typically dominated by saline water (in one-half of all these spills, the saline volume was >/= four times the crude oil volume);
28 % (n=4793) released only crude oil;
33 % (n=5741) released only saline water;
11,644 released crude oil with or without saline water (Web 6.18.2 table);
12,592 released saline water with or without crude oil (Web 6.18.2 table).

Web 6.18.3 Comparison of annual and total crude oil and saline spill rates and volumes for Alberta and Saskatchewan, 1991-2017. Volumes in m^3.

Medians	Alberta	Saskatchewan	Ratio Alberta : Saskatchewan
Crude oil spills/yr	729	461	1.58
Crude oil spill volume/yr	4699	3185	1.48
Saline spills/yr	731	489	1.49
Saline spill volume/yr	21,799	10,655	2.05
Totals for 1991-2017	Alberta	Saskatchewan	
Crude Oil Spills	19,900	11,613	1.71
Crude Oil Spill Volume	141,150	88,506	1.59
Saline Spills	19,928	12,545	1.59
Saline Spill Volume	675,078	299,004	2.26

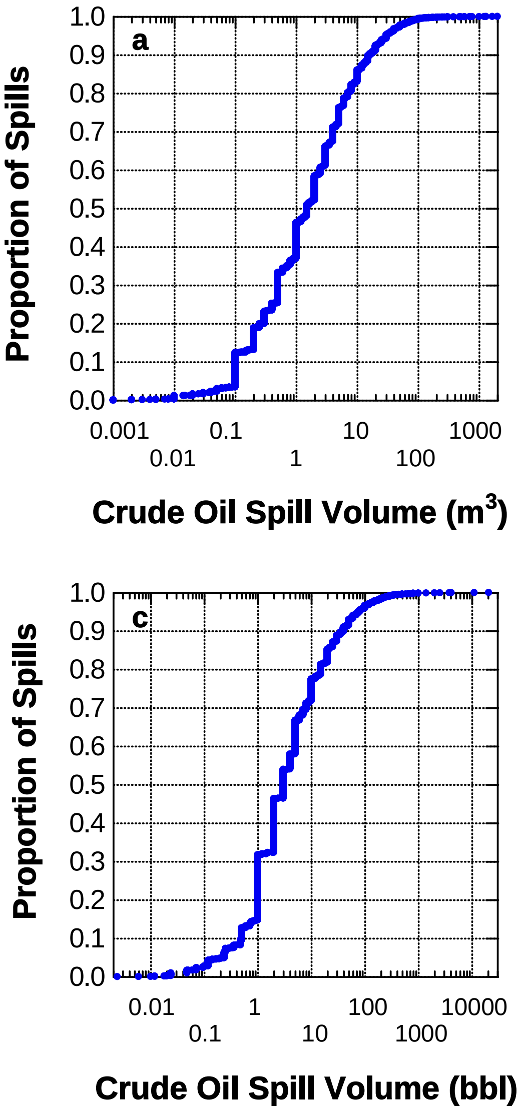
Web 6.18.4 Comparison of annual and total crude oil and saline spill rates and volumes for Alberta and North Dakota, 2006-2014. Volumes in m^3. [a]

Medians	**Alberta**	**North Dakota**	**Ratio Alberta : North Dakota**
Crude oil spills/yr	565	351	1.61
Crude oil spill volume/yr	2880	1939	1.49
Saline spills/yr	652	249	2.62
Saline spill volume/yr	21,537	4814	4.47
Totals for 2006-2014	Alberta	North Dakota	
Crude Oil Spills	5281	5051	1.05
Crude Oil Spill Volume	31,452	21,377	1.47
Saline Spills	6493	3552	1.83
Saline Spill Volume	177,760	44,767	3.97

[a] I used the comparison period of 2006-2014 because that is the total available record for North Dakota. North Dakota totals are pro-rated for 2014 to account for data ending on 6 Oct 2014 by multiplying the partial-year 2014 values by 1.308.

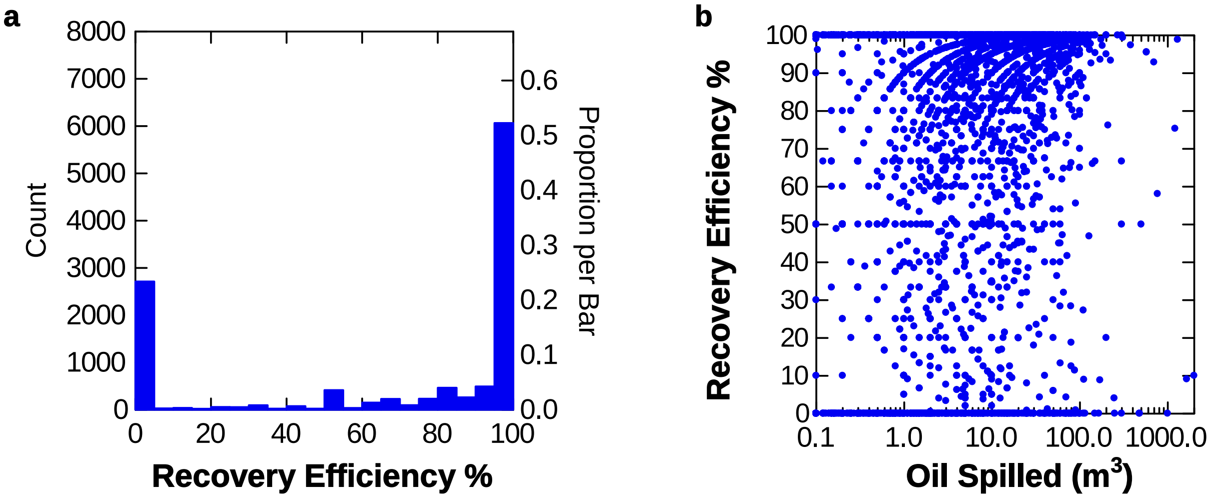
Comments:
Here are some summary statistics.
Of the total of 8690 reported spills in the North Dakota data (2006 to 6 Oct 2014):
82 % (n=7136) of those spills released either combined crude oil + saline water, pure crude oil, or pure saline water;
Of those 7136 spills of crude oil and/or saline water,
15 % (n=1071) released a combination of crude oil and saline water; of these combined oil/saline spills, spill volumes were typically dominated by saline water (in one-half of all these spills, the saline volume was >/= 1.5 times the crude oil volume);
53 % (n=3782) released only crude oil;
32 % (n=2283) released only saline water.

Web 6.18.5 Proportion of reported crude oil and saline spills in relation to spill volume for Saskatchewan (a, b) and North Dakota (c, d).

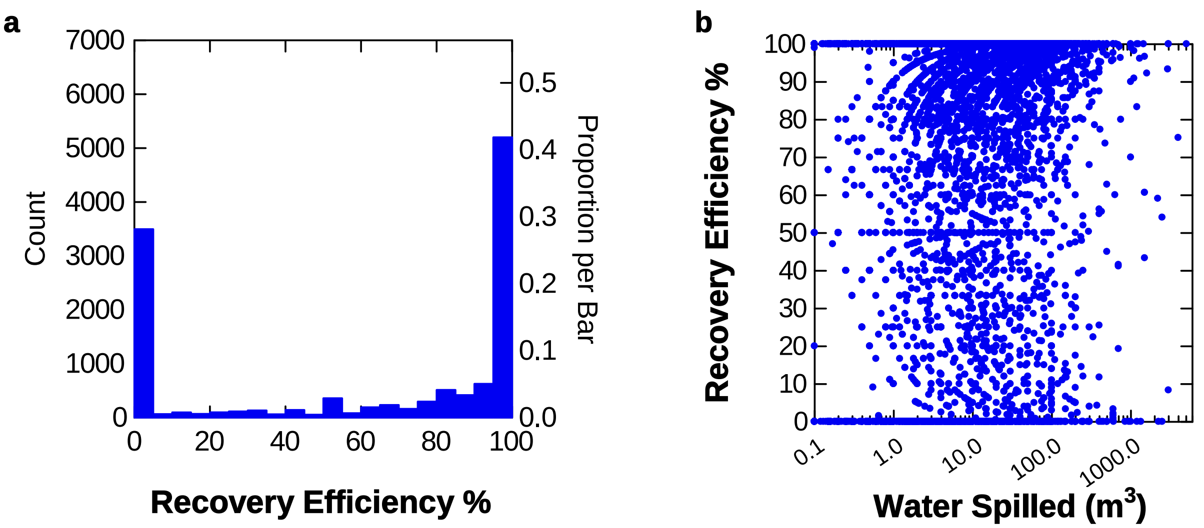


Comments:
The stepped frequency distribution in all panels indicates human choice of spill volumes rather than measurement. In the case of Saskatchewan crude oil spills (a), 0.1, 0.2, 0.3, 0.5, and 1 m^3 are preferred volumes. For Saskatchewan produced water spills (b), volumes of 0.1, 0.5, and 1 m^3 are preferred. For North Dakota, where spill volumes are reported in barrels, oil spill volumes (c) of 0.5, 1, 2 , 3, 4, 5, and 10 barrels are preferred whereas for saline spills (d), volumes of 1, 2, 3, 4, 5, 10, and 20 barrels are often chosen.
Minimum spill volumes in Saskatchewan are one liter (0.001 m^3) whereas minimum spill volumes in Alberta are 0.1 m^3, 100 times larger than in Saskatchewan.

Web 6.18.6 Crude oil and saline spill recovery efficiency and the falcon effect in Saskatchewan.



Web 6.18.6.1 Frequency of crude oil spills in relation to recovery efficiency (a) and crude oil recovery efficiency in relation to spill volume (b) for Saskatchewan spills, 1991-2017.



Web 6.18.6.2 Frequency of saline spills in relation to recovery efficiency (a) and saline water recovery efficiency in relation to spill volume (b) for Saskatchewan spills, 1991-2017.

Comments:
The Saskatchewan crude oil and produced water spill data are consistent with those from Alberta. For both crude oil and saline spills, perfect recovery is most often reported followed by zero recovery and a minor peak at 50 % recovery.
The relationship between recovery efficiency and spill volume reveals the familiar falcon effect (faked data effect) produced by guessing recovery volumes from a constrained set of acceptable answers. Thousands of data points overlap at zero and 100 % recovery.

Web 6.18.7. Crude oil and saline water volumes in combined oil/saline water spills in Alberta, Saskatchewan, and North Dakota and concluding comments

Reported spills of crude oil and saline water occur along a continuum from those reporting purely crude oil to those reporting purely saline water. Here we examine reported volumes for spills that are composed of a mixture of crude oil and saline water.

In Alberta, there were 45,533 spills of crude oil and/or saline water current to 10 July 2019. Of these, 63 reported release of crude oil and/or saline water but reported no volumes. Of the 45,470 spills with usable data, 33.7 % were reported as pure saline spills, 41.1 % as pure crude oil spills, and 25.2 % reported volumes for both crude oil and saline water. In comparison, in Saskatchewan and North Dakota, 39 % and 15 % respectively of the total reported crude oil and saline spills were combined spills that reported both crude oil and saline water spilled.

In the three jurisdictions then, the proportion of combined crude oil and saline water spills differs widely from 15 % (ND) to 25 % (Alberta) to 39 % (Saskatchewan) of all crude oil and saline spills. There is no ostensible reason for such a wide difference in the proportion of pure vs. mixed spills in Alberta, Saskatchewan, and North Dakota other than differences in reporting practices.

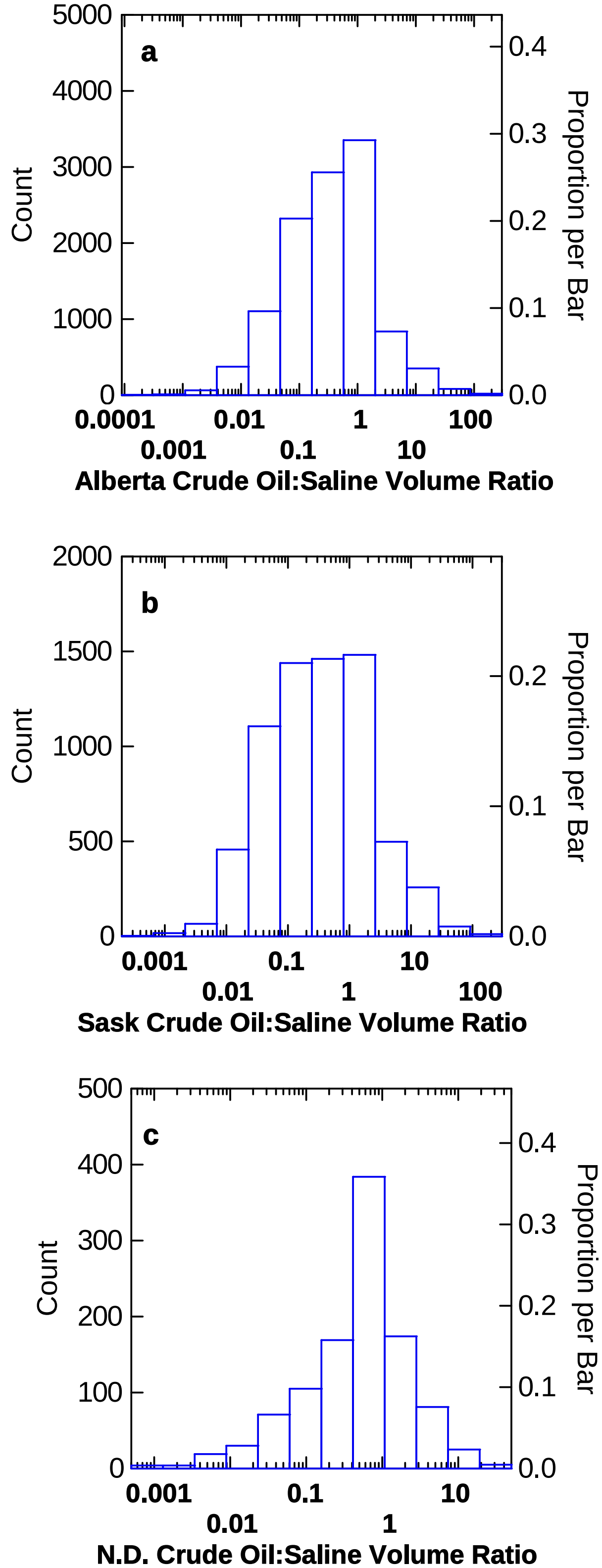
The ratios of crude oil to saline water spill volumes also differ significantly between the jurisdictions (Web 6.18.7.1). Saskatchewan reports the highest proportions of saline water in their combined spills: the median saline water volume is four times the crude oil volume. In Alberta, the median saline water volume is three times the crude oil volume and in North Dakota, the median saline water volume is 1.5 times the crude oil volume. The discrepancy is clear but explaining it is not. Perhaps more saline water is produced in crude oil spills in Saskatchewan than in Alberta and especially in North Dakota. Or, the explanation lies within the culture of the regulators and industry. For example, in North Dakota, perhaps less attention is paid to saline water spill volumes than in Saskatchewan.

At the very least, it's fair to conclude that reported spill volumes in combined oil/saline spills require further study to determine how closely they describe reality. Indeed when I examined the reported spill volumes in the 11,456 combined crude oil/saline spills in Alberta, I noticed a curious property: most often the combined spill volumes were whole numbers. For example, for the 4672 spills reporting a total volume from 1 to 5 m^3, 79 % of the spills reported integer (whole number) spill volumes of 1 to 5 m^3; only 21 % reported real numbers. The summed volumes were often composed of crude oil and saline spill volumes that conveniently summed to a whole number such as spill volumes of 1 m^3 composed of large numbers of spills reporting 0.1 m^3 of crude oil and 0.9 m^3 of saline water, or 0.5 m^3 of crude oil and 0.5 m^3 saline water. In other words, spill volumes were being chosen rather than measured.

I tested this surmise by Benford analysis of the first significant digits in the combined spill volumes in Alberta. The test revealed a strong departure from expectation ($p = 1.45*10^{-145}$) and evidence of human subjectivity in a preference for the numbers 2 and 5 and avoidance of the numbers 1 and 6-9. The preference for the number 2 in the summed volumes arises from humans preferring the number 1 in the crude oil and saline volumes (1 + 1 = 2; see Web 7.2, 7.4). Here again we see the hand of humans manipulating the data values, a serious concern when those numbers are meant to indicate the volume of toxins introduced into ecosystems.

The Saskatchewan spill data in aggregate are consistent with the Alberta data in that they demonstrate unreliable, unempirical data, subjectivity, underestimates of spill volumes, and recovery efficiencies that are too good to be true.

When asked recently (McSheffrey 2019) if the Saskatchewan Ministry of Energy and Resources is "confident that the falsification of documents is not an issue in Saskatchewan, it responded... [via email]: 'While it is possible that a licensee could file incorrect information, the Ministry does not rely solely on its incident reporting program for compliance purposes. In 2017-18, the Ministry of Energy and Resources conducted over 20,000 inspections of wells, facilities and pipelines to identify potential issues including unreported or under-reported spills, which includes follow-up inspections following clean-up activities.'"



Web 6.18.7.1. Ratio of crude oil : saline water volume in combined spills of crude oil and saline water in (a) Alberta, (b) Saskatchewan, and (c) North Dakota.

Web 6.18.8. Comparison of total crude oil and saline spill rates and volumes for Alberta and Montana, 1997-2019. Volumes in m^3. [a]

Totals for 1997-2019	Alberta	Montana	Ratio Alberta : Montana
Crude Oil Spills (n)	15,384	970	15.9
Crude Oil Spill Volume	94,116	11,644	8.1
Saline Spills (n)	16,342	881	18.5
Saline Spill Volume	481,986	45,606	10.6

[a] Because there were issues of missing and uncertain data, I've used a simple comparison. Over the 23-year period, in Montana, there were 970 crude oil and 881 saline (produced water) spills, but only 863 crude oil spills and 825 produced water spills reported volumes. Therefore, to estimate total volumes spilled in Montana, I pro-rated the crude oil volumes by the factor 1.124 (= 970/863) and the saline spill volumes by the factor 1.068 (= 881/825).

Comments:
Spill recovery volumes were reported for 145 crude oil spills and 224 produced water spills. With the provisos that this represents a fairly small number of spills, and the spill and recovery volumes are industry-reported, I found a median crude oil recovery of 98.3 %, with 49.7 % of spills reporting perfect recovery. For saline produced water spills, the median recovery was 81.6 % and 30.8 % of spills reported perfect recovery.

The frequencies of first significant digits in spill volumes reported for crude oil and produced water deviated strongly from the expected Benford distribution (Web 7.17). As with industry-reported spill volumes reported in other jurisdictions, spill volumes reported in Montana represent subjective decisions, not measured volumes.

Web 6.19. Data discrepancies

On 6 February 2017, the Alberta Wilderness Association requested and purchased the AER FIS spills database, which was then forwarded to me on 17 February 2017. The following analysis provides a comparison and overview of the original (current to 4 February 2013) and updated (current to 6 February 2017) data.

6.19.1. Comparison of the original and updated AER spills database, data summary

Total Records
"2013" Database: Between 1 January 1975 and 4 February 2013, there were a reported 61,582 fossil fuel industry spills in Alberta, and a total of 61,587 spills (five spills listed as pre-1975).
"2017" Database: For the period of overlap between the 2017 and 2013 databases (1 January 1975 and 4 February 2013, the 2017 database reported 61,619 spills in Alberta. During that period, the 2017 database reported an additional 37 spills, but that discrepancy is not accounted for by a simple addition of 37 missing spills. It's unclear how many of the 37 spills are newly-reported because of discrepancies in the reported years for the spills (see below). The 2017 database reported a total of 70,088 spills.

6.19.2. Data discrepancies: missing records and incorrect years

One spill, with an incident date of 2 March 1969, and an incident number of 20163248, was reported in the 2017 database and was missing from the 2013 database.

The five earliest spills in the 2013 database, with incident years of 1944, 1955, 1966, and two from 1970 were changed in the 2017 database to incidents dating from 1994, 1995, 1996, 1992, and 1995, respectively. If the revised dates are correct, this would mean that the 2013 database reported no spills prior to 1975.

Ten incidents reported in the 2013 database are missing from the 2017 database. These incidents are summarized below and occurred between 21 November 2011 and 3 February 2013.

There are more discrepancies. I retrieved an updated version of the FIS database current to 30 June 2019. For the period of overlap (1 January 1975 to 6 February 2017), I compared the 2017 database to the updated (2019) database. In the updated database, 48 spill incidents had been deleted. It is unknown why those incidents were deleted in the update.

Incident Years

AER data report three dates for each incident: the "incident date", the "incident notification date", and the "incident complete date". Additionally, each incident is identified by an incident number of eight digits, the first four digits specify the year in which the incident occurred and the last four digits specify the incident number within that year. For example, incident number 19750020 would identify the 20th incident recorded in 1975.

The year provided in the incident date should match the year provided in the incident number. Often this is not the case. Overall, 1421 releases reported incident years in the 2017 database that did not match the incident year reported in the incident number.

I asked the AER why there would be discrepancies in the incident years. Gilbart (pers. comm., AER, 22 Feb 2017) explained: "The system does not allow users to select the Incident Number. It automatically generates the next sequential number when a new record is created. As each year passes the system starts again at 0001 with the leading new, four-digit year. There a [sic] couple of reasons why the dates and incident numbers might not match up. The first and most common reason is early in the new year, we get calls about an incident that occurred in the previous year. So an incident may have occurred in Dec 2016 but we never got called about it until January 2017, thus when enter that incident from 2016, it gets a 2017 incident number.
Additionally, every now and then an incident can accidentally be deleted in error. If it's an older incident, the user must create a new record with a new incident number and in some cases the new incident number will be in a different incident year. The user will add a comment to the new record stating the original incident was deleted in error and its original incident number was 20######.
These two reasons are generally the most common for the incident date and incident number not matching up."

If that were the case, the incident month in the misclassified records should be December, which, allowing for a one-month delay in bookkeeping, would result in incident numbers with the subsequent year's date. Such was not the case. I extracted the implied incident by parsing it from the incident number. In 100 of the incidents, the parsed incident year differed from the incident year by 2 to 47 years with a mean discrepancy of 5.94 years. In 1319 of the incidents, the parsed year followed the incident year by one year. However, the delay in entering the incident into the database was as follows: 1 month delay, n = 735; 2 months delay, n = 164; three months delay, n = 128; four months delay, n = 74; five months delay, n = 54; six months delay, n = 54; seven months delay, n = 43; eight months delay, n = 18; nine months delay, n = 7; ten months delay, n = 6; 11 months delay, n = 5, 12 months delay, n = 31. In two incidents, the parsed year preceded the incident year. Why the regulator experiences consistent difficulties in the timely and accurate recording of incidents remains unclear.

6.19.3. Incidents reported in the "2013" database that were deleted from the "2017" database.

Incident Number	Incident Date	Particulars
20112326	21 Nov 2011	Husky Oil Operations Ltd; source: water pipeline; no substances listed as released or recovered, but release resulted in spilled materials flowing off-site
20120029	30 Dec 2011	Apache; source: water pipeline; spill of fresh water, but no volumes provided
20120322	6 Feb 2012	Penn West; source: natural gas pipeline; spill of 2 m^3 of salt/produced water, no recovery volume provided
20120719	31 Mar 2012	unknown company; source field left blank; spill of 8 m^3 of crude oil, no recovery volume provided
20121371	27 June 2012	Encana; source: suspended well; spill of 3.5 m^3 of drilling mud (hydrocarbon-based), blank volume reported recovered
20122481	9 Dec 2012	TORC Oil and Gas Ltd; source: suspended well; primary spill of 3 m^3 of crude oil, 3 m^3 reported recovered; secondary spill of 0.1 m^3 salt/produced water, 0.1 m^3 reported recovered
20130149	18 Jan 2013	Central Global Resources ULC; source: multiphase pipeline; spill of 0.1 m^3 of hydrotest fluids (methanol), blank volume reported recovered
20130215	28 Jan 2013	Manitok Energy Ltd; source: crude oil group battery; no substances listed as released or recovered, but release resulted in spilled materials flowing off-site
20130239	31 Jan 2013	Celtic Exploration Ltd; source: gas well; spill of 2 m^3 of condensate, blank volume reported recovered; release resulted in spilled materials flowing off-site
20130257	3 Feb 2013	Crew Energy Inc.; source: oil well fire, release of 100 m^3 of production gas, blank volume reported recovered; release resulted in materials leaving the site; a public evacuation order was issued

6.19.4. Examples of discrepancies in years of reported incidents in the 2017 AER spills database.

Incident	Incident Year Parsed (a)	Incident Number Parsed	Incident Month	Incident Day	Incident Year (b)	Difference in Years (= a minus b)
20163248	2016	3248	3	28	1969	47
20150800	2015	800	8	30	1985	30 [a]
20040830	2004	830	5	11	1975	29
20032669	2003	2669	6	7	1983	20
20032671	2003	2671	10	15	1984	19
20032662	2003	2662	9	2	1985	18
20090488	2009	488	1	2	1992	17
20032655	2003	2655	5	9	1989	14
20032654	2003	2654	8	4	1989	14
19941254	1994	1254	5	6	1982	12
20151180	2015	1180	4	25	2004	11
19940420	1994	420	1	1	1984	10
20032674	2003	2674	10	1	1993	10
20071583	2007	1583	6	1	1997	10
19940785	1994	785	9	2	1986	8
20040829	2004	829	6	1	1996	8
20040827	2004	827	6	12	1996	8

[a] this is a large spill of 30,000 m^3

Web 6.20. Annual reported number and volumes for crude oil and saline water spills, summary data for Alberta

Web 6.20.1. Annual total reported number and volumes for crude oil and saline water spills, January 1975 through June 2019.

	Crude Oil		Saline Water	
Year	n	Volume	n	Volume
1975	494	10663	196	19805
1976	394	8609	201	6799
1977	440	12042	217	14615
1978	466	5973	217	17380
1979	490	9581	217	21529
1980	533	15622	260	10216
1981	564	5824	278	14453
1982	586	9585	318	13743
1983	541	5817	337	7208
1984	692	11165	426	49123.1
1985	836	14268	479	15253
1986	729	7785	530	16722
1987	681	5242	561	15283
1988	743	5695	652	28525
1989	814	6989	627	26182
1990	850	12792	723	21837
1991	845	7163	683	18048
1992	720	6328	666	33249
1993	841	13560	635	22640
1994	856	6024.8	720	50967.9
1995	842	6152.5	711	34376
1996	988	10167.7	876	43438.2
1997	1652	8484.9	769	18885.2
1998	895	7746.6	851	24771
1999	827	5189.4	819	23630.7
2000	935	5947.6	884	21798.7
2001	870	6721.3	874	20111.8
2002	834	4699.3	949	19398.5
2003	839	6397.2	858	21024.2
2004	742	4016.8	844	74181.1
2005	729	3850.5	829	12854.1
2006	679	4537.4	854	27047.8
2007	689	2880.1	847	21537.2
2008	642	2694.6	878	24699
2009	542	2298.9	731	24333.7
2010	492	1905.5	637	13224.1
2011	576	7283.7	621	14251.2
2012	565	3917.1	650	12716.4
2013	550	2867.8	623	26515
2014	546	3066.6	652	13435.5
2015	422	1841.1	466	40682.2
2016	353	3341.6	507	8244
2017	429	2065.6	495	9017.3
2018	415	1776	502	6098.5
2019	161	585.9	202	3528.6

Comments:
The numbers and volumes of spills include primary through quaternary spills as reported to the regulator and are current through 30 June 2019. Here are some summary values.
Crude oil spills 1 Jan 1975 through 30 June 2019: 30,329 spills with a total reported release volume of 291,164 m^3 (1,831,418 barrels).

Saline/produced water spills 1 Jan 1975 through 30 June 2019: 26,872 spills with a total reported release volume of 983,378 m^3 (6,185,448 barrels).

Because some spills of crude oil contain saline water, and vice versa, the total number of crude oil and saline spills in the above table involves some double counting. This approach was needed to determine total spill volumes. The total number of crude oil and saline spills with reported spill volume data (excludes spills reported with zero or blank volumes), is 57,111 whereas the actual number of crude oil and saline spills was 45,533 without double counting. Both sets of numbers are correct: the larger number represents the total reported number of times in which crude oil and saline water were spilled; the smaller number represents the discrete events, thousands of which included spills of both crude oil and saline water. There were an additional 91 crude oil and/or saline spills that reported volumes of zero or blank for a grand total of 57,202 spills.

Web 6.20.2. Number of crude oil and saline/produced water spills by recovery efficiency[a] from 1 January 1975 through 30 June 2019.

Recovery Efficiency	Crude Oil (n)	Saline / Produced Water (n)
0 %	7465	7644
>0 %, <50 %	790	1795
Exactly 50 %	1026	868
>50 %, <100 %	4776	5883
Exactly 100 %	16038	10307
> 100 %	182	336
Missing data	52	39

[a] recovery efficiency = ((recovery volume/spill volume) * 100)

Comments:
For the 30,277 crude oil spills with recovery data, median recovery efficiency = 100 %; 53.5 % of crude oil spills reported >/=100 % recovery.
For the 26,833 saline/produced water spills with recovery data, median recovery efficiency = 85.7 %; 39.7 % of saline/produced water spills reported >/=100 % recovery.

Web 6.20.3. Rank correlations between Alberta annual crude oil and saline spills and spill volumes, time, conventional crude oil production (1975-2018, n = 44 years) and annual number of wells drilled (1975-2016, n = 42 years). Data on annual conventional crude oil production are from AER (2014a, 2018).

Indicator	Year	Annual Conventional Crude Oil Production in Alberta	Annual Number of Wells Drilled in Alberta
	r, p	r, p	r, p
Annual number of crude oil spills	-0.06, ns	0.10, ns	0.41, <0.01
Annual crude oil spill volume	-0.76, <0.0001	0.75, <0.0001	-0.23, ns
Annual number of saline spills	0.49, <0.001	-0.48, ~0.001	0.69, <0.001
Annual saline spill volume	0.01, ns	0.09, ns	0.18, ns
Annual conventional crude oil production	-0.95, <0.0001	---	---

Comments:
Over the period 1975-2018, annual crude oil spill volume declined while the annual number of saline spills increased. There were no temporal trends for the annual number of crude oil spills or for annual saline spill volume. Annual conventional crude oil production declined. Annual conventional crude oil production was positively correlated with annual crude oil spill volume but negatively correlated with the annual number of saline spills.

There were no significant correlations between crude oil production and the annual number of crude oil spills or between crude oil production and annual saline spill volume. Why this is so in unclear. The correlations are surprising given that crude oil production should be positively correlated with both the number of spills and the total volume of spills. Under-reporting of both spill occurrences and spill volumes, failure to report saline spills in the earlier decades, and complex interactions and lags between oil price fluctuations, hydrocarbon exploitation, bankruptcies, and monitoring may be at play.

Are the trends real? Whether variations in the number and volume of reported spills represent actual variations in spill rates or changes in reporting practices, or both, depends upon five factors that influence the number and volume of reported spills: (1) the actual spill rates; (2) unreported spills; (3) underestimates of spill volumes; (4) lumping saline spills under crude oil spills and vice versa, and (5) changes in the reporting threshold, which have been ambiguous and inconsistently applied over the years (see Chapter 15 and glossary: reportable releases).

Data on annual number of wells drilled in Alberta are derived from the "ST37" data published by the AER. Correlations between annual number of wells drilled and the spill data are inconsistent. As expected, the annual number of wells was correlated with annual number of crude oil spills and even more strongly with annual number of saline spills. Unexpectedly, annual crude oil spill volume was non-significantly but negatively correlated with the number of wells while annual saline spill volume was non-significantly but positively correlated with the number of wells.

Web 6.20.4. Rank correlations between Alberta annual crude oil and saline spill number and volume for various time periods.

Indicator	Crude oil spill volume	Number of saline spills	Saline spill volume
Period: 1975-2018, n = 44 years	r,p	r,p	r,p
Number of crude oil spills	0.35, ~0.02	0.70, <0.0001	0.52, < 0.001
Crude oil spill volume	---	-0.267, ns	0.06, ns
Number of saline spills	---	---	0.45, <0.005

Indicator	Crude oil spill volume	Number of saline spills	Saline spill volume
Period: 1998-2018, n = 21 years	r,p	r,p	r,p
Number of crude oil spills	0.81, <0.0001	0.85, <0.0001	0.37, ns
Crude oil spill volume	---	0.58, ~0.008	0.17, ns
Number of saline spills	---	---	0.34, ns

Indicator	Crude oil spill volume	Number of saline spills	Saline spill volume
Period: 1975-1997, n = 23 years	r,p	r,p	r,p
Number of crude oil spills	0.01, ns	0.95, <0.0001	0.60,~ 0.002
Crude oil spill volume	---	-0.14, ns	-0.06, ns
Number of saline spills	---	---	0.62, ~0.002

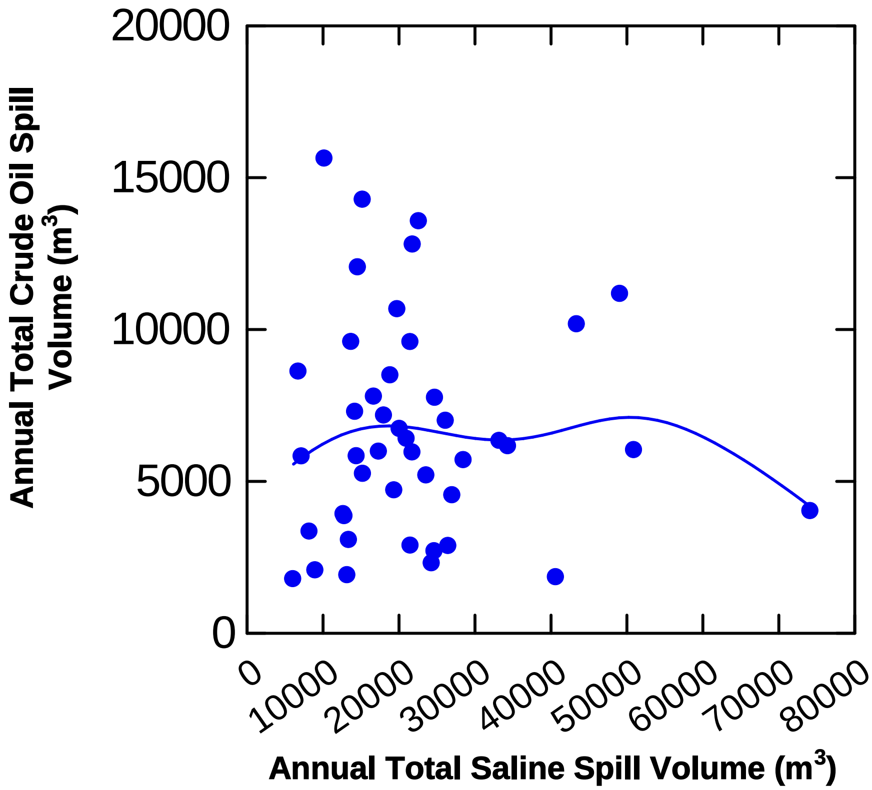
Comments:
Over the full record, the annual number of crude oil spills was positively correlated with annual crude oil spill volume, the annual number of saline spills, and annual saline spill volume. Crude oil spill volume was not significantly correlated with either the number of saline spills or with annual saline spill volume. The annual number of saline spills was positively correlated with annual saline spill volume. The lack of significant correlations between annual crude oil spill volume and both the number of annual saline spills and saline spill volume is puzzling because crude oil spills often occur in association with saline spills (Web 6.20.5).

Over the latter record, 1998-2018, annual saline spill volume was not correlated significantly with the other annual spill indicators. That both the annual number of saline spills and annual crude oil spill volume were not correlated with the annual volume of saline spills is surprising given that the values are ranked and therefore not influenced by outliers.

Over the early period, 1975-1997, the most significant result is the breakdown in the correlation between annual number of crude oil spills and annual crude oil spill volume. This result suggests significant unreliability in early crude oil spill data.

Has there been a change in reported median spill volumes over the years?

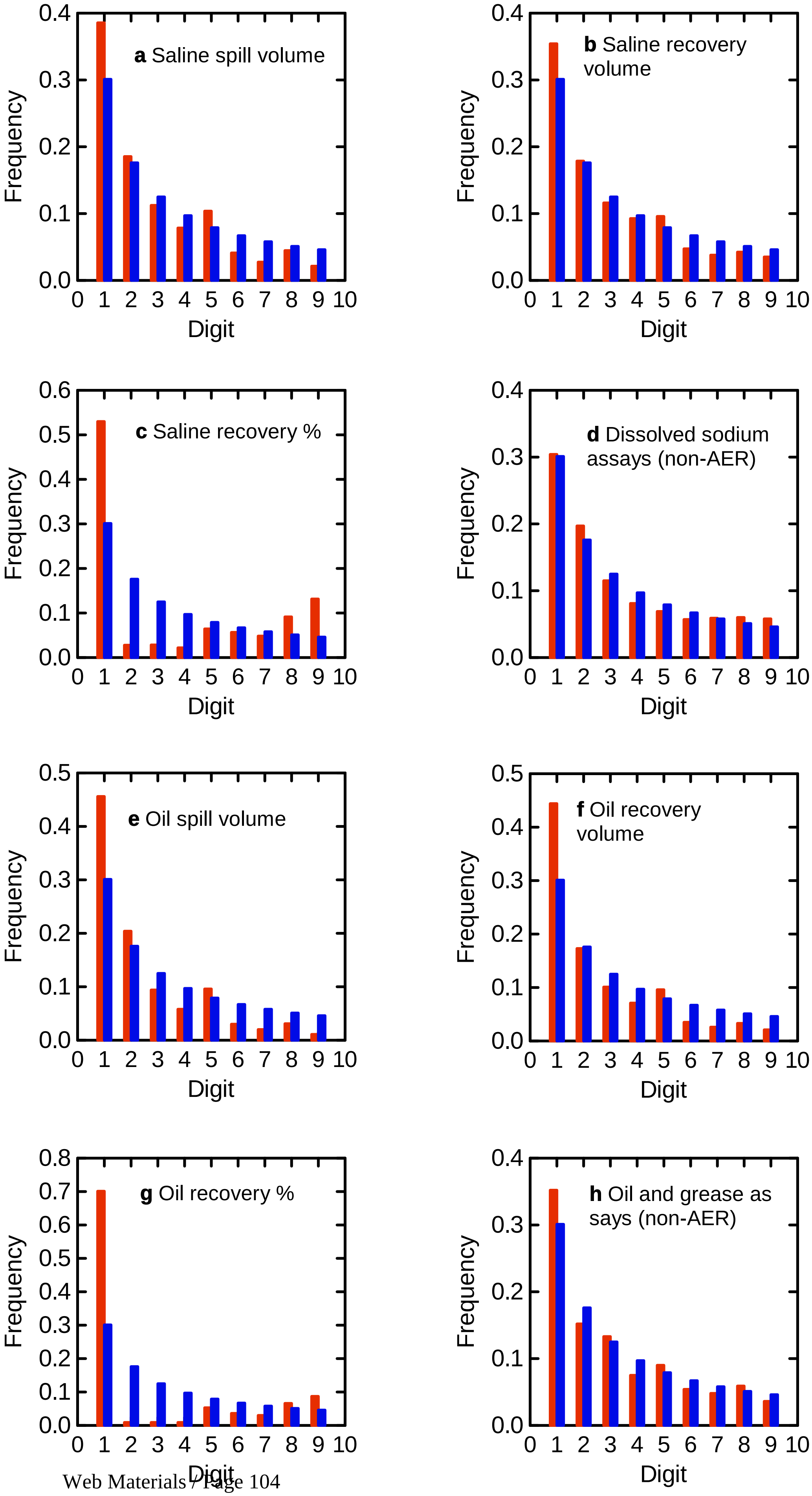
The data for primary spills indicate a small decline in reported median crude oil spill volume and no trend in reported median saline water spill volume. Declines over time in reported minimum volumes and 10^{th} percentile volumes are indicated, which suggests that threshold volumes for reporting spills have decreased. As a result, the number of reported spills should have increased over time (because more small spills would be reported). Instead, reported spills have decreased. But nothing is ever simple with the AER's data. Early reported spill volumes may have used 1 m^3 by convention for small spills, then later used 0.1 m^3 by convention. If that were the case, an apparent lowering of minimum spill volumes would be due to bookkeeping and would not affect the number of reported spills. Once again, making sense of the regulator's data is like grasping smoke.



Web 6.20.5. Relationship between annual total reported crude oil spill volume and annual saline/produced water spill volume, 1975-2018. Line is a distance-weighted least squares regression, tension = 1.

Web 7. Spill forensics

Results of the Benford and sensitive areas analyses, the causes of spills, the time delay between spill and reported clean-up, and the number of spills by days of week in Alberta; spill footprints in Saskatchewan; and Benford analyses of spill and other related data in Saskatchewan, North Dakota, Montana, and elsewhere.



Web 7.1. Observed (red bars) vs. expected (blue bars) frequencies of first significant digits for Alberta spills and laboratory assays. (a) Saline spill volume; (b) Saline recovery volume; (c) Saline recovery %; (d) Dissolved sodium assays; (e) Oil spill volume; (f) Oil recovery volume; (g) Oil recovery %; (h) Oil and grease assays. See Web 7.2-7.5 for details.

Web 7.2. Benford analysis of frequency of first significant digits in spill volume, recovery volume, and percent recovery data for oil spills in Alberta.

The following tables (Web 7.2-7.5) provide the Benford analysis results for AER spill volume, recovery volume, and recovery efficiency for crude oil and saline water, and, as comparisons, laboratory assay data for oil and grease and dissolved sodium, and US Coast Guard spill volume data.

The statistical significance of a given maximum deviation from the expected Benford distribution increases with increasing sample size. That deviation is Dmax (set in bold font in the tables), the largest deviation from the cumulative frequency of the digits 1 through 9. The statistical significance of those deviations is represented by vanishingly small p-values for all but laboratory assays and economic data. For all intents, the p-value is less important that is the value of Dmax, which varies in proportion to the degree of human subjectivity in the data.

For AER crude oil and saline spill volumes and recovery volumes, the digits 1, 2, and 5 were favored, and the digits 3, 4, and 6-9 were disfavored. For AER spill recovery efficiencies, the digits 1, 8, and 9 were favored and the digits 2-7 were disfavored. The AER data departed strongly from the expected Benford distribution as did the US Coast Guard spill volume data. Laboratory assays that quantified concentrations of oil and grease and dissolved sodium in river water were used as baseline comparisons for the crude oil and saline water quantification reported by the regulator. The laboratory assays conformed to Benford distributions.

For related Benford analyses please see Web 7.14 for Saskatchewan spills, Web 7.15 for North Dakota spills, Web 7.16 for world and Organization for Economic Cooperation and Development (OECD) oil production and usage data, and Web 15.5-15.6 for total annual emissions of volatile organic compounds in various Canadian and United States jurisdictions.

a. Oil Spill Volume [a, b]

	Observed			Expected			Statistics	
Digit	**N**	**Frequency**	**Cumul. Frequency**	**N**	**Frequency**	**Cumul. Frequency**	**Difference, D**	**Chi-square**
1	10776	0.456	0.456	7109.6	0.301	0.301	0.155	1890.7
2	4829	0.204	0.661	4157.1	0.176	0.477	**0.184**	108.6
3	2224	0.094	0.755	2952.5	0.125	0.602	0.153	179.8
4	1360	0.058	0.812	2291.1	0.097	0.699	0.113	378.4
5	2270	0.096	0.909	1866.0	0.079	0.778	0.131	87.5
6	716	0.030	0.939	1582.5	0.067	0.845	0.094	474.5
7	474	0.020	0.959	1370.0	0.058	0.903	0.056	586.0
8	721	0.031	0.989	1204.6	0.051	0.954	0.035	194.2
9	250	0.011	1.000	1086.5	0.046	1.000	0.000	644.0
Sum	23620	1.000		23620	1.000			4543.6

Chi-square test: p = 0.0 (too small to calculate); Dmax = largest difference between expected and observed cumulative frequency
K-S test for departure from Benford distribution: Dmax = 0.184,
$\sqrt{n}$ = 153.7, Dcrit at α 0.00000003 = 3/153.7 = 0.020; Dmax > Dcrit;
observed distribution different from Benford distribution
favored: 1,2,5; disfavored: 3, 4, 6-9 (based on chi-square table value of 10.83, 1 d.f., for α 0.001)

b. Oil Recovery Volume [c]

	Observed			Expected			Statistics	
Digit	**N**	**Frequency**	**Cumul. Frequency**	**N**	**Frequency**	**Cumul. Frequency**	**Difference, D**	**Chi-square**
1	7759	0.444	0.444	5263.6	0.301	0.301	**0.143**	1183.0
2	3031	0.173	0.617	3077.7	0.176	0.477	0.140	0.7
3	1760	0.101	0.718	2185.9	0.125	0.602	0.116	83.0
4	1249	0.071	0.789	1696.2	0.097	0.699	0.090	117.9

5	1681	0.096	0.885	1381.5	0.079	0.778	0.107	64.9
6	606	0.035	0.920	1171.6	0.067	0.845	0.075	273.1
7	454	0.026	0.946	1014.2	0.058	0.903	0.043	309.5
8	583	0.033	0.979	891.8	0.051	0.954	0.025	106.9
9	364	0.021	1.000	804.4	0.046	1	0.000	241.1
Sum	17487	1.000		17487	1.000			2380.2

Chi-square test: p = 0.0 (too small to calculate)
K-S test for departure from Benford distribution: Dmax = 0.143,
√n = 132.2, Dcrit at α 0.00000003 = 3/132.2 = 0.023; Dmax > Dcrit;
observed distribution different from Benford distribution
favored: 1, 5; disfavored: 3, 4, 6-9

c. Oil Recovery Percent [d]

	Observed			Expected			Statistics	
Digit	**N**	**Freq-uency**	**Cumul. Freq-uency**	**N**	**Freq-uency**	**Cumul. Freq-uency**	**Differ-ence, D**	**Chi-square**
1	12246	0.701	0.701	5261.8	0.301	0.301	**0.400**	9270.5
2	160	0.009	0.710	3076.7	0.176	0.477	0.233	2765.0
3	162	0.009	0.719	2185.1	0.125	0.602	0.117	1873.1
4	155	0.009	0.728	1695.7	0.097	0.699	0.029	1399.8
5	931	0.053	0.781	1381.0	0.079	0.778	0.003	146.6
6	637	0.036	0.818	1171.2	0.067	0.845	-0.027	243.7
7	517	0.030	0.847	1013.9	0.058	0.903	-0.056	243.5
8	1157	0.066	0.913	891.5	0.051	0.954	-0.041	79.0
9	1516	0.087	1.000	804.1	0.046	1.000	0.000	630.2
Sum	17481	1.000		17481	1.000			16651.5

Chi-square test: p = 0.0 (too small to calculate)
K-S test for departure from Benford distribution: Dmax = 0.400,
√n = 132.2, Dcrit at α 0.00000003 = 3/132.2 = 0.023; Dmax > Dcrit;
observed distribution different from Benford distribution
favored: 1, 8, 9; disfavored: 2-7

[a] 23,655 records, 35 records with spill volume of zero or blank, effective n = 23,655 – 35 = 23,620
[b] As a direct comparison, crude oil spill volumes compiled by the US Coast Guard for the year 2015 were subjected to the same analysis. There were 1329 valid records. Results: chi-square 142.5, p = 7.35 * 10^{-27}, Dmax = 0.084, KS p ~ 0.00000003
[c] 23,655 records, 6168 records with recovered volume of zero or blank, effective n = 23,655 – 6168 = 17,487
[d] 23,655 records, 6174 records with recovered percent volume of zero, blank, or incomplete, effective n = 23,655 – 6174 = 17,481

Note: The difference, D, is the difference between the observed and expected cumulative frequencies whereas the chi-square value is for the significance of the difference between the observed and expected frequencies for that digit.

Web 7.3. Benford analysis of frequency of first significant digits in laboratory-derived oil and grease concentration assays for the Peace and Athabasca Rivers.

Oil and Grease Concentration, Athabasca and Peace Rivers [a, b]								
	Observed			Expected			Statistics	
Digit	**N**	**Freq-uency**	**Cumul. Freq-uency**	**N**	**Freq-uency**	**Cumul. Freq-uency**	**Differ-ence, D**	**Chi-square**
1	234	0.352	0.352	199.9	0.301	0.301	**0.051**	5.0
2	101	0.152	0.505	116.9	0.176	0.477	0.028	2.5
3	88	0.133	0.637	83.0	0.125	0.602	0.035	0.3
4	50	0.075	0.712	64.4	0.097	0.699	0.013	4.2
5	60	0.090	0.803	52.5	0.079	0.778	0.025	0.9
6	36	0.054	0.857	44.5	0.067	0.845	0.012	2.0
7	32	0.048	0.905	38.5	0.058	0.903	0.002	1.3
8	39	0.059	0.964	33.9	0.051	0.954	0.010	0.7
9	24	0.036	1.000	30.5	0.046	1	0.000	1.8
Sum	664	1.000		664	1.000			18.6

Chi-square test: $p = 0.017$
K-S test for departure from Benford distribution: Dmax = 0.051,
$\sqrt{n} = 25.8$, Dcrit = Dmax at α 0.06 (1.327/25.8 = 0.051);
observed distribution conforms to Benford distribution

[a] Laboratory results from oil and grease concentration assays (mg/L) for the Athabasca River (stations AB07DA to DD, n = 662 records) and Peace River (stations AB07FA to KC, n = 257 records), parameters 6521 and 6524, courtesy of Alberta Environment; 919 total records, 205 records with concentration of 0 mg/L, 50 records reported as “less than”; effective n = 919 – 255 = 664

[b] Conversion of the oil and grease data to percent of maximum (to mimic the percent oil recovery 0-100+ data boundaries) resulted in a more significant p-value for chi-square ($p = 3.2 * 10^{-16}$), but the Dmax decreased to 0.040 and K-S test p increased to 0.23 (non-significant). Conversion of oil and grease data to percent of maximum strengthened the Benford-like pattern and further highlights the discrepancy between laboratory-measured values and unempirical spill data derived from human judgments. The fact that percent oil recovery did not conform to a Benford distribution suggests that the percent scale did not contribute to the statistical result.

Web 7.4. Benford analysis of frequency of first significant digits in spill volume, recovery volume, and percent recovery data for saline spills in Alberta.

a. Saline Spill Volume [a]

	Observed			Expected			Statistics	
Digit	**N**	**Freq-uency**	**Cumul. Freq-uency**	**N**	**Freq-uency**	**Cumul. Freq-uency**	**Differ-ence, D**	**Chi-square**
1	5712	0.386	0.386	4459.6	0.301	0.301	0.085	351.7
2	2746	0.185	0.571	2607.6	0.176	0.477	**0.094**	7.3
3	1664	0.112	0.683	1852.0	0.125	0.602	0.081	19.1
4	1163	0.078	0.762	1437.2	0.097	0.699	0.063	52.3
5	1537	0.104	0.865	1170.5	0.079	0.778	0.087	114.8
6	609	0.041	0.907	992.7	0.067	0.845	0.062	148.3
7	406	0.027	0.934	859.3	0.058	0.903	0.031	239.1
8	662	0.045	0.979	755.6	0.051	0.954	0.025	11.6
9	317	0.021	1.000	681.5	0.046	1.000	0.000	195.0
Sum	14816	1.000		14816	1.000			1139.2

Chi-square test: $p = 1.24 * 10^{-240}$
K-S test for departure from Benford distribution: Dmax = 0.094,
$\sqrt{n}$ = 121.7, Dcrit at α 0.00000003 = 3/121.7 = 0.025; Dmax > Dcrit;
observed distribution different from Benford distribution
favored: 1, 5; disfavored: 3, 4, 6-9

b. Saline Recovery Volume [b]

	Observed			Expected			Statistics	
Digit	**N**	**Freq-uency**	**Cumul. Freq-uency**	**N**	**Freq-uency**	**Cumul. Freq-uency**	**Differ-ence, D**	**Chi-square**
1	3575	0.354	0.354	3038.3	0.301	0.301	0.053	94.8
2	1803	0.179	0.533	1776.5	0.176	0.477	0.056	0.4
3	1171	0.116	0.649	1261.8	0.125	0.602	0.047	6.5
4	935	0.093	0.741	979.1	0.097	0.699	0.042	2.0
5	967	0.096	0.837	797.4	0.079	0.778	**0.059**	36.1
6	478	0.047	0.885	676.3	0.067	0.845	0.040	58.1
7	382	0.038	0.922	585.5	0.058	0.903	0.019	70.7
8	428	0.042	0.965	514.8	0.051	0.954	0.011	14.6
9	355	0.035	1.000	464.3	0.046	1.000	0.000	25.7
Sum	10094	1.000		10094	1.000			309.0

Chi-square test: $p = 5.01 * 10^{-62}$
K-S test for departure from Benford distribution: Dmax = 0.059,
$\sqrt{n}$ = 100.5, Dcrit at α 0.00000003 = 3/100.5 = 0.030; Dmax > Dcrit;
observed distribution different from Benford distribution
favored: 1, 5 disfavored: 6-9

c. Saline Recovery Percent [c]								
	Observed			**Expected**			**Statistics**	
Digit	**N**	**Freq-uency**	**Cumul. Freq-uency**	**N**	**Freq-uency**	**Cumul. Freq-uency**	**Differ-ence, D**	**Chi-square**
1	5343	0.530	0.530	3035.3	0.301	0.301	**0.229**	1754.5
2	280	0.028	0.558	1774.8	0.176	0.477	0.081	1259.0
3	286	0.028	0.586	1260.5	0.125	0.602	-0.016	753.4
4	221	0.022	0.608	978.1	0.097	0.699	-0.091	586.1
5	649	0.064	0.672	796.6	0.079	0.778	-0.106	27.4
6	571	0.057	0.729	675.6	0.067	0.845	-0.116	16.2
7	487	0.048	0.777	584.9	0.058	0.903	-0.126	16.4
8	921	0.091	0.869	514.3	0.051	0.954	-0.085	321.6
9	1326	0.131	1.000	463.9	0.046	1.000	0.000	1602.4
Sum	10084	1.000		10084	1.000			6336.9

Chi-square test: p = 0.0 (too small to calculate)
K-S test for departure from Benford distribution: Dmax = 0.229,
$\sqrt{n}$ = 100.4, Dcrit at α 0.00000003 = 3/100.4 = 0.030; Dmax > Dcrit;
observed distribution different from Benford distribution
favored: 1,8,9; disfavored: 2-7

a 14,833 records, 17 records with spill volume of zero or blank, effective n = 14,833 – 17 = 14,816
[b] 14,833 records, 4739 records with recovered volume of zero or blank, effective n = 14,833 – 4739 = 10,094
[c] 14,833 records, 4749 records with recovered percent volume of zero, blank, or incomplete, effective n = 14,833 – 4749 = 10,084

Web 7.5. Benford analysis of frequency of first significant digits in laboratory-derived dissolved sodium concentration assays for the Athabasca River.

Dissolved Sodium Concentration, Athabasca River [a,b]								
	Observed			Expected			Statistics	
Digit	**N**	**Freq-uency**	**Cumul. Freq-uency**	**N**	**Freq-uency**	**Cumul. Freq-uency**	**Differ-ence, D**	**Chi-square**
1	425	0.304	0.304	420.5	0.301	0.301	0.003	0.0
2	275	0.197	0.501	245.9	0.176	0.477	**0.024**	3.5
3	161	0.115	0.616	174.6	0.125	0.602	0.014	1.1
4	113	0.081	0.697	135.5	0.097	0.699	-0.002	3.7
5	96	0.069	0.766	110.4	0.079	0.778	-0.012	1.9
6	80	0.057	0.823	93.6	0.067	0.845	-0.022	2.0
7	82	0.059	0.882	81.0	0.058	0.903	-0.021	0.0
8	84	0.060	0.942	71.2	0.051	0.954	-0.012	2.3
9	81	0.058	1.000	64.3	0.046	1.000	0.000	4.4
Sum	1397	1.000		1397	1.000			18.8

Chi-square test: $p = 0.016$
K-S test for departure from Benford distribution: $D_{max} = 0.024$,
$\sqrt{n} = 37.4$, $D_{crit} = D_{max}$ at α 0.40 = 0.895/37.4 = 0.024;
observed distribution conforms to Benford distribution at α 0.40

[a] Laboratory results from dissolved sodium (filtered) concentration assays (mg/L) for the Athabasca River (stations AB07DA to DD), parameter 11103, courtesy of Alberta Environment; 1412 total records, 15 records with concentration reported as “less than”; effective n = 1412 – 15 = 1397
[b] Conversion of the sodium data to percent of maximum resulted in a similar result for chi-square ($p = 0.013$), but the Dmax increased to 0.036 and K-S test p decreased to 0.05

Web 7.6. Frequency of "sensitive" areas as designated by the AER categorized by crude oil and saline spills, environment type, and jurisdiction.

Crude Oil	Environment	Sensitive (n)		Sensitive %
		No	Yes	
	Air/Land	23276	28	0.120
	Flowing Water	924	9	0.965
	Muskeg/Stagnant	144	16	10.000
	Blank (no data)	550	0	0.000
	Totals, Overall %	24894	53	0.212
Saline Water	**Environment**	**Sensitive (n)**		**Sensitive %**
		No	**Yes**	
	Air/Land	14702	20	0.136
	Flowing Water	595	4	0.668
	Muskeg/Stagnant	174	19	9.845
	Blank (no data)	289	0	0.000
	Totals, Overall %	15760	43	0.272

Crude Oil	Jurisdiction	Sensitive (n)		Sensitive %
		No	Yes	
	Crown	14314	26	0.181
	Freehold Private	3977	21	0.525
	Canadian Forces Base	96	0	0.000
	First Nations	51	0	0.000
	L.C.R.C.	3	0	0.000
	Metis Settlement	13	0	0.000
	Blank (no data)	6467	6	0.093
	Totals, Overall %	24921	53	0.212
Saline Water	**Jurisdiction**	**Sensitive (n)**		**Sensitive %**
		No	**Yes**	
	Crown	8748	18	0.205
	Freehold Private	2987	20	0.665
	Canadian Forces Base	147	2	1.342
	First Nations	19	0	0.000
	Metis Settlement	21	0	0.000
	Blank (no data)	3856	3	0.078
	Totals, Overall %	15778	43	0.272

Comments:

Tabulation of ecological sensitivity by spill, environment type, and jurisdiction was initially conducted with data current to February 2013. Significantly, although the total number of crude oil and saline primary spills increased from February 2013 to February 2017 by 1366 and 1022 spills, respectively, the number of spills designated as occurring in sensitive areas was lower in the 2017 dataset. According to the 2013 data, there were 36, 15, and 22 crude oil spills designated as sensitive areas in the air/land, flowing water, and muskeg/stagnant water environments, and 28, 7, and 17 saline spills designated as sensitive areas in those same environments. According to the 2017 data, the number of crude oil spills designated as sensitive areas decreased to 28, 9, and 16 in the air/land, flowing water, and muskeg/stagnant water environments while the number of saline spills designated as sensitive areas decreased to 20, 4, and 19 in those environments.

Retabulation of ecological sensitivity by spill and jurisdiction resulted in similar declines in the number of spills in sensitive areas. According to the 2013 data, there were 40, 26, and 7 crude oil spills designated as sensitive areas on crown lands, private lands, and “blank” jurisdictions, and 22, 23, 2, and 5 saline spills designated as sensitive areas on crown lands, private lands, Canadian Forces bases, and “blank” jurisdictions. According to the 2017 data, the number of crude oil spills designated as sensitive areas decreased to 26, 21, and 6 on crown lands, private lands, and “blank” jurisdictions while the number of saline spills designated as sensitive areas decreased to 18, 20, 2, and 3 on crown lands, private lands, Canadian Forces bases, and “blank” jurisdictions.

The 2013 to 2017 decrease in the number of sensitive area spills in the crude oil (73 decreased to 53) and saline/produced water spill categories (52 decreased to 43) requires that spills classified as occurring in sensitive areas in 2013 were later recoded as occurring in non-sensitive areas. I asked AER to explain the recoding of sensitive areas to non-sensitive areas (Web 11.2). AER explained that because “sensitive area” is no longer accepted as a valid concept within AER, all spills dating from 2009 onwards were recoded as occurring in non-sensitive areas.

That such a sweeping change to the regulator’s sensitive area data would be made without scientific review or public discussion underscores the fact that the regulator’s environmental data are not credible. Furthermore, if the regulator believes that sensitive area is not a valid concept, then either the data field should be removed from the database, or the field be completed with “not applicable”. To retain the data field and use “no” for all spills is either intentionally misleading or poor data management. Why the regulator would conclude that “sensitive area” is not a valid concept is difficult to understand. Such a view is not rooted in science.

Web 7.6.1. Background information on Alberta Environment and Parks sensitive features

The Landscape Analysis Tool of Alberta Environment and Parks (AEP) maps five kinds of sensitive features: peat, plants, reserves, special access areas, and wildlife. Unfortunately, AEP's publicly-available map of sensitive features cannot be used to estimate the areal extent of ecologically sensitive areas for several reasons.

(1) "Peat" maps "peat availability" not the occurrence of peatlands. The map informs people who may wish to mine peat that an application for a surface lease is needed.

(2) "Plants" inexplicably maps the geographic extent of six natural subregions in the grassland and parkland natural regions, not the occurrence of sensitive plant species or sensitive vegetation. The layer was posted as background information on natural regions.

(3) "Reserves" maps the occurrence of grazing reserves and the Rocky Mountain forest reserve without reference to sensitivity. The layer was posted to inform industry that additional regulations might apply to their lease applications.

(4) The locations of grazing leases were posted for the same reason.

(5) Finally, AEP's sensitive features do not include areas of known ecological sensitivity such as old-growth forests, seepage areas, naturally saline landscapes, ecosystems underlain by sandy soils, and steep or unstable slopes.

After discussions with government staff in September 2018, I learned that the Landscape Analysis Tool has evolved over time as people have posted information that they think might be useful when industry or the public applies for a land use permit. In essence, "sensitive features" evolved as an administrative tool. It continues to evolve as new information is posted. It was not designed as a science-based map of sensitive area occurrence.

Conversely, AEP's special access areas (defined as wildlife refugia, a subset of the wildlife layer) and wildlife layers (occurrences of sensitive species and their critical habitat) can be used to map sensitive area extent. That information, along with the Alberta Wetland Inventory, was plotted within a geographic information system to provide an estimate of the extent of sensitive areas in Alberta in Chapter 7.

Web 7.6.2. Sensitive wildlife and wetland areal extent in Alberta exclusive of national parks as determined by Alberta Environment and Parks, 28 September 2018. Total Alberta area outside national parks is 60,730,762 ha.

Alberta Sensitive Wildlife	Sensitive Area (ha)	Sensitive Area % Outside NPs
Special Access Zone (wildlife refugia)	1,763,820	2.90
Colonial Nesting Bird	40,995	0.07
Key Wildlife and Biodiversity (many species)	4,690,290	7.72
Mountain Goat and Mountain Sheep Area	1,245,861	2.05
Grizzly Bear Zone	8,408,322	13.85
Trumpeter Swan Watercourse	170,353	0.28
Piping Plover Waterbodies	101,335	0.17
Total Sensitive Wildlife Area #	13,799,038	22.72
Alberta Wetlands *	**Sensitive Area (ha)**	**Sensitive Area % Outside NPs**
Bog	3,004,807	4.95
Fen	5,858,021	9.65
Marsh	1,603,874	2.64
Open Water	2,007,290	3.31
Swamp	4,615,513	7.60
Total Wetlands Area	17,089,504	28.14
Total Sensitive Area ^	28,071,991	46.22

Total sensitive wildlife is less than the raw sum due to overlap of different kinds of sensitive areas
* Alberta Wetland Inventory data released 15 March 2017
^ Corrected for overlap by subtracting wetland areas that overlap with wildlife areas

Web 7.7. What does the AER mean by "sensitive area"?

The following correspondence with the AER illustrates how the regulator struggles to answer a basic question posed by the public. More importantly, the correspondence reveals that the regulator fails to provide ecologically credible information about the impacts of spills. Join me for a trip deep into the weeds...

On 2 Jan 2017, I wrote to the AER: "... In the AER database of spills, there is a data field called "sensitive area" and the value in that field can be either a yes or a no. How does the AER define a sensitive area?"

The AER responded on 5 Jan 2017: "Hello Kevin, I have sent your inquiry to the appropriate subject matter expert. For future questions please send them to inquiries@aer.ca my staff there are just as capable to answer your questions as I would be, and I may not always be in the office or be I may be [sic] away from my desk attending meetings or projects... Customer Contact Centre, Information Business Excellence"

An AER internal memo on 5 Jan 2017 wrote: "Good Afternoon H..., On the compliance dashboard do you know how this is determined, or is it determined by the field centre and simply put into the compliance dashboard? Please review and assist."

An internal memo on 5 Jan 2017 replied to the Compliance Coordinator: "Hello, could you advise Kevin Timoney on his question or know who should the question [sic] of How does the AER define a sensitive area?... Compliance and Enforcement, Environment & Operational Performance"

The AER responded on 6 Jan 2017: "Hi Kevin Timoney, I assume this data based [sic] is at the AER website, correct? Can you direct me to the location/Path in our website? I need to contact the team managing that database for clarification... Compliance and Enforcement, Environment & Operational Performance"

I replied on 6 Jan 2017: "... I am surprised that such a basic question is difficult to answer. All AER spill incidents have a set of attributes that provides information about the spill. I have attached a page that shows a standard abbreviated AER record for two spills. The field of interest is "Sensitive Area". The field is filled with either a "yes" or "no". My question is: what is the AER definition of a sensitive area?"

An internal memo on 9 Jan 2017 wrote: "Hi W... We got a question regarding the term "sensitive area" in FIS (see e-mail and attachment). Do you know the AER's definition for this term?"

AER responded to me on 9 Jan 2017: "... Historically in FIS incidents this check the box [*sic*] was used in conjunction with a Conservation and Protected Areas map (I believe it was an Alberta Environment map). However, at some point this map and link were made no longer available, so the current process it that this check box should always say "No" and the use of this box is currently under review and will either be removed with the next FIS update or we will re-define appropriate map/triggers for this indicator."

AER added on 10 Jan 2017: "This particular dataset has a complex history. Prior to 2009, Sensitive Environment was actually defined by the Sustainable Resource Development (SRD) agency of the Alberta Government. The AER only referenced this in our release reports and used it as an indicator of the impact of the release event and how the AER would respond (response priority). In order for our inspectors to determine if the release event occurred within an SRD defined Sensitive Environment, our inspectors would go to a specific page on the SRD website that showed all the areas of the province the SRD considered to have Sensitive Environments. If the release occurred within one of these areas, the AER inspector would check this box off as "Yes". Sometime in late 2008, SRD stopped defining these areas and removed the webpage that showed these areas. I have no explanation to offer about why this happened but it did affect how we used this dataset within the AER as of 2009. It was decided at that time, since there was no longer an official definition for Sensitive Environment, the AER inspectors would always check off this box as "No". Under that business process rule, all release records from 2009 to date should have indicated all releases to have no sensitive environment. But unfortunately as time went on this business rule was lost in the many changes to AER staff, leadership and organizational transformations. Inspectors would check off the Sensitive Environment as "Yes" based on their own personal definitions or experience. Where one inspector would consider the environment to be sensitive, another would not. So that brings us to today. The SRD no longer exists and has been rolled into what is now Alberta Environment and Parks (AEP). Recently the AER rediscovered this data issue and a decision was made to go back into all the past release records (post-2009) and perform a data correction to switch all releases records that indicated the Sensitive Environment from the incorrect "Yes" to the correct "No". And as of November 18, 2016, our system was also enhanced to prevent inspectors from ever checking off this data item as "Yes". It will now always ever show as "No", eliminating the risk of human error. If you look at the same record in your example, Incident 20131107, it now will show the Sensitive Environment as “No”. So the short answer to your question is, there is no official definition of Sensitive Environment as the AER does not recognize it a validated and clearly defined dataset.”

Web 7.8. Comments on the causes of crude oil and saline water spills

Although assigning spill failure types to particular pieces of equipment may be instructive, it is potentially misleading to explain the failure of equipment without reference to those operating the equipment. Because any spill can be prevented theoretically, both human factors and equipment may be involved in spills. Spills attributed to corrosion, e.g., can be minimized by corrosion prevention and diligent monitoring that replaces corroded components before spills occur. Spills attributed to tank overflow or stuffing box failures are for the most part preventable given existing technology and diligent monitoring. Spills attributed to inadequate dikes are not equipment failures, *per se*, but are due to human error in dike construction or maintenance. Therefore, spills attributed to various equipment failures may not necessarily be the causes for the spills but can be viewed as the location within the production system where spills occurred.

The regulator’s data are illogical. For “failure type”, the AER lists “adverse effect” as a valid entry (see glossary). Setting aside the fact that an adverse effect is, by definition, an effect of a spill, not a cause, it’s relevant to ask what proportion of crude oil and saline spills that report an “adverse effect” also report damage to the environment. Of the 39 crude oil spills that report “adverse effect” as the failure type, three report no environment data and 36 state “no affect” (*sic*) on habitat or wildlife. Similarly, of the 37 saline water spills that list “adverse effect” as the failure type, one reports no environment data and 36 state “no affect” on habitat or wildlife. Therefore in none of these “adverse effect” spills does the AER state there has been an effect on the environment. That’s the essence of illogic.

Web 7.9. Number and proportion of spills by cause category for crude oil and saline water spills as reported in the AER FIS database.
Data current to 6 February 2017. Percent frequencies exclude the "conversion" (missing data) cause.

Spills	Crude Oil		Saline	
Cause Category	N	%	N	%
Conversion	19086	---	10805	---
Equipment Failure	3838	65.47	3698	73.99
External	235	4.01	132	2.64
Operator Error	1270	21.66	770	15.41
Procedural or Design	407	6.94	353	7.06
Unknown	95	1.62	30	0.60
Venting	1	0.02	0	0.00
Blank (no cause category)	16	0.27	15	0.30

Web 7.10. Number and proportion of spills by cause type for crude oil and saline water spills as reported in the AER FIS database.

Data current to 6 February 2017. Percent frequencies exclude "conversion" (missing data) cause.

Spills	Crude Oil		Saline	
Cause Types	N	%	N	%
Accidental	716	12.21	403	8.06
Construction	177	3.02	198	3.96
Contravention	2	0.03	1	0.02
Conversion	19086	---	10805	---
Defect	335	5.71	298	5.96
External Corrosion	343	5.85	242	4.84
Fracturing Incident	2	0.03	2	0.04
Inadequate equipment	69	1.18	38	0.76
Inadequate procedure	106	1.81	80	1.60
Internal corrosion	1090	18.59	1323	26.47
Malfunction	1040	17.74	732	14.65
Mechanical/structural	1030	17.57	1103	22.07
Natural phenomena	68	1.16	48	0.96
Non-procedural	112	1.91	61	1.22
Oversight	440	7.51	305	6.10
Poor design	55	0.94	37	0.74
Power failure	1	0.02	2	0.04
Third party damage	95	1.62	56	1.12
Unknown	95	1.62	30	0.60
Unplanned maintenance	1	0.02	0	0.00
Vandalism	69	1.18	24	0.48
Blank (no cause type)	16	0.27	15	0.30

Web 7.11. Number and proportion of spills and total spill volume by failure type for crude oil and saline water spills as reported in the AER FIS database.
Data current to 6 February 2017.

Spills	Crude Oil			Saline			General Category
Failure Type	**N**	**%**	**Vol (m^3)**	**N**	**%**	**Vol (m^3)**	
Acidizing Operations	7	0.03	24.4	0	0.00	0.0	operator/human error
Adverse Effect [a]	39	0.16	1213.3	37	0.23	3633.0	unclassified
Artesian Flow	0	0.00	0.0	1	0.01	3.0	environmental
Blowdown (from boiler)	66	0.26	83.8	28	0.18	1084.3	equipment failure
Blowout	79	0.32	2182.2	69	0.44	54197.9	equipment failure
Burn Pit	6	0.02	23.0	0	0.00	0.0	operator/human error
Casing Failure	4	0.02	33.3	8	0.05	565.7	equipment failure
Casing Valve	74	0.30	465.6	30	0.19	647.2	equipment failure
Catalyst Regeneration	0	0.00	0.0	1	0.01	3.0	equipment failure
Cementing Operations	3	0.01	5.0	4	0.03	6.5	operator/human error
Chemical Spill	2	0.01	0.5	2	0.01	3.0	operator/human error
Compressor Down	17	0.07	237.7	4	0.03	77.0	equipment failure
Compressor Noise	1	0.00	4.0	1	0.01	4.0	equipment failure
Condensate Carry Over	15	0.06	16.1	1	0.01	4.0	equipment failure
Construction Damage	443	1.78	4321.6	497	3.14	66800.0	operator/human error
Corrosion At Girth Or Fillet Weld	31	0.12	193.6	125	0.79	3700.3	equipment failure
Corrosion External	1482	5.94	6524.0	701	4.44	22198.6	equipment failure
Corrosion Internal	3328	13.34	18721.3	4866	30.79	148544.6	equipment failure
Cumulative Release	685	2.75	1372.0	14	0.09	51.0	equipment failure
Damage By Others	619	2.48	10792.6	172	1.09	1221.5	operator/human error
Dehydrator	4	0.02	22.1	1	0.01	3.0	equipment failure
Depressurizing	24	0.10	55.1	7	0.04	45.0	operator/human error
Dike Drain	16	0.06	36.1	6	0.04	81.5	equipment failure
Dike Inadequate	53	0.21	389.7	18	0.11	2174.2	equipment failure
Earth Movement	157	0.63	2436.0	91	0.58	2290.0	environmental
Emergency Flare	8	0.03	15.3	0	0.00	0.0	equipment failure
Equipment Failure	2977	11.93	34936.3	1879	11.89	54691.6	equipment failure
Equipment Spacing	9	0.04	92.2	8	0.05	71.5	equipment failure
Erosion	44	0.18	637.3	62	0.39	763.8	environmental
Fire	201	0.81	3948.5	22	0.14	342.2	environmental
Flange Loose	58	0.23	290.3	119	0.75	2833.8	equipment failure
Flare Out	12	0.05	12.5	1	0.01	20.0	equipment failure
Flare Pit	96	0.38	685.6	19	0.12	274.1	equipment failure
Flare Stack	456	1.83	658.2	22	0.14	74.6	equipment failure
Flare To Flush System	6	0.02	10.1	1	0.01	32.0	equipment failure
Fracturing Operation	28	0.11	86.2	3	0.02	71.4	operator/human error
Frost Heave	29	0.12	389.8	6	0.04	311.0	environmental
Girth Weld Failure	133	0.53	2049.5	102	0.65	17370.8	equipment failure
Header Failure	67	0.27	363.5	60	0.38	1737.1	equipment failure
Hi Level Switch	336	1.35	4511.7	158	1.00	5624.6	equipment failure
Hi Pressure Switch	78	0.31	515.9	29	0.18	376.3	equipment failure
Incinerator Stack	1	0.00	1.0	1	0.01	0.3	equipment failure

Spills	Crude Oil			Saline			General Category
Failure Type	**N**	**%**	**Vol (m^3)**	**N**	**%**	**Vol (m^3)**	
Installation Failure	82	0.33	3083.9	43	0.27	879.9	operator/human error
Insufficient Mud Density	0	0.00	0.0	1	0.01	1.0	operator/human error
Land Slippage	4	0.02	84.4	2	0.01	32.0	environmental
Line Failure	530	2.12	4443.8	732	4.63	19890.0	equipment failure
Line Heater	11	0.04	35.8	1	0.01	10.0	equipment failure
Line Plugged	119	0.48	1058.6	28	0.18	294.3	equipment failure
Livestock Or Wildlife	128	0.51	891.9	26	0.16	301.3	environmental
Lo Level Switch	0	0.00	0.0	3	0.02	69.0	equipment failure
Lubricator	9	0.04	21.9	0	0.00	0.0	equipment failure
Measurement Equipment	17	0.07	90.7	25	0.16	388.6	equipment failure
Mechanical Damage	88	0.35	662.6	50	0.32	1684.1	equipment failure
Mechanical Joint Failure	154	0.62	1096.7	262	1.66	13129.6	equipment failure
Mechanical Pipe Damage	25	0.10	55.6	22	0.14	688.0	equipment failure
Metal Fatigue	123	0.49	896.9	131	0.83	3217.8	equipment failure
Misc. (incl. misc. joint failure)	249	1.00	1953.5	235	1.49	13040.1	equipment failure
Motor Noise	7	0.03	60.0	0	0.00	0.0	equipment failure
Mud Pit	4	0.02	63.5	1	0.01	159.0	equipment failure
Mud Tanks	5	0.02	47.6	1	0.01	2.0	equipment failure
Neglect	318	1.27	2283.7	64	0.40	1188.6	operator/human error
Non-Pipeline Release	2	0.01	0.8	0	0.00	0.0	equipment failure
Operator Error	3111	12.47	30032.2	1048	6.63	64128.8	operator/human error
Other Weld Failure	35	0.14	251.4	52	0.33	4084.1	equipment failure
Overpressure Failure	395	1.58	11015.5	128	0.81	3632.8	operator/human error
Pig Trap [b]	121	0.49	682.6	19	0.12	408.9	equipment failure
Pipe Failure	261	1.05	17727.6	345	2.18	36926.6	equipment failure
Pipeline Pump	24	0.10	380.0	4	0.03	71.0	equipment failure
Plant Shut Down	2	0.01	11.0	0	0.00	0.0	equipment failure
Plant Start Up	2	0.01	17.0	0	0.00	0.0	equipment failure
Plant Turn Around	3	0.01	4.4	1	0.01	3.0	equipment failure
Pond Overflow	1	0.00	3.0	0	0.00	0.0	equipment failure
Pop Tank [c]	135	0.54	1483.8	16	0.10	155.2	equipment failure
Power Failure	59	0.24	726.4	55	0.35	2613.5	equipment failure
Pump Failure	175	0.70	2803.7	263	1.66	9466.0	equipment failure
Refuse	7	0.03	11.0	1	0.01	1.0	operator/human error
Rod Failure	243	0.97	993.4	38	0.24	295.4	equipment failure
Rod Stripping	15	0.06	30.2	2	0.01	2.9	equipment failure
Seam Rupture	95	0.38	8169.6	114	0.72	6462.3	equipment failure
Separator	226	0.91	1422.0	35	0.22	207.2	equipment failure
Service Rig Tank	58	0.23	115.1	14	0.09	61.5	equipment failure
Storage Tank	101	0.40	1250.7	81	0.51	1964.4	equipment failure
Stuffing Box [d]	1209	4.85	4466.3	181	1.15	1004.2	equipment failure
Sulphur Load	0	0.00	0.0	1	0.01	1.0	equipment failure
Sump Fluids	26	0.10	52.1	9	0.06	482.0	equipment failure
Tank Leak	435	1.74	8067.9	313	1.98	7244.9	equipment failure
Tank Overflow	1374	5.51	16417.6	583	3.69	13414.6	equipment failure

Spills	Crude Oil			Saline			General Category
Failure Type	**N**	**%**	**Vol (m^3)**	**N**	**%**	**Vol (m^3)**	
Treater	218	0.87	2723.0	16	0.10	295.0	equipment failure
Tubing Stripping	12	0.05	20.1	5	0.03	16.1	equipment failure
Unknown	510	2.04	3714.4	371	2.35	27074.4	unclassified
Valve Damage	102	0.41	1034.2	49	0.31	898.8	equipment failure
Valve Failure	978	3.92	11421.2	493	3.12	11614.0	equipment failure
Valve Leak	461	1.85	2912.1	313	1.98	3736.9	equipment failure
Valve Or Fitting Failure	233	0.93	2730.6	219	1.39	7532.7	equipment failure
Vandalism/Damage Others	390	1.56	7147.6	74	0.47	1643.8	operator/human error
Vapour Gathering System	9	0.04	70.4	0	0.00	0.0	equipment failure
Vehicle Accident	227	0.91	1479.9	110	0.70	588.7	operator/human error
Water Retention Pond	6	0.02	11.2	4	0.03	61.0	equipment failure
Weld Failure	2	0.01	4.2	2	0.01	12.3	equipment failure
Wellhead Leak	31	0.12	63.6	11	0.07	210.4	equipment failure
Blank (no failure type)	87	0.35	630.3	30	0.19	563.8	unclassified

[a] "adverse effect" is not a failure type *per se*; by definition, it is an effect (defined by AER (2016a) as "impairment of or damage to the environment, human health, or safety or property"); the following cause types were attached to the spills citing "adverse effect": accidental, conversion, inadequate procedure, inadequate equipment, oversight, malfunction, mechanical/structural, natural phenomena, unknown

[b] pig trap: a "pig" is a pipeline intervention gadget used to conduct cleaning or inspection within a pipeline; a pig trap is a device used to launch or receive a pipeline pig

[c] pop tank: an open tank connected to a pressure vessel that receives oil well production; the contents of the pressure vessel are piped to the pop tank when a pressure-relief device activates in order to manage pressure and flow without damage to the pressure vessel

[d] stuffing box: a ring-shaped assembly on a pump jack that contains deformable packing used to minimize leakage of crude oil, saline water, and other fluids from the top of the well bore at the pump rod assembly

Web 7.12. The delay between spill and clean-up, and, number and volume of spills reported by days of week.

Alberta provincial spill volume and delay between incident date and clean-up date for primary spills of crude oil and saline water in Alberta compared to hydrocarbon spill cleanup delays in NEB interprovincial pipelines and crude oil and saline water spills in Montana.

Days elapsed between spill and cleanup date	FIS Spills (n)	FIS Median Release Volume (m^3)	FIS Spills %	NEB Spills (n)	NEB Spills %	Montana Spills (n)	Montana Spills %
no clean up date	249	2.0	0.62	27	2.06	37	2.00
0	10887	2.0	26.72	0	0.00	106	5.73
1	6689	2.0	16.41	0	0.00	233	12.59
2	2948	2.5	7.23	0	0.00	183	9.89
3	1802	3.0	4.42	0	0.00	127	6.86
4	1220	3.0	2.99	0	0.00	125	6.75
5	850	2.0	2.09	0	0.00	83	4.48
6	704	3.0	1.73	0	0.00	74	4.00
7	618	2.5	1.52	0	0.00	54	2.92
8	483	2.6	1.19	0	0.00	50	2.70
9	370	2.0	0.91	0	0.00	32	1.73
10	299	2.0	0.73	0	0.00	26	1.40
11	275	2.0	0.67	0	0.00	28	1.51
12	220	2.0	0.54	0	0.00	19	1.03
13	200	3.0	0.49	0	0.00	30	1.62
14	215	2.0	0.53	0	0.00	17	0.92
15	174	3.5	0.43	0	0.00	15	0.81
16	158	2.0	0.39	0	0.00	15	0.81
17	116	3.0	0.28	0	0.00	20	1.08
18	122	4.0	0.30	1	0.08	11	0.59
19	130	3.0	0.32	1	0.08	13	0.70
20	123	2.8	0.30	0	0.00	11	0.59
21	103	2.0	0.25	0	0.00	5	0.27
22	111	2.5	0.27	0	0.00	14	0.76
23	81	2.0	0.20	0	0.00	9	0.49
24	64	4.0	0.16	0	0.00	3	0.16
25	77	2.5	0.19	0	0.00	15	0.81
26	73	3.0	0.18	0	0.00	6	0.32
27	56	3.0	0.14	0	0.00	12	0.65
28	79	2.0	0.19	0	0.00	12	0.65
29	87	2.0	0.21	0	0.00	8	0.43
30	98	2.0	0.24	1	0.08	5	0.27
31	98	2.0	0.24	2	0.15	11	0.59
32	65	4.0	0.16	0	0.00	12	0.65
33	69	3.0	0.17	0	0.00	5	0.27
34	67	2.0	0.16	1	0.08	5	0.27
35	62	4.0	0.15	1	0.08	10	0.54
36	62	3.0	0.15	2	0.15	7	0.38

37	60	2.0	0.15	1	0.08	10	0.54
38	46	3.0	0.11	0	0.00	4	0.22
39	53	3.0	0.13	0	0.00	3	0.16
40	41	3.0	0.10	1	0.08	8	0.43
41	54	2.0	0.13	1	0.08	3	0.16
42	54	2.0	0.13	2	0.15	7	0.38
43	50	2.0	0.12	2	0.15	4	0.22
44	45	2.0	0.11	1	0.08	4	0.22
45	40	1.0	0.10	2	0.15	7	0.38
46	36	7.0	0.09	0	0.00	6	0.32
47	41	2.0	0.10	1	0.08	1	0.05
48	41	3.0	0.10	3	0.23	10	0.54
49	43	3.0	0.11	1	0.08	5	0.27
50	54	5.5	0.13	1	0.08	4	0.22
51	25	4.0	0.06	6	0.46	8	0.43
52	36	2.0	0.09	3	0.23	3	0.16
53	38	3.5	0.09	1	0.08	1	0.05
54	33	2.0	0.08	2	0.15	1	0.05
55	33	2.0	0.08	1	0.08	4	0.22
56	36	2.5	0.09	2	0.15	2	0.11
57	41	3.0	0.10	1	0.08	3	0.16
58	22	2.0	0.05	2	0.15	11	0.59
59	26	4.5	0.06	0	0.00	0	0.00
60	27	8.0	0.07	1	0.08	4	0.22
61	39	2.0	0.10	2	0.15	6	0.32
62	35	5.1	0.09	1	0.08	2	0.11
63	30	3.5	0.07	0	0.00	3	0.16
64	38	3.0	0.09	1	0.08	2	0.11
65	39	3.0	0.10	1	0.08	1	0.05
66	40	5.0	0.10	2	0.15	4	0.22
67	22	2.0	0.05	0	0.00	1	0.05
68	28	3.0	0.07	1	0.08	2	0.11
69	31	2.8	0.08	3	0.23	4	0.22
70	30	3.0	0.07	1	0.08	4	0.22
71	37	8.0	0.09	2	0.15	2	0.11
72	34	4.5	0.08	1	0.08	1	0.05
73	23	2.0	0.06	2	0.15	4	0.22
74	24	3.0	0.06	3	0.23	1	0.05
75	25	2.5	0.06	0	0.00	2	0.11
76	26	3.5	0.06	5	0.38	1	0.05
77	26	4.1	0.06	4	0.31	3	0.16
78	37	7.0	0.09	0	0.00	1	0.05
79	27	3.0	0.07	1	0.08	4	0.22
80	34	3.0	0.08	2	0.15	3	0.16
81	22	2.5	0.05	5	0.38	4	0.22
82	20	2.0	0.05	0	0.00	1	0.05

83	30	3.5	0.07	1	0.08	0	0.00
84	20	2.0	0.05	2	0.15	2	0.11
85	18	7.0	0.04	6	0.46	1	0.05
86	23	3.0	0.06	6	0.46	1	0.05
87	21	9.0	0.05	5	0.38	0	0.00
88	17	3.0	0.04	6	0.46	0	0.00
89	32	6.0	0.08	6	0.46	2	0.11
90	30	2.0	0.07	2	0.15	2	0.11
91	23	3.0	0.06	5	0.38	0	0.00
92	34	3.0	0.08	2	0.15	2	0.11
93	19	2.0	0.05	7	0.53	0	0.00
94	28	5.0	0.07	6	0.46	1	0.05
95	20	4.0	0.05	3	0.23	3	0.16
96	18	3.5	0.04	2	0.15	0	0.00
97	25	8.0	0.06	6	0.46	0	0.00
98	23	2.2	0.06	1	0.08	6	0.32
99	10	2.5	0.02	1	0.08	1	0.05
100	20	2.0	0.05	3	0.23	1	0.05
>100	8592	5.0	21.08	1158	88.46	212	11.45

Comments:
For the Alberta data, larger spill volumes and larger recovery volumes required more time to clean up, and, more recent spills were reported as cleaned-up sooner than older spills. But for spill and recovery volumes, the correlation with clean-up delay is fairly weak. The median clean-up delay for crude oil spills was 2 days (24,823 spills) and 2 days for saline spills (15,677 spills). For the NEB data, there was no significant correlation between crude oil spill volume and clean-up delay.

The details: For the Alberta data, the Spearman correlation between clean-up delay and crude oil spill volume was $r = 0.2244$, $n = 24,823$, $p < 0.0001$; that between clean-up delay and recovery volume was $r = 0.0828$, $n = 24.155$, $p < 0.001$, and that between clean- up delay and year of spill was $r = -0.4027$, $n = 24,823$, $p << 0.0001$.
The Spearman correlation between clean-up delay and saline spill volume was $r = 0.2174$, $n = 15,677$, $p < 0.0001$; that between clean-up delay and recovery volume was $r = 0.0098$, $n = 15,161$, $p < 0.001$, and that between clean-up delay and year of spill was $r = -0.4194$, $n = 15,677$, $p << 0.0001$.

For the NEB data, clean-up delay was not correlated significantly with spill volume. The Spearman correlation between clean-up delay and crude oil pipeline spill volume was $r = -0.1340$, $n = 46$, $p > 0.1$. The median clean-up delay was 424 days for all hydrocarbon spills (1336 spills with complete data) and 584 days for crude oil spills (n=46 spills with complete data).

Similarly, for the Montana data, clean-up delay was not correlated significantly with spill volume. The Spearman correlation between clean-up delay and crude oil spill volume was $r = 0.0450$, $n = 851$, $p > 0.05$; the Spearman correlation between clean-up delay and saline spill volume was $r = -0.0481$, $n = 816$, $p > 0.05$.

Web 7.12.1. Observed and expected frequencies of Alberta spills by days of the week^

Here we examine the observed and expected frequency of spill occurrence in relation to days of the week. Spills are unplanned and can occur on any day of the week. Therefore, they should occur with equal frequency for all seven days of the week if spills are reported without regard to human schedules.

The Alberta data below are tallied from all sources of 74,975 spills in the FIS database current to 10 July 2019. Reported spills differed in their frequencies by days of the week. Spills were more frequently reported on Monday through Thursday. Spills were least frequently reported on Saturdays followed by Sundays. The probability of observing the pattern by chance is essentially zero (chi-square = 2241, 6 df).

I repeated the exercise for spills classified into three main sources (Web 7.12.2): wells, batteries, and satellites (30,550 spills); pipelines (34,164 spills); and all other sources (10,261 spills). Again, there was a strong departure in the expected frequency of spills for the days of the week. For all three sources, spills were less frequently reported on Saturday and Sunday. For wells, batteries, and satellites, spills were more frequently reported on Monday through Wednesday. For pipelines, spills were more frequently reported on Monday through Thursday. For other sources, spills were more frequently reported on Tuesday through Thursday.

Day Incident Reported	Observed N	Observed Frequency	Expected Frequency	Expected N	chi-square	observed-expected frequency	higher or lower than expected^
Monday	12639	0.169	0.143	10711	347.1	0.026	higher
Tuesday	12052	0.161	0.143	10711	167.9	0.018	higher
Wednesday	12046	0.161	0.143	10711	166.4	0.018	higher
Thursday	11789	0.157	0.143	10711	108.5	0.014	higher
Friday	10598	0.141	0.143	10711	1.2	-0.002	no difference
Saturday	7836	0.105	0.143	10711	771.7	-0.038	lower
Sunday	8015	0.107	0.143	10711	678.6	-0.036	lower

^ Chi-square value of 10.8 at alpha 0.001 used to decide significance of deviations in frequency for individual days of week

Web 7.12.2 Summary of observed and expected frequencies of spills in five jurisdictions by days of the week.^

Dataset	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Chi-square, p, n spills
Alberta (all)	Fav	Fav	Fav	Fav		Disfav	Disfav	2241, 0, 74, 975
Alberta (wells, batteries, satellites)	Fav	Fav	Fav			Disfav	Disfav	548, $3.8*10^{-115}$, 30,550
Alberta (pipelines)	Fav	Fav	Fav	Fav		Disfav	Disfav	1835, 0, 34,164
Alberta (all other sources)		Fav	Fav	Fav		Disfav	Disfav	182, $1.2*10^{-36}$, 10,261
Saskatchewan	Fav	Fav	Fav			Disfav	Disfav	253, $1.1*10^{-51}$, 19,511
North Dakota	Fav			Fav		Disfav	Disfav	151, $4.5*10^{-30}$, 8690
Montana	Fav	Fav	Fav	Fav	Fav	Disfav	Disfav	2328, 0, 16,797
NEB				Fav		Disfav	Disfav	188, $8.9*10^{-38}$, 1336

^ Fav = favored (more frequent than expected); Disfav = disfavored; Chi-square value of 10.8 at alpha 0.001 used to decide significance of deviations in frequency for individual days of week

Comments:

In all jurisdictions, there were large differences in the observed and expected frequencies of spills by the days of the week. Alberta and Montana showed the strongest departures from the expectation of temporally random spills while North Dakota and National Energy Board spills showed smaller departures.

Web 7.12.3 Daily differences in spill volumes

What might account for the apparent reduced spill occurrence on weekends? If hydrocarbon production functioned on a five-day work week, such as do schools and universities, it would make sense for more spills to be reported on weekdays, but that's not how the upstream industry works. The costs of drilling or servicing wells, or shutting down and restarting batteries and other facilities, mean that these activities are continuous as long as conditions allow. Furthermore, once wells and pipelines are constructed, they work more or less constantly unless taken offline for servicing; they don't shut down on the weekend. The most likely explanation for the weekly temporal pattern in spill occurrence is that, on the weekend, reduced monitoring results in fewer reported spills. Spills occur, but some aren't reported until later in the week. With reduced vigilance, perhaps smaller spills are not being reported. Is there a way to test that hypothesis?

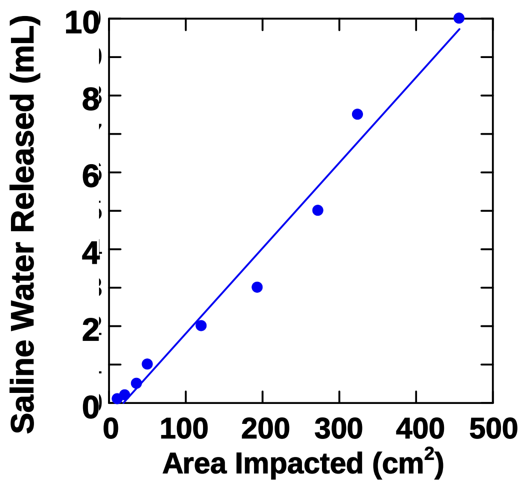
Given the unreliability of the industry-reported data for spill volumes, it's difficult to peer through the firewall and find the reasons for the reduced number of spills reported on the weekend. But let's hypothesize that reduced vigilance on the weekend results in some smaller spills not being reported. If so, there should be a statistically significant difference in spill volumes for the days of the week. I tested this hypothesis for primary spills of crude oil and saline produced water in Alberta.

For both types of spills, reported spill volumes are indeed higher on Saturdays and Sundays (crude oil spills: Kruskal-Wallis statistic 84.4, $p < 0.000000001$, $n = 22,809$; saline water spills: Kruskal-Wallis statistic 50.9, $p = 0.000000003$, $n = 14,685$). For crude oil spills, median volumes = 2.0 m^3 on Saturdays and Sundays and 2.0, 1.0, 1.0, 1.5, and 2.0 m^3 for Monday through Friday. For saline spills, median volumes = 6.0 m^3 on Saturdays and Sundays and 5.0 m^3 for Monday through Friday.

When examined together the data on daily frequency and spill volumes paint a consistent picture. Spills are reported more frequently on weekdays because companies are catching up on spills not reported on the weekend. Reduced vigilance on the weekend results in a shift towards larger spill volumes. The data suggest deficiencies in monitoring and reporting.

Web 7.13. The relationship between spill volumes and spill footprints in Saskatchewan

Understanding and therefore being able to predict how large an area will be impacted by a spill of a given volume and type is important for spill remediation and quantification of ecological impacts. To demonstrate the relationship between a spill and its footprint I used graph paper onto which I spilled saline water of known volume along with a blue dye. I waited until the colored area stopped expanding and measured the footprint of each spill. The diagram on the right shows the measured footprints in these mini-saline spills.



In the real world with say, spills in winter or summer, or on sand vs. clay vs. peat, or on a hilltop vs. in a depression, greater variation in the relationship between spill volume and footprint would than on a tabletop experiment.

Now for industry's data. Unfortunately, the Alberta data cannot be used to determine the areal impact of spills because the regulator uses three size-classes for spill footprints (≤100 m^2, 100-1000 m^2, and >1000 m^2) rather than actual footprints. Furthermore, the Alberta data contain no information on area impacted for most spills, and finally, the Alberta case studies demonstrate that reported areal footprint size-classes and spill volumes underestimate the true values. The Alberta data on spill footprints are, for all intents, worthless.

Fortunately, the Saskatchewan data report spill volumes and area impacted for spills of various types. Here we examine that footprint relationship for spills of saline water, crude oil, saline water + crude oil, and total liquids.

If we plot the relationship between spill volume and the square root of spill footprints (m^2) for crude oil and saline spills, we observe the "dust bunny" distribution (McCune and Root 2015) (Web 7.13.1). The dust bunny distribution in this case is the result of a weak (noisy) relationship between spill volume and spill footprint.

If instead we plot the log10 of spill volumes against the log10 of spill footprints (Figure 7.2) we can see into the dust bunny and observe the extreme variability in the spill/footprint relationship. Due to that extreme variability and the non-normality of the data, I could not find useful statistical relationships to predict individual footprints from individual spill volumes. Therefore, even when we know the reported volume of a spill, we have almost no idea of the footprint for that spill. Controlling for season of spill (winter = Jan-Apr and Nov-Dec; summer = May-Oct) or for whether a water body was affected did not improve the relationship between spill volumes and footprints.

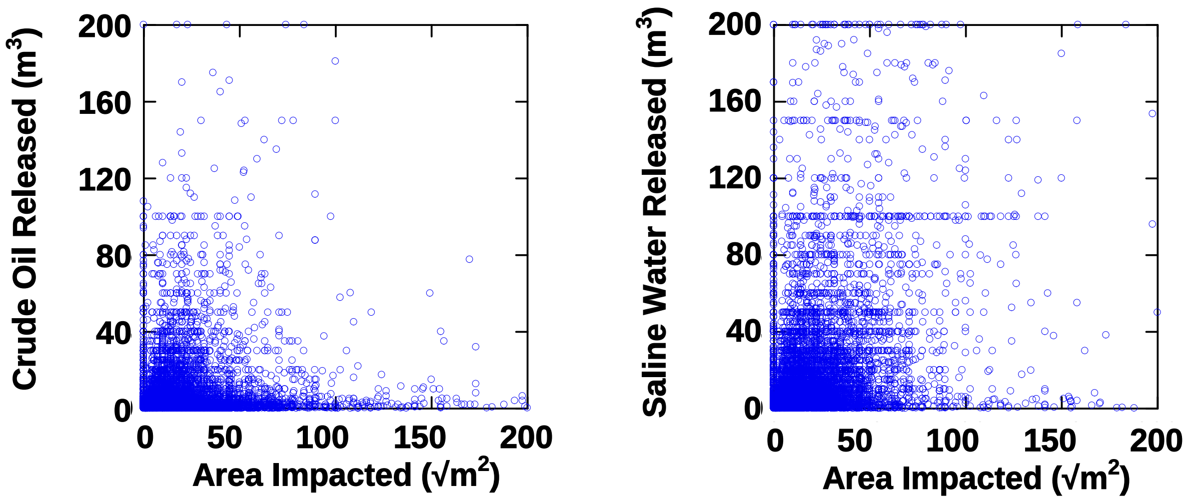
There are two salient results. The first is the impossibly large range in footprints reported for spills of a given volume, and the similarly impossible range of volumes reported for a given footprint (Web 7.14). This is significant because it indicates that the true spill volumes and areas impacted are not being reported (Web 7.13.2). The second major finding is that spill concentrations, expressed as liters per m^2, increase with increasing spill volumes (Web 7.13.3). So, on average, the larger the spill volume, the greater the concentration of spilled liquid within the spill footprint.

Spill Volumes and Off-Lease Impacts

Finally, let's examine the relationship between spill volume and proportion of a spill footprint that flows off-lease. Again, the Alberta data are mute on this topic but the Saskatchewan data provide interesting insight into industrial reporting. First, three facts to bear in mind. (1) Upstream industrial facilities occupy leases. All spills therefore begin on leases and then may flow off-lease. (2) In order for a spill to occur, it must have a non-zero volume. A zero volume spill cannot have a footprint and cannot flow off-lease. (3) With increasing spill volumes, the proportion of the spill footprint that flowed off-lease should increase.

Putting those facts together, it's surprising that of 1926 spills that reported a zero release volume for saline water + crude oil, 64 % (1236) of those spills reported a non-zero spill footprint, and 26 % (496) of those zero-volume spills reported that the entire spill footprint was located off-lease. If the data were credible, these would be physical impossibilities.

There should be a positive correlation between spill volume and the proportion of a spill footprint reported as flowing off-lease. Is there? Not really. For 19,311 spills, the rank correlations between spill volume and percent of off-lease footprint were as follows: Saline water volume, r = 0.088, crude oil volume, r = -0.089, saline water + crude oil volume, r = -0.023, and total liquid release volume, r = -0.025. Although logic tells us there should be, there is no consistent relationship between spill volume and the proportion of the spill footprint that is reported as flowing off-lease (Web 7.13.3.2). Reported spill volume and/or spill footprint and/or proportion of the spill footprint that is reported as flowing off-lease can't be credible.



Web 7.13.1. The dust bunny distribution in the relationships between crude oil and saline spill release volumes and their spill footprints. There are over 11 thousand points in the crude oil dust bunny and over 12.5 thousand points in the saline spill dust bunny.

Web 7.13.2. Areal Footprints for Spills Reported as Exactly x m^3 for (a) Saline, (b) Crude Oil, (c) Saline + Crude Oil, and (d) Total Liquids Spills in Saskatchewan.

(a) Saline Spills (m^3)	**Area Impacted (m^2)**			
	Median (range)	10^{th} tile	90^{th} tile	N
0.5	40 (0-21,375)	5	645	486
1	70 (0-168,195)	10	520	655
2	100 (0-20,000)	10	650	625
5	150 (0-79,020)	20	1000	466
10	200 (0-528,114)	29	1550	455
20	315 (0-47,520)	60	2023	278
50	860 (0-41,200)	100	5000	135
100	2090 (0-20,000)	150	11,736	111
150	1368 (0-25,000)	100	10,077	32
200	1550 (0-33,712)	400	7689	43
(b) Crude Oil Spills (m^3)	**Area Impacted (m^2)**			
	Median (range)	10^{th} tile	90^{th} tile	N
0.5	100 (0-82,600)	10	1560	854
1	160 (0-168,195)	10	2000	1007
2	111 (0-57,600)	10	1825	687
5	150 (0-49,500)	25.4	2090	440
10	180 (0-23,807)	21	2000	311
20	290 (0-10,521)	50	2990	142
50	450 (0-60,000)	100	5200	45
100	385 (0-9521)	100	2400	24
150	5200 (900-10,000)	---	---	5
200	1205 (0-6996)	---	---	6
(c) Saline + Crude Oil Spills (m^3)	**Area Impacted (m^2)**			
	Median (range)	10^{th} tile	90^{th} tile	N
0.5	33 (0-82,600)	4.7	850	763
1	69.5 (0-79,362)	5	890	934
2	90 (0-168,195)	10	614	1287
5	140 (0-49,500)	20	1050	981
10	200 (0-528,114)	25	1540	896
20	300 (0-20,000)	50	2023.4	513
50	625 (0-60,000)	100	4150	259
100	1500 (0-39,000)	150	9000	150
150	1457 (0-25,000)	118.6	10,000	50
200	1450 (0-33,712)	300	8096	52
(d) Total Liquid Spills (m^3) *	**Area Impacted (m^2)**			
	Median (range)	10^{th} tile	90^{th} tile	N
0.5	38 (0-82,600)	4	850	802
1	70 (0-79,632)	5	907	990
2	90 (0-168,195)	10	614	1332
5	144 (0-49,500)	20	1072	1008
10	200 (0-528,114)	26	1600	919
20	309 (0-20,000)	50	2090	521
50	648 (0-60,000)	100	4150	266
100	1500 (0-39,000)	150	10,000	152
150	1500 (0-25,000)	118.6	10,000	51
200	1550 (0-33,712)	400	8096	53

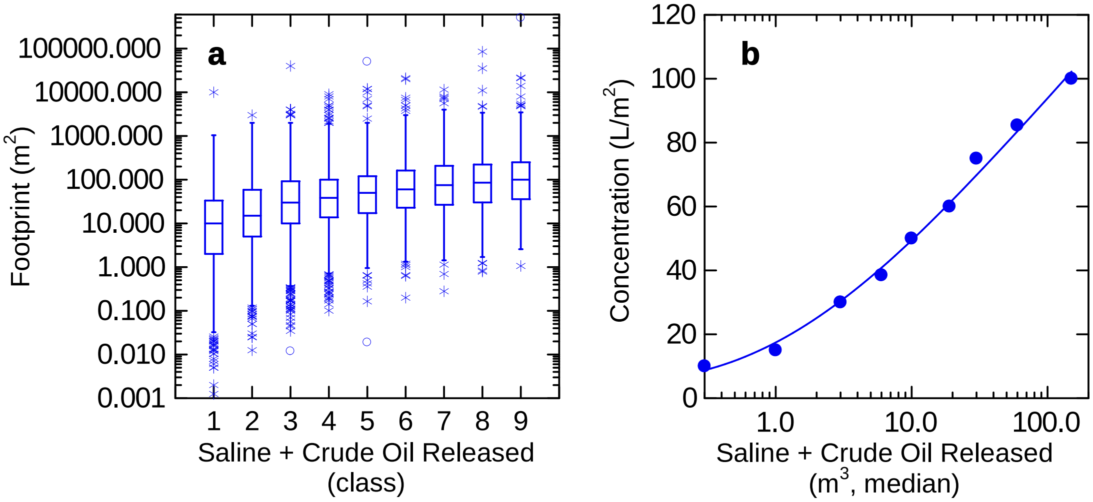
* “Total liquid” is the sum of all liquids spilled, which is strongly dominated by saline water and crude oil as the comparison of sections (c) and (d) in the table demonstrates

Web 7.13.3. Spill Volumes and Areal Footprints for Spills by Volume Classes for (a) Saline, (b) Crude Oil, (c) Saline + Crude Oil, and (d) Total Liquids Spills in Saskatchewan.

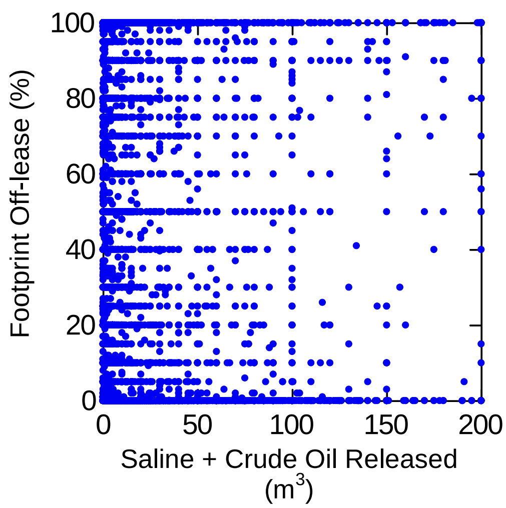
a. Saline Spill Class in m^3 (median volume)	**Sum Volume (m^3)**	**Sum Footprint (m^2)**	**L/m^2 (median) [a]**	**N**
>0 to <1 (0.4)	854	948136	0.9 (6.7)	2035
≥1 to <2 (1.2)	1919	721766	2.7 (14.4)	1381
≥2 to <5 (4)	8102	1145620	7.1 (22.8)	2474
≥5 to <10 (6)	12374	1039370	11.9 (31.7)	1723
≥10 to <15 (10)	11623	1138850	10.2 (41.5)	957
≥15 to <25 (15)	19832	884911	22.4 (50.0)	1016
≥25 to <50 (32)	36229	1361660	26.6 (63.0)	1006
≥50 to <100 (64.8)	43998	1283750	34.3 (70.0)	617
≥100 to <1000 (150)	109659	1967720	55.7 (86.9)	497
b. Crude Oil Spill Class in m^3 (median volume)	**Sum Volume (m^3)**	**Sum Footprint (m^2)**	**L/m^2 (median) [a]**	**N**
>0 to <1 (0.2)	1285	2434170	0.5 (2.1)	3999
≥1 to <2 (1)	2093	1526630	1.4 (6.7)	1657
≥2 to <5 (4)	6734	1769480	3.8 (20.0)	2181
≥5 to <10 (6)	8078	1155840	7.0 (33.3)	1203
≥10 to <15 (10)	6972	569952	12.2 (49.0)	583
≥15 to <25 (18)	9948	517258	19.2 (63.9)	524
≥25 to <50 (30)	15833	526279	30.1 (83.3)	454
≥50 to <100 (63)	14906	346718	43.0 (108.3)	213
≥100 to <1000 (124.5)	15718	314458	50.0 (106.4)	79
c. Saline + Crude Oil Spill Class in m^3 (median volume, class)	**Sum Volume (m^3)**	**Sum Footprint (m^2)**	**L/m^2 (median) [a, b]**	**N**
>0 to <1 (0.3, 1)	870	971788	0.9 (10.0)	2342
≥1 to <2 (1, 2)	1950	866098	2.3 (15.0)	1508
≥2 to <5 (3, 3)	11609	1932640	6.0 (30.0)	3731
≥5 to <10 (6, 4)	17394	1526400	11.4 (38.5)	2574
≥10 to <15 (10, 5)	17243	1557580	11.1 (50.0)	1486
≥15 to <25 (19, 6)	28949	1202770	24.1 (60.0)	1509
≥25 to <50 (30, 7)	50430	1612240	31.3 (75.0)	1437
≥50 to <100 (60, 8)	61943	1693130	36.6 (85.4)	904
≥100 to <1000 (150, 9)	133156	2543260	52.4 (100.0)	630
d. Total Liquid Spill Class in m^3 (median volume)	**Sum Volume (m^3)**	**Sum Footprint (m^2)**	**L/m^2 (median) [a]**	**N**
>0 to <1 (0.3)	939	1112440	0.8 (10.0)	2623
≥1 to <2 (1)	2039	920186	2.2 (15.0)	1584
≥2 to <5 (3)	12007	1991030	6.0 (28.6)	3861
≥5 to <10 (6)	17817	1573210	11.3 (37.5)	2639
≥10 to <15 (10)	17634	1607480	11.0 (48.0)	1520
≥15 to <25 (19)	29455	1235550	23.8 (60.0)	1534
≥25 to <50 (30)	51127	1642500	31.1 (73.7)	1459
≥50 to <100 (60)	63099	1734960	36.4 (85.7)	922
≥100 to <1000 (150)	137930	2510440	54.9 (100.0)	645

[a] L/m^2 were estimated by two methods: by dividing the sum of the volume by the sum of the footprint within each volume class and by dividing each spill volume by its footprint and determining the median L/m^2 within each volume class. These concentrations represent the overall concentrations within a footprint, rather than the concentration to be expected at all locations within the footprint. Given that the two methods provide different values, the values of the concentrations are less important than are the consistent trends of increasing concentration with increasing spill volume observed across methods and spill types.

[b] For graphs of saline +crude oil released in relation to spill footprints, see Web 7.13.3.1



Web 7.13.3.1. Volumes of spills of saline + crude oil in relation to footprints and concentrations for the spills, (a) box plots of spill footprints in relation to spill volume class (logarithmic y-axis) and (b) median spill concentration in relation to median spill volume within the spill volume classes (logarithmic x-axis).



Web 7.13.3.2 Volumes of spills of saline + crude oil in relation to proportion of the spill footprint reported as off-lease. The graph depicts 19,288 spills; the data are limited to spills of </= 200 m^3. Note the high proportion of spills reporting exactly 0, 10, 20, 25 % etc. off-lease, indicative of subjectivity.

Web 7.14. Benford analysis of frequency of first significant digits in saline and crude oil spill volumes and area impacted data from Saskatchewan spills.

a. Saline Spill Volume (m^3)								
	Observed			Expected			Statistics	
Digit	N	Freq-uency	Cumul. Freq-uency	N	Freq-uency	Cumul. Freq-uency	Differ-ence, D	Chi-square
1	3882	0.308	0.308	3790.2	0.301	0.301	0.007	2.224
2	2466	0.196	0.504	2216.2	0.176	0.477	0.027	28.158
3	1433	0.114	0.618	1574.0	0.125	0.602	0.016	12.631
4	1259	0.100	0.7 18	1221.4	0.097	0.699	0.019	1.156
5	1504	0.119	0.837	994.8	0.079	0.778	**0.059**	260.681
6	540	0.043	0.880	843.7	0.067	0.845	0.035	109.299
7	472	0.037	0.918	730.4	0.058	0.903	0.015	91.379
8	520	0.041	0.959	642.2	0.051	0.954	0.005	23.250
9	516	0.041	1.000	579.2	0.046	1.000	0.000	6.903
Sum	12592	1		12592	1			535.681

Chi-square test: $p = 1.54 * 10^{-110}$; Dmax = largest difference between expected and observed cumulative frequency
K-S test for departure from Benford distribution: Dmax = 0.059,
$\sqrt{n}$ = 112.2, Dcrit at α 0.00000003 = 3/153.7 = 0.027; Dmax > Dcrit;
observed distribution different from Benford distribution
favored: 2,5; disfavored: 6-8

b. Crude Oil Spill Volume (m^3)								
	Observed			Expected			Statistics	
Digit	N	Freq-uency	Cumul. Freq-uency	N	Freq-uency	Cumul. Freq-uency	Differ-ence, D	Chi-square
1	4030	0.346	0.346	3504.8	0.301	0.301	0.045	78.688
2	2274	0.195	0.541	2049.3	0.176	0.477	0.064	24.628
3	1415	0.122	0.663	1455.5	0.125	0.602	0.061	1.127
4	914	0.078	0.741	1129.5	0.097	0.699	0.042	41.105
5	1648	0.142	0.883	919.9	0.079	0.778	**0.105**	576.344
6	474	0.041	0.924	780.1	0.067	0.845	0.079	120.140
7	339	0.029	0.953	675.3	0.058	0.903	0.050	167.517
8	388	0.033	0.986	593.8	0.051	0.954	0.032	71.352
9	162	0.014	1.000	535.6	0.046	1.000	0.000	260.621
Sum	11644	1		11644	1			1341.519

Chi-square test: $p = 2.49 * 10^{-284}$
K-S test for departure from Benford distribution: Dmax = 0.105,
$\sqrt{n}$ = 107.9, Dcrit at α 0.00000003 = 3/107.9 = 0.028; Dmax > Dcrit;
observed distribution different from Benford distribution
favored: 1, 2, 5; disfavored: 4, 6-9

c. Area Impacted by Spill (m^2)								
	Observed			Expected			Statistics	
Digit	**N**	**Freq-uency**	**Cumul. Freq-uency**	**N**	**Freq-uency**	**Cumul. Freq-uency**	**Differ-ence, D**	**Chi-square**
1	5381	0.325	0.325	4976.1	0.301	0.301	0.024	32.941
2	3293	0.199	0.524	2909.6	0.176	0.477	0.047	50.512
3	1838	0.111	0.635	2066.5	0.125	0.602	0.033	25.266
4	1662	0.101	0.736	1603.6	0.097	0.699	0.037	2.127
5	1561	0.094	0.830	1306.0	0.079	0.778	**0.052**	49.777
6	985	0.060	0.890	1107.6	0.067	0.845	0.045	13.580
7	646	0.039	0.929	958.9	0.058	0.903	0.026	102.079
8	606	0.037	0.966	843.1	0.051	0.954	0.012	66.694
9	560	0.034	1.000	760.5	0.046	1.000	0.000	52.847
Sum	16532	1		16532	1			395.822

Chi-square test: $p = 1.47 * 10^{-80}$
K-S test for departure from Benford distribution: Dmax = 0.052,
$\sqrt{n} = 128.6$, Dcrit at α 0.00000003 = 3/128.6 = 0.023; Dmax > Dcrit;
observed distribution different from Benford distribution
favored: 1, 2, 5; disfavored: 3, 6-9

Note: The difference, D, is the difference between the observed and expected cumulative frequencies whereas the chi-square value is for the significance of the difference between the observed and expected frequencies for that digit.

Web 7.15. Benford analysis of frequency of first significant digits in saline and crude oil spill volumes from North Dakota spills.

a. Saline Spill Volume (barrels)									
		Observed			Expected			Statistics	
Digit	**N**	**Freq-uency**	**Cumul. Freq-uency**	**N**	**Freq-uency**	**Cumul. Freq-uency**	**Differ-ence, D**	**Chi-square**	
1	1044	0.311	0.311	1009.5	0.301	0.301	0.010	1.175	
2	727	0.217	0.528	590.3	0.176	0.477	0.051	31.655	
3	429	0.128	0.656	419.3	0.125	0.602	0.054	0.227	
4	276	0.082	0.738	325.3	0.097	0.699	0.039	7.482	
5	459	0.137	0.875	265.0	0.079	0.778	**0.097**	142.091	
6	110	0.033	0.908	224.7	0.067	0.845	0.063	58.563	
7	115	0.034	0.942	194.5	0.058	0.903	0.039	32.516	
8	135	0.040	0.982	171.0	0.051	0.954	0.028	7.599	
9	59	0.018	1.000	154.3	0.046	1.000	0.000	58.846	
Sum	3354	1		3354	1			340.154	

Chi-square test: p = 1.14 * 10^{-68}; Dmax = largest difference between expected and observed cumulative frequency
K-S test for departure from Benford distribution: Dmax = 0.097,
√n = 57.9, Dcrit at α 0.00000003 = 3/57.9 = 0.052; Dmax > Dcrit;
observed distribution different from Benford distribution
favored: 2,5; disfavored: 6, 7, 9

b. Crude Oil Spill Volume (barrels)								
		Observed			Expected			Statistics
Digit	**N**	**Freq-uency**	**Cumul. Freq-uency**	**N**	**Freq-uency**	**Cumul. Freq-uency**	**Differ-ence, D**	**Chi-square**
1	1564	0.322	0.322	1460.7	0.301	0.301	0.021	7.298
2	1153	0.238	0.560	854.1	0.176	0.477	0.083	104.580
3	549	0.113	0.673	606.6	0.125	0.602	0.071	5.474
4	377	0.078	0.750	470.7	0.097	0.699	0.051	18.667
5	698	0.144	0.894	383.4	0.079	0.778	**0.116**	258.176
6	113	0.023	0.918	325.1	0.067	0.845	0.073	138.422
7	199	0.041	0.959	281.5	0.058	0.903	0.056	24.166
8	127	0.026	0.985	247.5	0.051	0.954	0.031	58.670
9	73	0.015	1.000	223.2	0.046	1	0.000	101.109
Sum	4853	1		4853	1			716.561

Chi-square test: p = 1.94 * 10^{-149}
K-S test for departure from Benford distribution: Dmax = 0.116,
√n = 69.7, Dcrit at α 0.00000003 = 3/69.7 = 0.043; Dmax > Dcrit;
observed distribution different from Benford distribution
favored: 2, 5; disfavored: 4, 6-9

Web 7.16. Benford analysis of world crude oil production, net oil deliveries for OECD countries, and closing stock levels for OECD countries.

See Figure 7.1.

a. World Crude Oil Production (terawatt-hours) by Country and Year *

	Observed			Expected			Statistics	
Digit	**N**	**Freq-uency**	**Cumul. Freq-uency**	**N**	**Freq-uency**	**Cumul. Freq-uency**	**Differ-ence, D**	**Chi-square**
1	2131	0.302	0.302	2120.5	0.301	0.301	0.001	0.052
2	1199	0.170	0.472	1239.9	0.176	0.477	-0.005	1.350
3	853	0.121	0.593	880.6	0.125	0.602	-0.009	0.867
4	641	0.091	0.684	683.4	0.097	0.699	**-0.015**	2.626
5	655	0.093	0.777	556.5	0.079	0.778	-0.001	17.413
6	447	0.063	0.841	472.0	0.067	0.845	-0.004	1.326
7	363	0.052	0.892	408.6	0.058	0.903	-0.011	5.091
8	388	0.055	0.947	359.3	0.051	0.954	-0.007	2.293
9	368	0.052	1.000	324.1	0.046	1	0	5.955
Sum	7045	1		7045	1			36.973

Chi-square test: $p = 1.16 * 10^{-5}$; Dmax = largest difference between expected and observed cumulative frequency
K-S test for departure from Benford distribution: Dmax = 0.015,
$\sqrt{n}$ = 83.9, Dmax = Dcrit at α 0.084 (= 1.26/83.9 = 0.015);
observed distribution conforms to Benford distribution
favored: 5; disfavored: none

b. Net Oil Deliveries for OECD Countries (metric kilotonnes) @

	Observed			Expected			Statistics	
Digit	**N**	**Freq-uency**	**Cumul. Freq-uency**	**N**	**Freq-uency**	**Cumul. Freq-uency**	**Differ-ence, D**	**Chi-square**
1	609	0.289	0.289	633.9	0.301	0.301	-0.012	0.979
2	348	0.165	0.454	370.7	0.176	0.477	**-0.023**	1.385
3	277	0.132	0.586	263.2	0.125	0.602	-0.016	0.718
4	236	0.112	0.698	204.3	0.097	0.699	-0.001	4.925
5	152	0.072	0.770	166.4	0.079	0.778	-0.008	1.242
6	140	0.066	0.836	141.1	0.067	0.845	-0.009	0.009
7	136	0.065	0.901	122.1	0.058	0.903	-0.002	1.571
8	115	0.055	0.956	107.4	0.051	0.954	0.002	0.537
9	93	0.044	1.000	96.9	0.046	1	0	0.155
Sum	2106	1		2106	1			11.520

Chi-square test: p = 0.174
K-S test for departure from Benford distribution: Dmax = 0.023,
$\sqrt{n}$ = 45.9, Dcrit = Dmax at α 0.211 (= 1.06/45.9 = 0.023);
observed distribution conforms to Benford distribution
favored: none; disfavored: none

c. Closing Stock Levels for OECD Countries (metric kilotonnes) #								
	Observed			**Expected**			**Statistics**	
Digit	**N**	**Freq-uency**	**Cumul. Freq-uency**	**N**	**Freq-uency**	**Cumul. Freq-uency**	**Differ-ence, D**	**Chi-square**
1	566	0.322	0.322	529.2	0.301	0.301	0.021	2.565
2	326	0.185	0.507	309.4	0.176	0.477	0.030	0.890
3	235	0.134	0.641	219.7	0.125	0.602	**0.039**	1.058
4	135	0.077	0.718	170.5	0.097	0.699	0.019	7.401
5	151	0.086	0.804	138.9	0.079	0.778	0.026	1.057
6	128	0.073	0.877	117.8	0.067	0.845	0.032	0.886
7	75	0.043	0.919	102.0	0.058	0.903	0.016	7.131
8	69	0.039	0.959	89.7	0.051	0.954	0.005	4.760
9	73	0.042	1.000	80.9	0.046	1	0	0.766
Sum	1758	1		1758.0	1			26.513

Chi-square test: p = 0.000857
K-S test for departure from Benford distribution: Dmax = 0.039,
$\sqrt{n}$ = 41.9, Dcrit = Dmax at α 0.009 (= 1.64/41.9 = 0.039);
observed distribution different from Benford distribution
favored: none; disfavored: none

* World Crude Oil Production by Country and Year from: https://ourworldindata.org/fossil-fuels, dataset: fossil-fuel-production-over-the-long-term.xlsx

@ Net Oil Deliveries for OECD Countries from: https://www.iea.org, dataset in: OIL_WEB.xls, Monthly Oil Statistics, Next Release 15 November 2019, Table 8

Closing Stock Levels for OECD Countries from: https://www.iea.org, dataset in: OIL_WEB.xls, Monthly Oil Statistics, Next Release 15 November 2019, Table 9

Web 7.17. Benford analysis of Montana crude oil and produced water spill volumes.*

a. Montana Crude Oil Spill Volume								
	Observed			**Expected**			**Statistics**	
Digit	**N**	**Freq-uency**	**Cumul. Freq-uency**	**N**	**Freq-uency**	**Cumul. Freq-uency**	**Differ-ence, D**	**Chi-square**
1	250	0.290	0.290	259.8	0.301	0.301	-0.011	0.367
2	180	0.209	0.498	151.9	0.176	0.477	0.021	5.203
3	93	0.108	0.606	107.9	0.125	0.602	0.004	2.051
4	75	0.087	0.693	83.7	0.097	0.699	-0.006	0.906
5	166	0.192	0.885	68.2	0.079	0.778	**0.107**	140.360
6	28	0.032	0.918	57.8	0.067	0.845	0.073	15.380
7	22	0.025	0.943	50.1	0.058	0.903	0.040	15.724
8	33	0.038	0.981	44.0	0.051	0.954	0.027	2.756
9	16	0.019	1.000	39.7	0.046	1	0.000	14.147
Sum	863	1		863	1			196.894

Chi-square test: $p = 2.87 * 10^{-38}$;
K-S test for departure from Benford distribution: Dmax = 0.107,
√n = 29.4, Dcrit at α 0.00000003 = 3/29.4 = 0.102; Dmax > Dcrit
observed distribution different from Benford distribution
favored: 5; disfavored: 6,7,9

b. Montana Produced Water Volume								
	Observed			**Expected**			**Statistics**	
Digit	**N**	**Freq-uency**	**Cumul. Freq-uency**	**N**	**Freq-uency**	**Cumul. Freq-uency**	**Differ-ence, D**	**Chi-square**
1	252	0.305	0.305	248.3	0.301	0.301	0.004	0.054
2	155	0.188	0.493	145.2	0.176	0.477	0.016	0.661
3	123	0.149	0.642	103.1	0.125	0.602	0.040	3.830
4	64	0.078	0.720	80.0	0.097	0.699	0.021	3.209
5	104	0.126	0.846	65.2	0.079	0.778	**0.068**	23.128
6	38	0.046	0.892	55.3	0.067	0.845	0.047	5.399
7	34	0.041	0.933	47.9	0.058	0.903	0.030	4.009
8	41	0.050	0.983	42.1	0.051	0.954	0.029	0.027
9	14	0.017	1.000	38.0	0.046	1	0.000	15.115
Sum	825	1		825	1			55.433

Chi-square test: $p = 3.69 * 10^{-9}$;
K-S test for departure from Benford distribution: Dmax = 0.068,
√n = 28.7, Dmax = Dcrit at α 0.000996 (= 1.95/28.7 = 0.068);
observed distribution different from Benford distribution
favored: 5; disfavored: 9

* The frequency of significant digits 1-9 used the original units used by the Montana DEQ which were typically reported in barrels or gallons.

Web 8. Supplementary information on spills missing from the regulator's data.

Web 8.1. AER incidents associated with the BP Zama (Apache Zama) spill site (Plots 6, 10) at 14-12-16-6-W6. Sorted by date.

Incident Number	Incident Date	Incident Notification Date	Incident Complete Date	Source	Failure Type	Release Cleanup Date	Substance Released	Volume Released m^3	Volume Recovered m^3
19780105	2/1/1978	2/1/1978	2/1/1978	Water Pipeline	Corrosion Internal	2/1/1978	Salt/ Produced Water	1	0
19790856	10/29/1979	10/29/1979	6/22/1987	Water Pipeline	Corrosion Internal	6/22/1987	Salt/ Produced Water	1	1
19800426	5/12/1980	5/12/1980	6/22/1987	Water Pipeline	Construction Damage	6/22/1987	Salt/ Produced Water	40	20
19892002	12/27/1989	12/27/1989	12/28/1989	Water Pipeline	Corrosion Internal	12/28/1989	Salt/ Produced Water	40	40
19900202	2/4/1990	2/4/1990	2/5/1990	Water Pipeline	Corrosion Internal	2/5/1990	Salt/ Produced Water	8	7
19921673	11/4/1992	11/4/1992	5/12/1994	Water Pipeline	Corrosion Internal	5/12/1994	Salt/ Produced Water	9	8
19931824	10/28/1993	10/28/1993	5/12/1994	Crude Oil Group Battery	Equipment Failure	5/12/1994	Crude Oil	16	16
19931824	continued--						Salt/ Produced Water	40	38
19942133	6/22/1994	6/22/1994	9/21/1994	Crude Oil Group Battery	Equipment Failure	9/21/1994	Salt/ Produced Water	21	21
19952528	11/1/1995	11/1/1995	11/1/1995	Crude Oil Group Battery	Pump Failure	11/1/1995	Salt/ Produced Water	50	50
19961542	7/2/1996	7/2/1996	7/29/1997	Crude Oil Group Battery	Equipment Failure	7/29/1997	Salt/ Produced Water	30	20
19972158	6/20/1997	6/20/1997	7/29/1997	Crude Oil Group Battery	Equipment Failure	7/29/1997	Salt/ Produced Water	90	90
19990680	3/20/1999	3/20/1999	4/21/1999	Crude Oil Group Battery	Equipment Failure	4/21/1999	Salt/ Produced Water	75	75
19990740	3/25/1999	3/25/1999	6/27/2000	Water Pipeline	Construction Damage	6/27/2000	Salt/ Produced Water [a]	50	20
19992800	12/22/1999	12/22/1999	1/26/2000	Custom Treating Facility	Flange Loose	1/26/2000	Salt/ Produced Water	41	0

20011798	7/10/2001	7/10/2001	7/10/2001	Crude Oil Group Battery	Pump Failure	7/10/2001	Salt/ Produced Water	4	4
20012120	8/8/2001	8/8/2001	8/8/2001	Miscellaneous	Operator Error	8/8/2001	Crude Oil	0.8	0.8
20091810	9/17/2009	9/17/2009	10/1/2009	Other Pipeline	Valve Or Fitting Failure	9/17/2009	Fuel Gas	1000	0
20101037	6/7/2010	6/7/2010		Crude Oil Group Battery	Line Failure	6/8/2010	Salt/ Produced Water	12	12
20101792	10/1/2010	10/1/2010	3/10/2011	Crude Oil Group Battery	Fire	10/2/2010	Heating Oil	25	???
20130119	12/14/2012	12/14/2012		Crude Oil Group Battery	Adverse Effect	??? none provided	Salt/ Produced Water	???	???
20132558	12/23/2013	12/23/2013	03/04/2014	Crude Oil Group Battery	Adverse Effect	12/23/2013	Salt/ Produced Water	70	70
20153256	12/08/2015	12/08/2015	07/20/2016	Crude Oil Group Battery	Operator Error	12/08/2015	Production gas (raw)	100	0

[a] This spill may have affected the area documented in the field study (Plot 6) on the pipeline right-of-way; the FOIPed inspection report noted: “Spill off lease. Spill around P/L ROW. Spill travelled off lease to the south to approximately 700 m. The first 150 m travel along new pipeline ROW then the remainder of the distance on the west hand side of road... Several spills have managed to overflow or breach this lease berm and then resulting in off lease spills.”

Web 8.2. Background on the incidents at the Amber Battery released under FOIP

This section provides details on some of the incidents that have been reported at the Amber site and the responses of the regulator to those incidents. The Amber Battery is referred to as "Barrier Virgo 02/16-21". Extraction and use of the information was made difficult by the regulator supplying the text as graphics rather than in the requested text format, and by the records being supplied in random chronological order. I ask your forbearance for the poor quality of the screen-captured imagery.

1. In an inspection on 22 July 1998 of the Crude Oil Group Battery the comment indicates "housekeeping excellent". This is confusing for two reasons: (1) The comment on the 22 July 1998 inspection is dated 10 January 2004. (2) The leasee is given as Amber Energy Inc. but at that time the leasee should have been Sunoma Energy Corp.

2. On 17 August 1998, incident 19982113 took place in which 8 m^3 of crude oil were reported spilled and 8 m^3 were reported recovered at the Amber Crude Oil Group Battery. Licensee: Sunoma Energy Corp. Incident complete date: 9 June 1999. However, the AER document indicates that on 9 June 1999: "Spill not adequately cleaned up (Free fluids still remain)."

Comments

ENV Conversion > ENV Conversion

17 Aug 1998 12:00 PM Author: Garnet Hall

INSPECTOR WRC INSPECTION DATE 14 JAN 1999 SPILL INSIDE & OUTSIDE TANK DYKE AREA. ALL FREE OIL PICKED UP WILL STEAM GROUND AND HAUL TO NOS. INSPECTED BY WRC ON 14 JAN. 1999 - More cleanup required in the spring; lots of snow cover. Wait until spring to assess cleanup. Further flushing and recovery required. Monitor and check again in the spring. Covered under snow, can't confirm that cleanup is complete. INSPECTED BY WRC ON 20 APRIL 1999 - The following must be completed by 1 June 1999 - Cleanup oil spilled near Rainbow Pipelines metering building and barrel near tank dyke. Major cleanup required outside recylce pump building and throughout lease on east and south side along the lease berm. Scrape up heavy oil staining and haul to Newalta Zama for disposal. Cleanup oil spill inside the flare stack berm and haul to Newalta Zama for disposal. Cleanup oil spill inside the flare stack berm and haul to Newalta Zama for disposal. Cleanup oil spill inside tank closest to Rainbow pipeline metering station, northside and east side all within the tank dyke area. Some oil floating on the water needs to be picked up. Please comply to these requirements, failure to do so will result in further escalating consequences either a meeting with upper management and/ or shut down of operations. Thank you for your cooperation concerning this matter. Any questions, please call me at 460-3821. INSPECTED BY WRC ON 09 JUNE 1999 - CLEANUP COMPLETE; NO FURTHER WORK REQUIRED - WRITE OFF.

The report noted that cleanup was not sufficient on 14 January 1999 and that further cleanup would be required in the spring. It noted that all free oil had been recovered as of 14 January 1999. At the 9 June 1999 inspection, AER noted that cleanup was complete, no further work required—"Write off". This is inconsistent with the finding, also on 9 June 1999 that "Spill not adequately cleaned up (Free fluids still remain)."

3. On 23 December 1998, incident 19983070 took place in which 50 m^3 of crude oil were reported spilled and 0 m^3 were reported recovered at the Amber Crude Oil Group Battery. Licensee: Amber Energy Inc. Incident complete date: 26 August 1999. However, the AER document indicates that on 26 August 1999: “Spill not adequately cleaned up (Free fluids still remain).”

23 Dec 1998 05:00 AM Author: Trina Wakelin

INSPECTOR WRC INSPECTION DATE 13 JAN 1999 A fitting on the recycle pump failed. Two vacuum trucks are presently sucking up the free fluid. INSPECTED BY WRC ON 13 JAN. 1999 - More cleanup required in the spring lots of snow cover. Wait until spring to assess cleanup. Further flushing and recovery required. Monitor and check again in the Spring Covered under snow; can't confirm that cleanup is complete. INSPECTED BY WRC ON 20 APRIL 1999 - THE FOLLOWING MUST BE COMPLETED BY 01 JUNE 1999. Cleanup oil spilled near rainbow pipelines metering bldg and barrel near tank dyke. Major cleanup required outside recyclce pump building and throughout lease on east and south side along the lease berm. Scrape up heavy oil staining and haul to Newalta Zama for disposal. Cleanup oil spill inside the flare stack berm & haul to New- alta Zama for disposal. Cleanup oil spill inside tank farm closest to Rainbow pipeline metering station, northside and east side all within the tank dyke area. Some oil floating on the water needs to be picked up. Please comply to these requirements: failure to do so will result in further escalating consequences either a meeting with upper management and/or shutdown of operations. Thank you for your cooperation concerning this matter. Any questions, please call me. INSPECTED BY WRC ON JUNE 9, 1999 - THE FOLLOWING MUST BE COMPLETED FINALIZE CLEANUP OF CRUDE OIL SOAKED CONTAMINATED SOIL AROUND THE PROPANE TANK, UNDER THE PIPERACK REMOVE AND DISPOSE OF CONTAMINATED SOIL TO NEWALTA ZAMA. WORK IN/RAKE IN REMAINING CRUDE OIL. HEAVY CRUDE OIL STAINING WITHIN THE FLARE STACK AREA MUST BE SCRAPED UP AND HAULED TO NEWALTA ZAMA FOR DISPOSAL. INSPECTED BY WRC ON JUNE 09, 1999 - Further cleanup is required - remove contaminated soil, scrape up remaining soils, and work on remaining material on lease. END OF JULY SHOULD BE FINALIZED FOR CLEANUP; HAS BEEN VERY WET. THE FOLLOWING MUST BE COMPLETED - FINALIZE CLEANUP OF CRUDE OIL SOAKED CONTAMINATED SOIL AROUND THE PROPANE TANK, UNDER THE PIPERACK REMOVE AND DISPOSE OF CONTAMINATED SOIL TO NEWALTA ZAMA, WORK IN/RAKE IN REMAINING CRUDE OIL. HEAVY CRUDE OIL STAINING WITHIN THE FLARE STACK AREA MUST BE SCRAPED UP AND HAULED TO NEWALTA ZAMA FOR DISPOSAL. INSPECTED BY WRC ON 26 AUGUST 1999 - Cleanup complete - no further work required - write off. - Complete

“Heavy crude oil staining” indicates a significant oil spill into soil. The company was required to have the cleanup completed to the regulator’s satisfaction by 1 June 1999. This deadline was not met as of 9 June 1999. The site was considered cleaned-up with no further work required on 26 August 1999. The clean status of the site is brought into question at later inspections. The first page of this record indicates 50 m^3 crude oil spilled and no recovery of oil, but the comments above state that cleanup was complete.

4. An inspection on 20 October 1999 of the Crude Oil Group Battery observed “high risk” non-compliance, “unsatisfactory” inspection results, odor emissions, and “low risk” non-compliance with other EUB (Energy and Utilities Board) requirements; “no enforcement action” and “no investigation”.
The comments for this inspection, dated 10 January 2004 follow:

#8: FACILITIES WITH H2S IN EXCESS OF 10 MOLES/KMOLE(1%) MUST BE FENCED IN ACCORDANCE WITH SECTION 8.170 OF THE O&GC REGS. #14: H2S ODORS ARE EVIDENT OFF SITE DOWNWIND OF THE FLARE STACK. STRONG WIND IS BLOWING OUT OF THE WEST. THE FLARE WENT OUT WHILE I WAS ON SITE, POSSIBLE AS A RESULT OF GAS FLOW TO THE FLARE WHEN TREATER BURNERS CUT IN. THE IGNITOR IS OPERATING AND DID TEMPORARILY RE-LIGHT THE FLARE A COUPLE OF TIMES OVER ABOUT 1/2 HR PERIOD. SONOMA PROPOSED TO ADD SUFFICIENT PROPANE TO THE FLARE TO ENSURE IT STAYS LIT UNTIL PERMANENT MODIFICATIONS/REPAIRS ARE COMPLETED TO ENSURE THE FLARE STAYS LIT. IF THIS TEMPORARY MEASURE CANNOT BE COMPLETED WITHIN THE HOUR (BY 5:30PM) OR DOES NOT ELIMINATE THIS EMISSION PROBLEM, OPERATIONS MUST BE SUSPENDED UNTIL THEY CAN BE ELIMINATED. BECAUSE OF THE ODORS FROM THE FLARE STACK, I COULD NOT DETERMINE IF THE PRODUCTION TANKS WERE ALSO CONTRIBUTING TO THE EMISSION PROBLEM. I SUSPECT THAT THEY MAY BE BECAUSE NO VAPOUR CONTROL OTHER THAN THE GAS BOOT IS INSTALLED ON THE OIL TANKS. NO VAPOUR CONTROL IS INSTALLED ON THE WATER TANK. H2S EMISSIONS DUE TO LOADING, UNLOADING, AND TRANSPORT OF PRODUCED FLUIDS IS NOT ACCEPTABLE. OIL PRODUCTION IS SHIPPED BY PIPELINE AND WATER IS RE-INJECTED. #22: SUSPENDED WELLS MUST BE SUSPENDED IN ACCORDANCE WITH ID 90-4 AND ID 91-5.

The salient points of the inspection are that the facility must be fenced due to its high H2S levels; that odors are evident off site; that the flare self-extinguished during the inspection; that repairs must be complete by 5:30 PM of that day or the facility must be shut down; that H2S levels were unacceptable; that emissions from the production tanks could be a problem because they lacked vapor controls.

5. Three months later, an inspection on 17 January 2000 observed a “satisfactory” inspection result and a satisfactory compliance level. There is no indication that the H2S emissions had been eliminated or that vapor controls had been installed. The inspector decided (13 January 2000) that the company did not need to comply with regulations to install fencing around the H2S source because “this would likely be considered remote and not required.” That the inspector considered the facility “remote” and therefore not requiring adherence to safety regulations is instructive. It suggests a lack of concern for local people and wildlife. The close social relationship between the regulator and the company is evident. The inspection report follows.

- 13 JAN/2000 - I CALLED DAVE REID WITH SUNOMA TO FOLLOW UP ON MY PREVIOUS INSPECTION AND LETTER. DAVE ADVISED ME THAT THE SUNOMA'S EDMONTON OFFICE HAS BEEN CLOSED AND RALPH LIKES IS NO LONGER WITH SUNOMA. I FAXED DAVE COPIES OF MY INSPECTION AND LETTER AND ASKED FOR A RESPONSE BY 18 JAN 2000 OR I WOULD HAVE TO ESCALATE ENFORCEMENT AS STATED IN PREVIOUS CORRESPONDENCE. 17 JAN/2000 - I RECEIVED A LETTER FROM DAVE REID WITH SUNOMA. HE SAID FENCING WOULD BE INSTALLED IN THE SPRING. A PROPANE PILOT WAS INSTALLED ON THE FLARE TO ENSURE IT STAYS LIT. SUNOMA WILL REVIEW IT'S RECORDS AND SUBMIT DOCUMENTATION REGARDING SUSPENDED WELLS AND PIPELINES. 31 JAN/2000 - I CALLED DAVE REID. I TOLD HIM TO HOLD OFF ON THE FENCING AS THIS WOULD LIKELY BE CONSIDERED REMOTE AND NOT REQUIRED. DAVE, I HAVE CONSIDERED THESE ITEMS AS NOW BEING SATISFACTOR Y. I HAVE ENTERED A DEADLINE DATE THOUGH FOR FOLLOW UP ON THE SUSPENDED WELLS AND PIPELINES. IF YOU HAVE ANY PROBLEM WITH THE DEADLINE, PLEASE CALL ME. THANKS FOR YOUR LETTER.

6. An inspection 11 months later (12 December 2000) observed an unsatisfactory inspection result and low risk non-compliance for odor emissions and non-compliance with other EUB requirements. The inspection, however, makes no mention of the H2S emissions. The inspection focusses on poor record keeping for wells and pipelines. The leasee was Sunoma Energy Corp. The inspection report follows.

TODATE I HAVE NOT RECEIVED CONFIRMATION OF FOLLOW-UP OF SUS-PENDED PIPELINES AND WELLS REQUESTED IN MY PREVIOUS INSPECTIONS. REVIEW OF OUR RECORDS INDICATE THAT IDLE PIPE- LINES ARE STILL IDENIFIED AS OPERATING. A QUICK REVIEW OF THE PIPELINES INDICATES THE FOLLOWING LINES APPEAR TO BE IDLE; HOWEVER, OUR RECORDS IDENTIFY THEM AS OPERATING. LICENCE #28191 - LINES #2,3,4,5,6,7,8,9 THE FOLLOWING WELLS ARE SUSPENDED. 00/12-16-114-05 W6M DATE LAST PRODUCED: NOVEMBER 1987 00/07-20-114-08 W6M DATE LAST PRODUCED: JANUARY 1999 00/10-20-114-06 W6M DATE LAST PRODUCED: SEPTEMBER 1987 PLEASE DO NOT LIMIT YOUR FOLLOW UP TO THESE PIPELINES AND WELLS AS THERE MAY WELL BE SOME OTHERS WHICH I HAVE MISSED. PLEASE CONFIRM ALL SUSPENDED WELLS AND PIPELINES ASSOCIATED WITH THIS FACILITY IN COMPLIANCE WITH REQUIREMENTS OF THE EUB AND OUR RECORDS ARE UPDATED.

7. A satisfactory inspection of the site on 6 February 2001, then leased to Lexin Resources Ltd, is interesting for two reasons. (1) The comments section reads: “Received letter dated January 31, 2001 from Compton Petroleum Corporation. Deficiencies satisfactory.” There are no records of deficiencies. Perhaps the deficiencies are those noted for 12 December 2000, but they referred to Sunoma Energy Corp. Were the deficiencies associated with Compton not released by AER? (2) Why was there a letter from Compton when the leasee was listed as Lexin Resources?

8. Inspection of the site on 12 December 2002, then leased to Lexin Resources Ltd, was satisfactory. There is then nearly a three year gap in the records, which is significant given the next set of findings.

9. A 17 October 2005 inspection of the site, then leased to Lexin Resources Ltd was unsatisfactory, low risk non-compliance. The description was “Environment – Housekeeping – Oil or saltwater staining on lease.” The comments were:

> There is significant stainng in the secondary containment area around the tanks that are still left on the site.
>
> There is old equipment on the site, and the site has not been active for about two years. would prefer that the equipment be removed soon.
>
> Colin Buchan Spoke with Compton representative regarding the non-compliance and the lack of action taken. At this time the Compton representative indicated that immediate would be taken to correct the deficiency. The compton representative indicated that Compton was trying to sell the battery.
>
> Colin Buchan was contacted by a Compton field operator and discussed the deficiency. The operator indicated that no action had been taken and indicated that Compton was planning to abandon the site in the spring and that it might be better to clean up the staining then.
>
> Colin Buchan spoke with the compton representative and indicated that due to the inaction and conflicting information given to him regarding the future of the site that the enforcement would be escalated to a minor level 2. The compton representative indicated that the field operator had given the inspector inaccurate information and that future communication should be with the foreman.

These comments are significant. “Staining” means an oil spill. Old equipment lying on the site was still evident in July 2016. Although the Compton representative indicated that immediate action would be taken, immediate action was not taken. The fact that Compton was trying to sell the battery highlights one of the shortcomings of the regulatory system. Ownership is often in a state of flux with the result that non-compliance issues and cleanup requirements are unresolved. In spite of the inaction and conflicting, inaccurate information provided to the regulator, the regulator’s response was to inform the company that the issue “would be escalated to a minor level”.

Given the nearly three-year gap in records, it’s unclear how long the oil spill had existed prior to the October 2005 inspection.

10. A 21 December 2005 letter from EUB to Compton Petroleum Corporation, notes that Compton has failed to properly complete remedial action required as a result of an inspection on 17 October 2005.

The compliance required of Compton related to oil staining on the lease. The letter required that Compton "Conduct and confirm completion of remedial action. Provide a written explanation why previous EUB directives were not adequately addressed. Provide a written acceptable action plan that ensures future EUB directives are followed. Failure to comply with the above requirements by January 11, 2006 will result in enforcement action being escalated to Minor Level 3 of the Field Surveillance Enforcement Ladder. This level of enforcement will result in the full or partial suspension of operations at the noncompliant site until all requirements are met and compliance achieved. A noncompliance record will also be added to the EUB's Compliance and Operations Management System (COM)."

11. In response to the letter from EUB, a production superintendent for Compton wrote (9 January 2006):

Compton Petroleum Corporation is pleased to respond to the EUB's letter dated December 21, 2005 that outlined a deficiency pertaining to staining in the secondary containment area at 16-21-114-6 w6.

The staining has been clean-up, and attached are pictures showing the staining before clean-up and area after successful clean-up. Craig Ostertag, a staff Compton representative from our Environment, Health and Safety (EH&S) team, has been to site to also verify the proper clean-up is complete.

EUB directives were not adequately followed due to two main causes. Firstly, as indicated on the pictures the staining occurred after a recent snowfall as shown by the oil staining being on top the fresh snow. In this case, Compton did not identify the staining as quickly as desirable. Compton takes full ownership of this responsibility. Secondly, Compton did not adequately meet the timeline for remedial action as outlined in the Minor Level 1 inspection performed on October 17, 2005. There was some confusion in communication between our Area Operations team and the new contract operator for the area, as well as a head office staff change due to the departure very shortly before the October 17, 2005 Minor Level 1 inspection and subsequent replacement in personnel responsible for monitoring the EUB's FIS system. Again, Compton takes full ownership of this responsibility.

Compton's action plan that ensures future EUB directives are followed is as follows. Compton has increased staffing levels in it's EH&S group to facilitate increased manpower to meet the needs of a growing company. Compton already has in place ongoing audits of it's field operations and key service providers by our EH&S group and also completes a yearly

The letter is interesting for three reasons: (1) The photographs attached to the letter suggest that the oil spill was visible, not hidden, as implied in the letter (see image below). (2) Poor communications between staff and contract operators is not a reasonable excuse for failing to clean up a spill. (3) Although the letter states that the photographs show the site before and after cleanup, none of the eight photographs demonstrate a "successful clean-up".

One of the images attached to the letter from Compton to EUB. The oil stained snow is evident.

12. A 29 September 2006 inspection of the site (leasee Lexin Resources Ltd) found unsatisfactory, low risk non-compliance. "The description was "Environment – Housekeeping – Oil or saltwater staining on lease." The brief comment was: "Oil staining inside the containment area of the tank farm." The document noted: "No investigation" and "No bioremediation" and that an action plan was not required.

13. A 24 August 2010 inspection of the site (leasee Chinook Energy Inc.) found satisfactory conditions for "Environment – Housekeeping" with no actions required.

This is the last of the records supplied by AER in the FOIP request. As such, there is a six-year gap between this inspection and the 2016 fieldwork which found the Amber site to be highly contaminated.

The AER documents demonstrate a failure of the regulator to protect the environment.

Web 8.3. Notes on Alberta Environment spills and related incidents not reported to AER

I provide this information to illustrate the point that the AER fails to document many thousands of incidents of environmental contamination stemming from hydrocarbon production. Readers interested in learning more about contamination events in the bitumen sands region of Alberta may wish to read Timoney and Lee (2013), available at: https://databasin.org/galleries/0267510a7beb4142a55857290b8f922a#expand=152256%2C152270.

The AER database does not include spills reported to Alberta Environment's Environment Management System (EMS). Within the bitumen sands region near Fort McMurray, Alberta, over the 17-year period 1996-2012, 1432 releases to land, surface water, and groundwater were documented (Timoney and Lee 2013) via a freedom of information request to Alberta Environment.

Alberta Environment has no available records of spills prior to 1996. For example, a Suncor pipeline break in 1970 spilled 3000 m^3 of oil into the Athabasca River; an oil slick was observed for about six days near the mouth of the Athabasca River Delta. Another oil spill from Suncor in 1982 caused closure of the commercial fishing season on Lake Athabasca and reportedly caused illnesses among people in Ft. McKay. There are also major spills missing from the Alberta Environment database after 1996, such as Suncor's September 2007 release into the Athabasca River of 9800 m^3 of industrial wastewater containing hydrocarbons and other contaminants.

Here are four examples that illustrate undocumented toxic sites reminiscent of the illegal dump sites in Ocean County, New Jersey. The quoted text is verbatim from the EMS records.

(1) "They were excavating and found an old garbage dump full of old drums. It is not on their records. He has talked to Sadiq already. They will be dealing with it accordingly." (113368, Syncrude Mildred Lake, Alleged Contravention, Waste).

This incident was categorized under "Waste", which is an underused category in the EMS; events of this sort are typically categorized under "Land". This incident offers a glimpse into the hidden legacy of contamination. This incident illustrates a chance discovery of industrial product drums in a garbage dump. The number of such dumps in the region is unknown. The potential for widespread hidden contamination requires study.

(2) "1500 barrels naphtha spilled from tank 20D14" [Suncor, 21 July 1997]

(3) "Reporting they were excavating hole for new sewer line, found gasoline and stained soil. Don't know how much area affected, spill seems to be old. Probably a buried tank. Will find out area effected [sic] and clean up." [Suncor, 24 March 1999]

(4) "Found a historic contaminated site where doing an excavation by their wastewater pond system. A layer of bitumen was identified as being there a while." [Suncor, 10 Jan 2002]

Here are 40 representative examples of the thousands of spills and other environmental incidents reported from the bitumen sands region that are not part of the AER records (from Timoney and Lee (2013).

(1) "Source has violated section 3.6.5 of Approval 94-01-21 - Clearing & Timber Salvage. Late 1999-Early 2000... [redacted]...and that burnt timber was in log decks (They did haul some away). ...[redacted]...has transcripts. Source reclamation officer has stated he hid info from AENV before… [redacted]... also has info about huge unreported spills of oil and bitumen." ([AESRD incident number =] 126411, Syncrude Mildred Lake).

This incident is troubling in several ways. (1) Syncrude reportedly burned and therefore wasted timber (hence the air contravention designation). (2) "Source reclamation officer has stated he hid info from AENV before…" suggests an admission of illegal practices such as the contraventions themselves and hiding those incidents from the regulator. (3) The source reportedly had "info about huge unreported spills of oil and bitumen." This indicates important spills of contaminants going undetected, unmonitored, and unprosecuted. (4) What did the government do to investigate? AESRD was asked to provide the status of this incident, but the Chief Information Officer declined to provide an answer. Taken together, items 1-4 suggest a systematic lack of due diligence, oversight, and enforcement. Incidents such as these undermine statements made by government that Alberta has high environmental standards and sustainable management.

(2) "Reporting a spill of 800-1000 litres of diesel in open pit at Aurora Mine Site. A quick coupler failed." (89271, Syncrude Mildred Lake).

The incident demonstrates that some “regulation/reporting” incidents (which sound like routine bookkeeping issues), would be better classified as air, land, or water incidents. Regulation/reporting and “no impact” incidents are not necessarily harmless. No information was provided on clean-up.

(3) “Reporting they were doing random sampling on the Aurora site and discovered hydrocarbons in one of their monitoring wells. They have pumped the well enough to say with confidence there was very little hydrocarbon (~10 L). They believe it may have come from a pump.” (130801, Syncrude Mildred Lake).

(4) “While conducting some work at the millennium upgrade site, located an UST [underground storage tank] with possible soil contamination.” (57656, Suncor Oil Sands).

(5) “Found contaminated soil around 34V6 HC [hydrocarbon] recovery basin, investigating, crack in system confirmed.” (71681, Suncor Oil Sands).

(6) “Notification of a leaking underground natural gas line on site. ATCO Gas on site, bleeding down line to make repairs.” (96105, Syncrude Mildred Lake).

(7) “Potential PCB spill. Old spill discovered in storage yard where old transformers are. Field test indicated >50 ppm PCB. Sending sample for analysis. Cleaning.” (40742, Suncor Oil Sands).

(8) “Gravel pit - Cl [chloride] levels at 1200 mg/l sample taken yesterday - just got results. Pit is getting older - saline levels higher. Water from gravel pit goes to environment (allowed under approval). Has been stopped until further notice.” (292029, Syncrude Mildred Lake, Alleged Contravention, Land).

The incident illustrates high salinity on the mined landscape and how landscape salinity may increase with time. It also illustrates release to the environment of harmful materials and that this is allowed under approval.

(9) “Sent sand samples to lab for testing to see if hazardous. Sand is hazardous with leachable toluene. Have been disposing of 30 one gallon cans/day sand to landfill.” (32705, Suncor Oil Sands).

The total amount of toluene released to the environment is not specified, nor is the amount of sand involved. How many cans of toluene were disposed of in the dump? Is a landfill an appropriate place to dispose of toluene?

(10) “Friday afternoon - discovered a few improperly stored drums in East mine. Contents - mixed bag. Also in this area - poorly managed run- off. They are cleaning the whole area up.” (139812, Suncor Oil Sands).

The incident illustrates chance discovery of undescribed materials and also poorly managed runoff. The cleanup operation is not described. What materials were found? How much contamination remains on the site? No other information was provided.

(11) “Fire at plant 5. Ongoing and started at midnight. Not sure of cause. Still fighting fire. No injuries. The area was evacuated; the plant was not evacuated. The EOC has been activated (Emergency Operations Centre; deciding what to do from there.). Not sure how large fire is. Not sure what exactly is engulfed in flame. JC [EPO initials]; Fire at Suncor's upgrader 1, burned for approximately 51 hours and was extinguished on February 11 [2010]. A fire investigation report was produced by Suncor which included the following findings; -a gas oil line located in Plant 5 of the upgrader cracked and released hot gas oil that was above its auto ignition temperature. As the fuel source could not be isolated immediately, the fire spread to include slop oil exchanger 10E-13A and Fractionator exchangers SE59A and 5E-7B. AENV continues to work with Suncor on such emergency issues such as this fire. No further action taken by AENv at this time.” (353224, Suncor Oil Sands)

The incident is a good illustration that the combination of system complexity, interconnectedness, and the processing of hazardous and flammable materials makes environmental incidents and resultant impacts essentially inevitable. The text string “AENV continues to work with [industry]” is standard script in relation to odour complaints.

(12) Release of propane, 2200 gallons. Caller doesn't know any other information as to the cause or time of the event etc. She said there is limited staff on site so she won’t be able to follow up until Monday.” (441176, Suncor Oil Sands).

The incident documents a release of propane, a lack of information as to cause, and the fact that limited staff prevented a timely response. No information was provided on clean-up or mitigation.

(13) “7500 litres diesel spilled when a vehicle drove off while refueling. Contained in bermed area. 500 litres soaked into tarsand. 7000 litres in bermed area will be vacuumed & 500 litres in tarsand will be reclaimed.” (33796, Suncor Oil Sands).

This incident illustrates a typical spill. It raises the question of what proportion of a spill is captured and how much escapes to the environment. Incidentally, the incident also illustrates use of the term “tarsand” by industry.

(14) “He just heard about a spill of processed material that may not be in containment. Not sure if its [it’s] his company’s or the site's company's responsibility to report. He has not [no] more info - but will provide update ASAP.; Clarification on report #153276. Contractor would normally call it in to her company and then she would call AENV. They found hole in gypsum line at tank farm which was isolated and purged. Moved gyp. line to emergency line - now there's a problem with emerg. line so tank is overflowing - lost 3-400 gallons. Gypsum diverted to flyash pond (pond c outfall is closed) . Contained on site. This type of spill is generally nonreportable because it is under 10,000 gallons and contained. Notification only.” (178882, Suncor).

This incident illustrates some of the complexity of the bitumen operations. A single incident may ripple through the system. It also illustrates a lack of clarity in reporting responsibilities and lax reporting requirements (e.g., under 10,000 gals not reportable). Finally it illustrates uncertainty about the fate of the material spilled.

(15) “Reporting spill of sand & slurry from tailings line. Spill contained on site, some into buffalo pasture. (43494, Syncrude Mildred Lake).

This incidents illustrates contamination of Syncrude’s buffalo pasture. No other information was available on the spill as to its volume, chemistry, and whether any actions were taken.

(16) “At 0430 they were commissioning a portion of the intersite pipeline (between Aurora and Base Plant) A vent line was left open and they lost 1000 bbl [barrels] of bitumen to the ground at base plant. Mostly flowed into their dirty water ditch. Cleaning up now, vac truck and excavator.” (127698, Syncrude Mildred Lake).

The incident illustrates a common cause of a spill—a line or valve left open by human error. It also raises the question of how much is captured when vacuuming and/or excavating a spill.

(17) “Leigh took a call from. ...earlier today.... has some questions/concerns possible gasoline contamination of an aviation site, and a possible oil spill under ice from Suncor... wants an investigator to call..” (90928, Suncor Oil Sands).

This call also includes Release to Water. This call pertained to two incidents. The caller type was “in-house” (i.e. AESRD employee). There is no indication that an investigation of the two incidents was undertaken. Unless government can produce evidence that these incidents did not happen, it can be assumed that they did. Would a government employee phone these incidents into the system without reason? An oil spill under the ice would be relatively easy to conceal and would result in unwelcome publicity and scrutiny. Therefore the incentive to conceal the incident would be great.

(18) “Spill of 2500 L caustic at train 2 slurry prep. Drain valve left partially open when filled Dec 11, 2005 hrs. Discovered Dec 13, 0210 hrs. Closed valve, neutralized spill - inside dyke. will clean in morning. Should have been discovered earlier - will investigate internally. Possibly due to many new employees – preventative details in 7-day report. Spill of 50 % caustic. Valve left open. No other details available; believe it went into ditch and eventually into their system. Contained inside dyke.” (213950, Syncrude Aurora Mine).

This incident illustrates the complexity of the operation, poor training of employees, lack of critical information, and reliance on the opinion of vested interests (e.g., “believe it went into ditch”).

(19) “East tank farm -contractor was hydro testing a line - elbow failed. Release of 62000 L of glycol. No drains or waterways. Went to ditch, cleanup is underway. No injuries. No ERP activation. Spill is on site. bs [EPO initials] Site inspection conducted. All contained in ditch (bermed on-site). Vac trucks on-site to haul to existing Eveready storage containment on-site. Spill result of pressure test of pipeline 200 psi, catastrophic failure (240 psi required test pressure).” (295203, Suncor Oil Sands)

The incident illustrates a pipeline spill.

(20) “Leak of Ammonium Sulphate. Due to catastrophic failure on G1 pump for plant 26-1. Was leaking 37000 gal/min for ~ 15 min, starting @ 0006 hrs [spill total of about 555,000 gallons]. Slow leak rate now. Slurry mix and no release to air. Contained on plant site and cleanup underway.” (399468, Syncrude Mildred Lake)

This incident illustrates one of the many kinds of chemical spills. How much is cleaned up and how much escapes?

(21) “Caller reporting a leak from a tailings return line. A high density polyethylene line carrying recycled water with 30 MFT is leaking underground along Hwy 63. The leak is visible in the ditch. There is bubbling over the soil near a water pond. The leak is contained in the ditch. The line will need repairs.” (163593, Syncrude Mildred Lake).

This incident illustrates a common source of contamination: leakage from pipelines containing tailings. How much was captured, how much escaped to the environment? What monitoring was conducted after the spill, if any, and what did the monitoring indicate?

(22) “Reporting they struck oil from oil pipeline on plant, leaking HVGO, product oil. Being excavated now & will haul to landfill. Amount unknown. Valves closed on abandoned pipeline. (59249, Suncor Oil Sands).

This incident illustrates a pipeline spill of oil of unknown volume. Soil was then hauled to landfill where contaminants may then migrate to contaminate elsewhere.

(23) “New contractor @ landfill not handling & operating the waste properly. Disposing of anything there. No certified landfill managers. Noticed since August its [it’s] been getting worst [worse]. CM [EPO initials]: Advised by Dean Litzenberger that it is an industrial landfill and does not require certified operators/managers. Should be inspected however because flammable/hazardous liquids are apparently being disposed of there.” (315233, Suncor Oil Sands).

As with many incidents, although the information is sparse, it raises serious concerns about industrial practices and environmental unknowns. The incident documents that flammable and/or hazardous substances were being disposed of in a landfill. The incident was noted on 15 October 2008, had been ongoing since August, and the incident was closed on 23 November 2008 without enforcement action. What materials were being disposed? Why would an industrial landfill not require certified operators and managers? The incident, exposed by a public complaint and not by industrial self-reporting suggests chronic poor management practices, under-reporting, poor oversight, and lax enforcement.

(24) “Spill - boiler feed water. Unknown amount, investigating. Most caught in berm, the rest went to snow covered gravel. Vac truck used for clean up. Cs [EPO initials] -Power outage caused the steam generators to Emergency Shut Down and vent steam or blowdown to the blowdown tank causing tank to vent to atmosphere creating approx. >1m3 and <5m3 of water droplets to be carry over outside the containment area. The process steam consisted is [*sic*] high in salinity, alkalinity and organics.” (319975, Japan Canada OS, JACOS).

The incident demonstrates that blowdown water may contain substances that are not innocuous.

(25) “Spill of tailings -amount unknown however it is over 100 m^3 [100,000 L], will confirm actual volume tomorrow or Monday when engineers do calculation. Spill got into a marsh area, offsite contamination. There are dykes on both sides but park [part] of the dyke was broken and the spill leaked out and now has dead vegetation. The pipeline has been shut in. No emergency protocol has been enacted. The dyke has now been fixed. The spill is in a contained area offsite. JC [EPO initials] 7-Day Letter confirmed $100m^3$, spread over $2000m^2$ area off-site (in isolated "fingers"), clean-up and remediation plan provided: timeline Aug 08-30, 2010. NORM assessment samples collected w/report due Aug 30,2010.-DW” (372247, CNRL Horizon).

The incident documents a spill of 100,000 L of tailings that resulted in offsite contamination. The tailings spread over a 2,000 m^2 marsh area and killed vegetation. No documentation was provided on the clean-up. Again, the question arises as to what proportion of a spill is effectively captured during a “clean-up”. Was the marsh remediated? What is the condition of the marsh today?

(26) “Basal leak in one of their pipelines. This is a ground water leak. Cause unknown. 16 cubes water to ground [16 m^3 = 16,000 L]. Clean up done. "Produced water".” (362463, CNRL Horizon).

The incident documents a leak of industrial process water to groundwater.

(27) “Heavy rain cause failure in sediment fence & berm. Resulting in 20m^3 of sand & silt clay washing into River. Rain has now stopped. Under investigation.” (308529, Fort Hills Energy).

The incident provides one of many examples of how industry increases the sediment load of the region’s rivers, in this case, 20,000 L of sand, silt, and clay.

(28) “~ 293 barrels of unrecovered Naphtha to tailings ponds (as opposed to NRU). Due to 48A pump trip. Happened on Feb 14 @ 2330-0100 hrs on Feb 15.” (433519, Syncrude Mildred Lake).

Over time, the naphtha would evaporate from the pond and enter the atmosphere.

(29) “Release of untested surface water runoff from VU-SED-03 sedimentation pond. Overflowed through outfall into a muskeg area, into Ruth Lake channel. Might have started last night/this morning. Out there tonight to do samples. No estimate of volume. bs [EPO initials]: 15,000m^3-17,000 m^3 released.” (328258, Suncor Oil Sands).

This release of 15-17 million L of untested surface runoff water is another example of how industry contributes to sediment and other kinds of loading to the region’s surface waters.

(30) “Ground water problem. While digging at 8 ft below ground, it [what?] hit hydrocarbon pocket and ignited it for a while.” (Closed - Information Only, Suncor Oil Sands).

This incident suggests subsoil contamination, perhaps from a former spill or dumping. No other information is available.

(31) “Notification. Release of PCB containing oil -it just went to tailings pond. Occurred approx 1 hour ago. Caused by a contractor error. It was supposed to go offsite and contractor took it into pond. The oil will not be removed from the pond; the amount of PCB would be negligible compared to the size of the pond. TK [EPO initials]: <50 gal of PCB containing oil, <5 ppm PCB. Tailings ponds permitted to accept used oil. PCB content negligible concentration will be incredibly small in the pond. Incident closed.” (324919, Suncor Oil Sands).

(32) “Concerned about spill that Source had into River - ...Wants more info on…[redacted]” (188356, Suncor Oil Sands).

No other information is available. Was this a spill into the Athabasca River?

(33) “Just observed orange floating scum in the river by Source - 1 km wide.” (225508, Suncor Oil Sands).

No other information is available. What was the source of the orange “scum”?

(34) “Reports of source finding and burying 150 ducks. Call came in from anonymous caller last night. No other information was available. bs [EPO initials] public complaint returned calls and left messages.” (302403, Syncrude Mildred Lake).

No other information is available. Interestingly, this call type was classified as “no impact”. Given the nature of the observation and the fact that it was classified as call type “impact”, classifying the call reason as “no impact” is difficult to understand.

(35) “[redacted]....SO2 ....[redacted]” (54155, Suncor Oil Sands)

This is one of the most heavily redacted incidents in the database; only one word was disclosed. No other information is available. Why was the incident redacted?

(36) “Two birds landed in one of the lagoons. Diversion lagoon. Brine solution (water). Birds died. Not sure what to do with birds.” (165379, Petro-Canada MacKay River).

The call reason for this incident was “no impact”. It is difficult to understand how bird mortalities due to exposure to industrial brine does not constitute an impact. The caller type was industry. Why did the caller not know what to do with the bird? It also begs the question, how many birds die at this and other brine ponds and are not found or reported? The fact that the caller did not know what to do with the birds, nor even what species of birds were found, indicates that the company is not training its staff adequately.

(37) “Land clearing by oil sand company; trees in crown land.” (303174, Shell Canada Jackpine).

The incident type was given as “property damage” and the incident was closed. Why was there no investigation or enforcement?

(38) “While fuelling barge, couple [coupling?] leaked under water and 50,000 litres gasoline spilled. All contained in berm area and will be pumped to the tailings area. No release. No affect [*sic*] to environment.” (30574, Syncrude Mildred Lake, Alleged Contravention, Surface Water).

How much of the gasoline would have been captured? How can an underwater gasoline leak of 50,000 L be contained in a bermed area? How much gasoline escaped or percolated to groundwater? In what waterbody was the barge? Without testing, how can it be concluded there was no effect to environment and no release?

(39) “Raw water from utilities cooled compressor system and went into industrial sewer. The sewer could not handle the volume and the water overflowed to the sanitary sewer. All water is to go to river through Pond E.” (1637, Suncor Oil Sands, Notification, Surface Water)

The incident illustrates a release to the environment of untested water of unknown volume. Pond E releases directly to the Athabasca River. Why is this a notification and not an alleged contravention or release?

(40) “Caller reporting a release of gas oil (crude oil like substance) feed to unit 43. There was a failure on charge pump for the oil pump. -2m3 of product were release. The product went into the drainage trench and plugged it up. -1m3 spilled out of trench and was released to ground. No waterways impacted. Clean up is complete. ERCB was notified last night. Fire hall did respond as a precaution. No evacs. Contained on site. ” (442782, CNRL)

This incident illustrates a release of a “crude oil like substance” that was reported to the regulator (then known as ERCB), but is nevertheless missing from the FIS database.

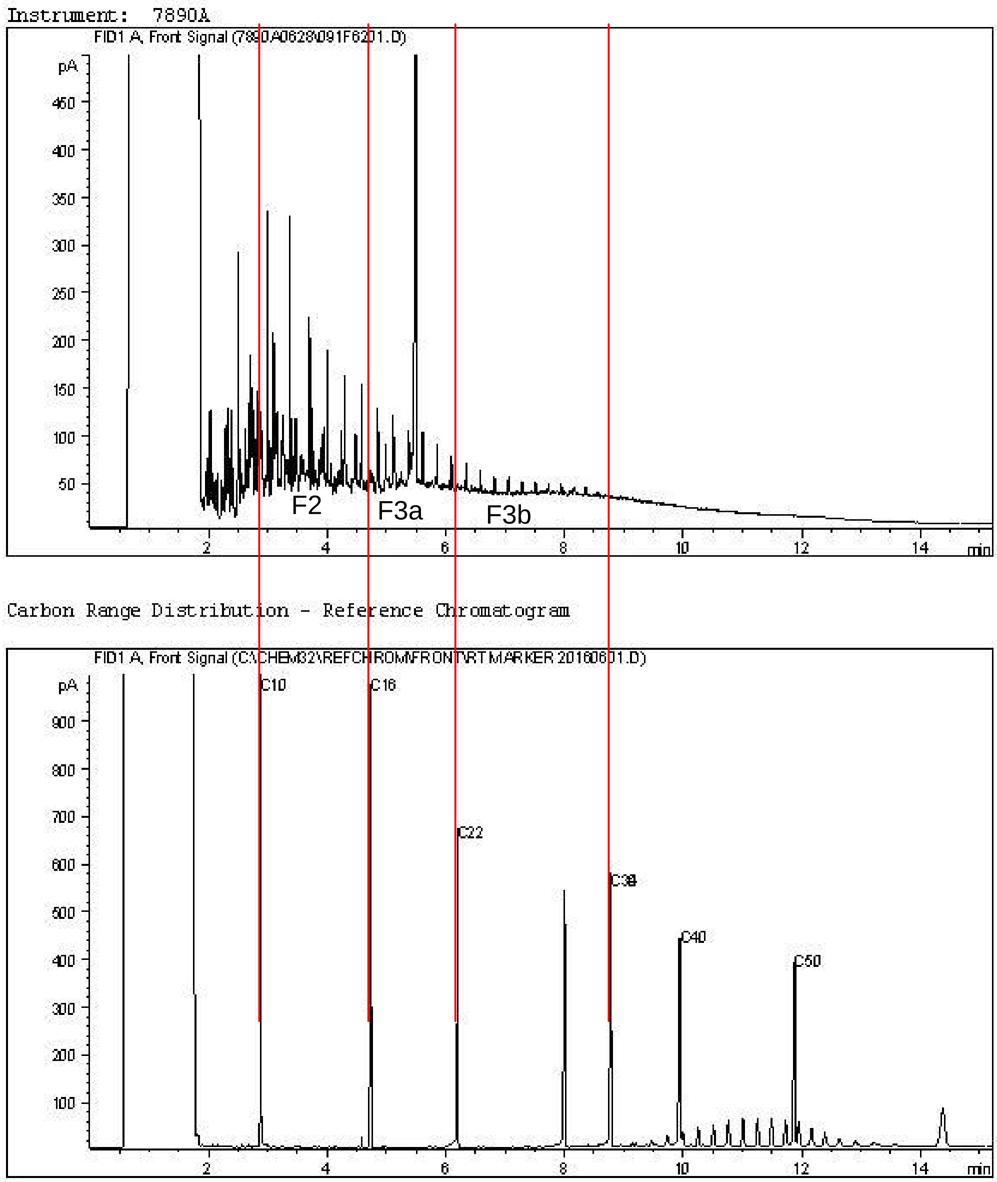
Web 9. Chemistry data for the field study sites.

Web 9.1. Chemistry results for the field study sites in northwestern Alberta.
Soil hydrocarbon concentrations (F1-F4) at the sites.

	Site	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 4**	**Plot 5**	**Plot 6**	**Plot 10**	**Plot 7**	**Plot 8**	**Plot 9**	**Plot 11**	**Site A2**
	Name	**Barn-well Spill**	**Barnwell ROW**	**Barnwell Control**	**Apache Spill**	**Apache Control**	**BP Zama (Apache Zama) Spill**	**BP Zama Control**	**Beaver Pond Spill**	**Pace-Spyglass Spill**	**Pace-Spyglass Bog Control**	**Pace-Spyglass Marsh-Fen Control**	**Amber Spill**
Parameter	Units												
Moisture	%	12	86	86	21	29	17	17	70	31	88	79	25
F2 (C10-C16)	mg/kg	27	<70 (1)	<69 (1)	22	<10	<10	<10	12	1100 (1)	<11 (4)	<47 (2)	5700 (1)
F3 (C16-C34)	mg/kg	160	390 (1)	880 (1)	120	59	130	77	340	1500 (1)	390 (4)	370 (2)	86000 (1)
F4 (C34-C50)	mg/kg	<50	<350 (1)	460 (1)	<50	<50	69	<50	74	520 (1)	74 (4)	<240 (2)	32000 (1)
Reached Baseline at C50	mg/kg	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No (7)
F4 Gravimetric	mg/kg	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	120000 (1)
Benzene	mg/kg	<0.0050	<0.032 (2)	<0.029 (2)	<0.0050	<0.0050	<0.0050	<0.0050	<0.017 (2)	0.013	<0.038 (2)	<0.022 (3)	<0.0050
Toluene	mg/kg	<0.020	<0.13 (2)	<0.12 (2)	<0.020	<0.020	<0.020	<0.020	0.15 (2)	<0.020	<0.15 (2)	<0.086 (3)	<0.020
Ethylbenzene	mg/kg	<0.010	<0.063 (2)	<0.058 (2)	<0.010	<0.010	<0.010	<0.010	<0.033 (2)	0.28	<0.076 (2)	<0.043 (3)	0.021
Xylenes (Total)	mg/kg	<0.040	<0.25 (3)	<0.23 (3)	<0.040	<0.040	<0.040	<0.040	<0.13 (2)	2.4	<0.30 (3)	<0.17 (3)	<0.040
m & p-Xylene	mg/kg	<0.040	<0.25 (2)	<0.23 (2)	<0.040	<0.040	<0.040	<0.040	<0.13 (2)	2.2	<0.30 (2)	<0.17 (3)	<0.040
o-Xylene	mg/kg	<0.020	<0.13 (2)	<0.12 (2)	<0.020	<0.020	<0.020	<0.020	<0.066 (2)	0.18	<0.15 (2)	<0.086 (3)	0.033
BTEX sum (8)	mg/kg	0	0	0	0	0	0	0	0.15	2.67	0	0	0.054
F1 (C6-C10) - BTEX	mg/kg	<12	<76 (3)	<70 (3)	<12	<12	<12	<12	<40 (2)	477.33	<91 (3)	<52 (3)	<12
F1 (C6-C10)	mg/kg	<12	<76 (2)	<70 (2)	<12	<12	<12	<12	<40 (2)	480	<91 (2)	<52 (3)	<12
Total F1-F4 (5)	mg/kg	218	638	1410	173	95	210	113	446.15	3600	515	540	211706
Total F1-F4 (6)	mg/kg	187	390	1340	142	59	199	77	426.15	3600	464	370	211700
Surrogate Recovery	%												
1,4-Difluoro-benzene	%	102	100	99	102	95	96	100	99	94	100	101	99
4-Bromo-fluorobenzene	%	99	101	101	99	102	103	99	109	105	100	100	100
D10-Ethylbenzene	%	105	100	107	105	93	93	123	93	117	103	111	103

D4-1,2-Dichloroethane	%	113	110	113	114	100	100	96	107	96	111	98	97
O-Terphenyl	%	106	106	104	110	103	103	119	103	92	95	87	180 (4)

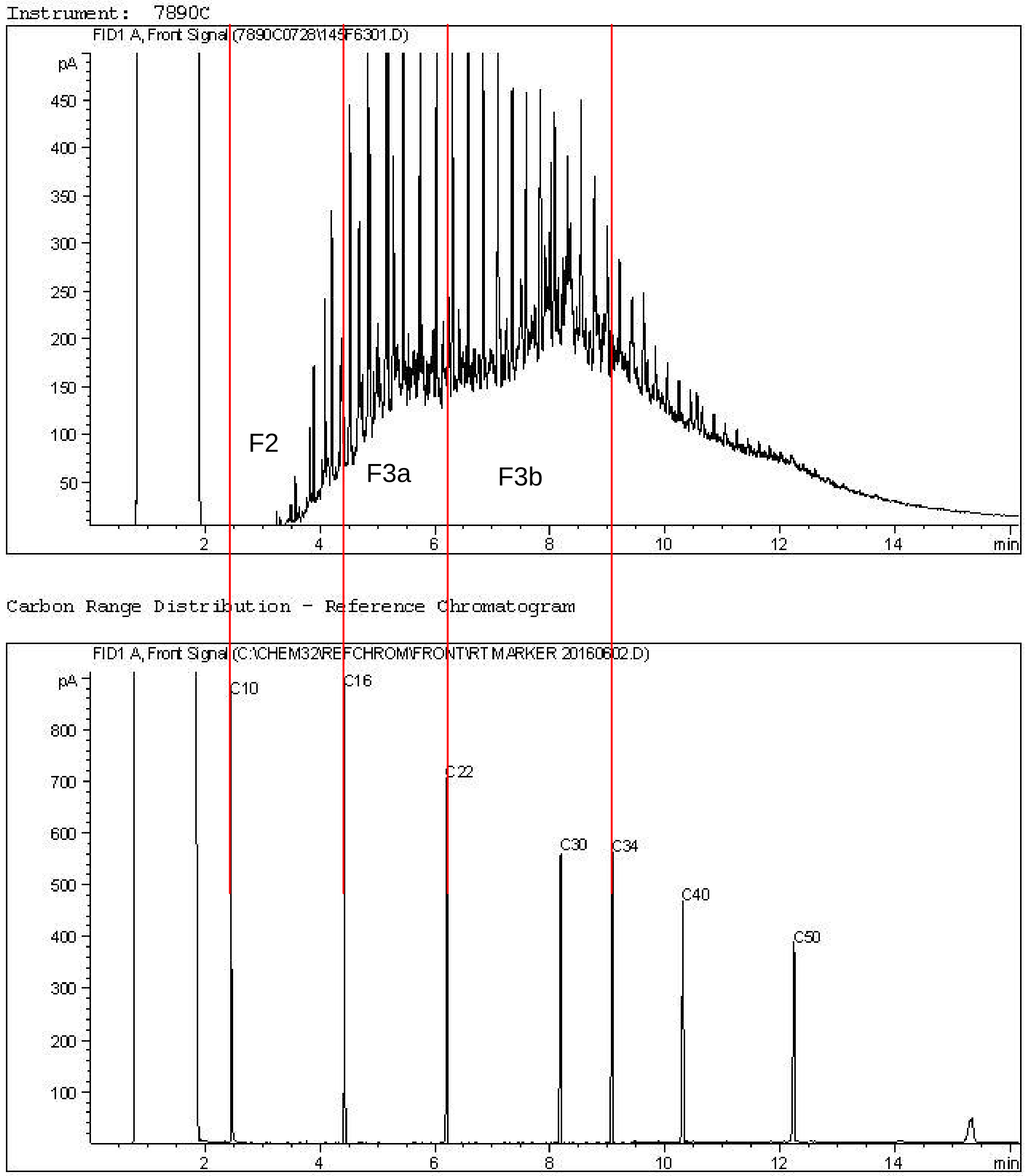
Notes:
(1) Detection limits raised due to dilution to bring analyte within the calibrated range.
(2) Detection limits raised due to high moisture content.
(3) Detection limits raised due to high moisture content, sample contains => 50% moisture.
(4) Surrogate recovery exceeds acceptance criteria due to matrix interference. I contacted Maxxam and asked whether the high recovery of o-terphenyl affected the reliability of the values. Beaudet (pers. comm. 25 August 2016) wrote: “Sample PC2311 (SITE A2) is high level through CCME F2 (C10-C16) and CCME F3 (C16-C34). The o-terphenyl surrogate elutes at approximately C18 and is effectively “buried” in the chromatographic fingerprint present. Typically the surrogate recovery is a measure of extraction efficiency but, in this case, it seems like the actual quantification of the surrogate is affected by the background levels of hydrocarbon present. However, as we’re using an external calibration/standard method to quantify CCME F2-F4, the data reported for these fractions should not be impacted by the over-recovery of the surrogate.”
(5) Total for F1-F4 assumes 1/2 value of detection limit for quantification of non-detects
(6) Total for F1-F4 assumes zero value for quantification of non-detects
(7) When baseline is not reached, a gravimetric test is employed that quantifies all long-chain hydrocarbons (C34 and above)
(8) Total BTEX assumes zero for value for quantification of non-detects
(9) Beaver Pond site: Dene Tha First Nation people were employed on site to assist in the cleanup, indicating that the spill did occur in spite of AER possessing no record. The low concentration of hydrocarbons in the soil suggests that subsequent high flows along the creek may have flushed the oil downstream. The lack of a record in the AER database for this recent spill is troubling.



TYPICAL PRODUCT CARBON NUMBER RANGES

Gasoline:	C4 - C12	Diesel:	C8 - C22
Varsol:	C8 - C12	Lubricating Oils:	C20 - C40
Kerosene:	C7 - C16	Crude Oils:	C3 - C60+

Web 9.2. F2-F4 chromatogram for Plot 8, Pace-Spyglass spill.
The F2 (C10-16), F3a (C16-22), and F3b (C22-34) are demarcated by the red lines. The high F2:F3b ratio confirms the petroleum hydrocarbon contamination (see Kelly-Hooper, n.d.). The chromatogram reveals a complex mixture of hydrocarbon molecules with a large proportion containing fewer than 22 carbon atoms.



TYPICAL PRODUCT CARBON NUMBER RANGES

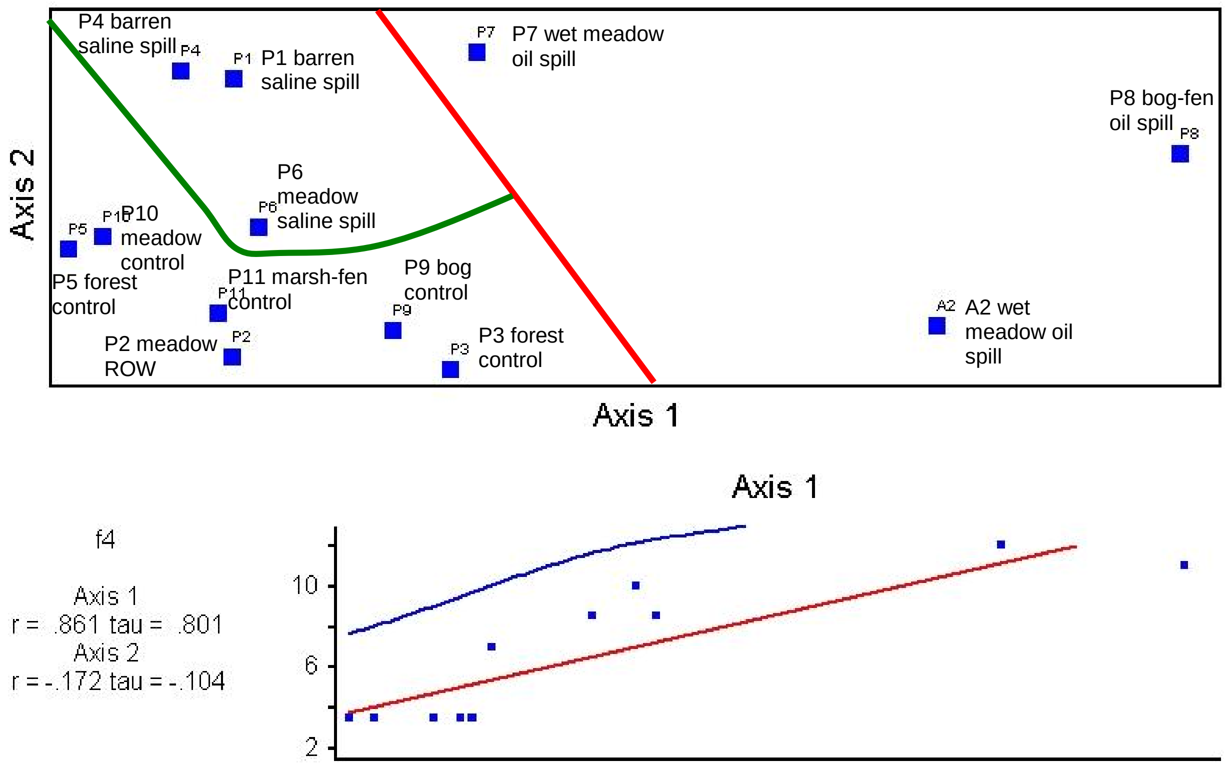
Gasoline:	C4 - C12	Diesel:	C8 - C22
Varsol:	C8 - C12	Lubricating Oils:	C20 - C40
Kerosene:	C7 - C16	Crude Oils:	C3 - C60+

Web 9.3. F2-F4 chromatogram for Site A2, Amber spill.
Although the F2:F3b ratio is fairly low, the broad spectrum of hydrocarbons from F2 through F4 demonstrates the presence of petroleum hydrocarbons. The chromatogram indicates a complex mixture of crude oil molecules containing from 12 to >50 carbon atoms.

Web 9.4. Stress in relation to dimensionality in the NMS ordination of 12 study sites in soil hydrocarbon-space.[a]

	Stress in Real Data, 250 runs			Stress in Randomized Data, Monte Carlo test, 250 runs			
Axes	**Minimum**	**Mean**	**Maximum**	**Minimum**	**Mean**	**Maximum**	**p**
1	10.6	27.9	52.7	0	41.0	52.7	0.008
2	5.5	6.6	32.4	0	15.0	34.8	0.012

[a] Sorensen distance measure; random starting coordinates; no penalty for ties; 47 iterations of the final solution; 2-dimensional solution; final instability = 0.00000



Web 9.5. NMS ordination 2-d solution of 12 study sites in soil hydrocarbon-space.
Axes scaled to percent of maximum. The oil spill sites are positioned to the right of the red line. The saline spill sites are delimited in upper left by the green line. The bottom panel plots the ranked concentrations of F4 hydrocarbons (y-axis) in relation to study site position (x-axis). See Web 9.4 for details.

In order to visualize how the sites differ in soil hydrocarbons, the samples were ordinated on the basis of nine soil hydrocarbon attributes (total F1, F2, F3, F4, benzene, toluene, ethylbenzene, m and p-xylene, and o-xylene). There were 12 sites with hydrocarbon data (in order to conserve on limited funds, hydrocarbon assays were not done at sites A1, C1, and C2 where no hydrocarbons were expected). Because of the extremely high hydrocarbon concentrations at Site A2, hydrocarbon concentrations were transformed by ranking such that the lowest concentration was replaced with a value of 1, the second-lowest with a 2, etc. up to 12 for each hydrocarbon attribute. This ranking had the effect of de-emphasizing the influence of F2, F3, and F4 concentrations on ordination position.

Controls are placed in the lower left; oil spill sites are placed on the right. Saline spill sites are clustered in the upper left, which suggests that soils in the saline spills differed in their hydrocarbons from those of controls.

Web 9.6. Concentrations of soluble ions and related parameters at the sites.
If more than one trial was conducted, values are averages (trial values in parentheses).

Site		Plot 1	Plot 2	Plot 3	Plot 4 (15-09)	Plot 5	Plot 6	Plot 10	Plot 7	Plot 8	Plot 9	Plot 11	Site A1	Site A2	Site C1 (11-26)	Site C2 (11-26)
Name		**Barnwell Spill**	**Barnwell ROW**	**Barnwell Control**	**Apache Spill**	**Apache Control**	**BP Zama Spill**	**BP Zama Control**	**Beaver Pond Spill**	**Pace-Spyglass Spill**	**Pace-Spyglass Bog Control**	**Pace-Spyglass Marsh-Fen Control**	**Amber Battery**	**Amber Spill**	**Apache Spill 2**	**Apache Spill 2**
Parameters	Units															
Chloride (Cl)	mg/L	5.6	5.8 (5.6, 6.0)	6.8 (6.7, 6.9)	27.2 (27.0, 27.4)	84.8 (85.3, 84.4)	2150.0	291.0	3.9 (3.8, 3.9)	28.8 (28.7, 29.0)	0.1 (0.1, 0.1)	<0.1	54.1	242.9	384.2	765.0
Conductivity	µS/cm	3060	1580	2210	3420	2320	10100	1730	901	758	83	916	3520	4950	4460	5050
pH (CaCl2)	pH	8.09	7.80	4.94	7.64	7.27	7.88	5.47	4.33	8.53	3.75	6.89	8.26	8.24	7.97	7.99
Calcium (Ca)	mg/L	543.4 (542.7, 544.1)	215.1 (215.7, 214.4)	376.5 (377.7, 375.4)	494.4 (497.3, 491.5)	147.4 (145.9, 148.8)	671.8 (667.7, 678.3, 669.5)	50.7	34.6 (36.0, 33.3)	120.7 (129.3, 112.2)	0.66 (0.65, 0.67)	128.0	390.0	528.3	583.2	709.5
Magnesium (Mg)	mg/L	148.3 (150.3, 146.3)	66.2 (68.1, 64.4)	86.4 (88.4, 84.4)	218.8 (223.0, 214.5)	102.5 (103.4, 101.6)	151.4 (155.3, 153.5, 145.5)	18.8	9.0 (9.6, 8.5)	16.4 (17.0, 15.8)	0.11 (0.11, 0.11)	23.1	72.8	67.2	197.8	177.3
Sodium (Na)	mg/L	41.2 (40.3, 42.0)	33.1 (33.1, 33.0)	47.6 (47.0, 48.1)	80.3 (78.2, 82.4)	184.8 (178.0, 191.7)	1408.5 (1443.0, 1373.9)	128.5	37.7 (37.0, 38.5)	23.1 (24.2, 21.9)	0.60 (0.60, 0.59)	21.7	57.6	94.2	130.3	461.0
Potassium (K)	mg/L	18.2 (17.7, 18.6)	13.9 (13.7, 14.1)	28.1 (27.2, 29.0)	24.6 (22.8, 26.4)	7.1 (6.7, 7.4)	68.1 (74.6, 58.8, 70.8)	10.7	7.3 (6.9, 7.8)	1.9 (1.8, 1.9)	0.15 (0.15, 0.15)	3.3	23.0	11.9	12.5	15.2
Sulfate (SO4)	mg/L	2073.5 (2045, 2102)	504.6 (495.8, 513.5)	1310.0	2335.5 (2308, 2363)	1164.0	2596.0	83.1	245.9 (242.5, 249.4)	2.1 (2.1, 2.2)	7.1 (7.0, 7.1)	416.0	1281.0	1238.0	609.8	585.6
Cl:SO4	ratio	0.003	0.011	0.005	0.012	0.073	0.828	3.502	0.016	13.714	0.014	0.000	0.042	0.196	0.630	1.306

Comments: At the Barnwell ROW site (Plot 2), soil levels of conductivity, calcium, magnesium, sodium, potassium, and sulphate were lower than at the control while pH was elevated and similar to the spill site. The elevated sulphate levels at the spill site relative to the ROW and control sites suggest that gypsum may have been added to the spill site in order to lower sodium levels. I requested remediation information but none was supplied.

Apache: Due to the pervasiveness of industrial disturbance in the area, the “control” may not represent undisturbed conditions. The forested control (Plot 5) is surrounded by industrial disturbance on all four sides and plot boundaries were roughly 10 m from industrial disturbances. The higher levels of sodium and chloride in the control plot relative to spill plot may have resulted from saline water from the spill flowing into the surrounding upland forests (noted in FOIPed documents, AER 2017b). Furthermore, contaminated soil was excavated from the area of Plot 4 prior to establishment of the plot. In order to remediate soils high in sodium, a calcium amendment (such as calcium sulphate or calcium nitrate) can be added to replace sodium (Alberta Environment 2001). The elevated conductivity and sulphate in the spill site soil indicates that the spill may exert lingering effects on the biota. Interestingly, Plot 4 contained significant levels of soil nitrate (31.3 mg/L). The only other sites with detectable nitrate were Sites C1 and C2 (also an Apache spill site); perhaps nitrogen fertilizer had been applied.

BP Zama: The fact that levels of calcium and sulphate were much higher and the chloride:sulphate ratio much lower at the spill (Plot 6) than at the control (Plot 10) suggests that gypsum was added to the soil as an amendment.

Beaver Pond: pH and calcium levels were relatively low for a freshwater marsh on alluvial silt. Why this was so is unclear given that the site’s disturbance history is unclear and there are no AER spill records for this location.

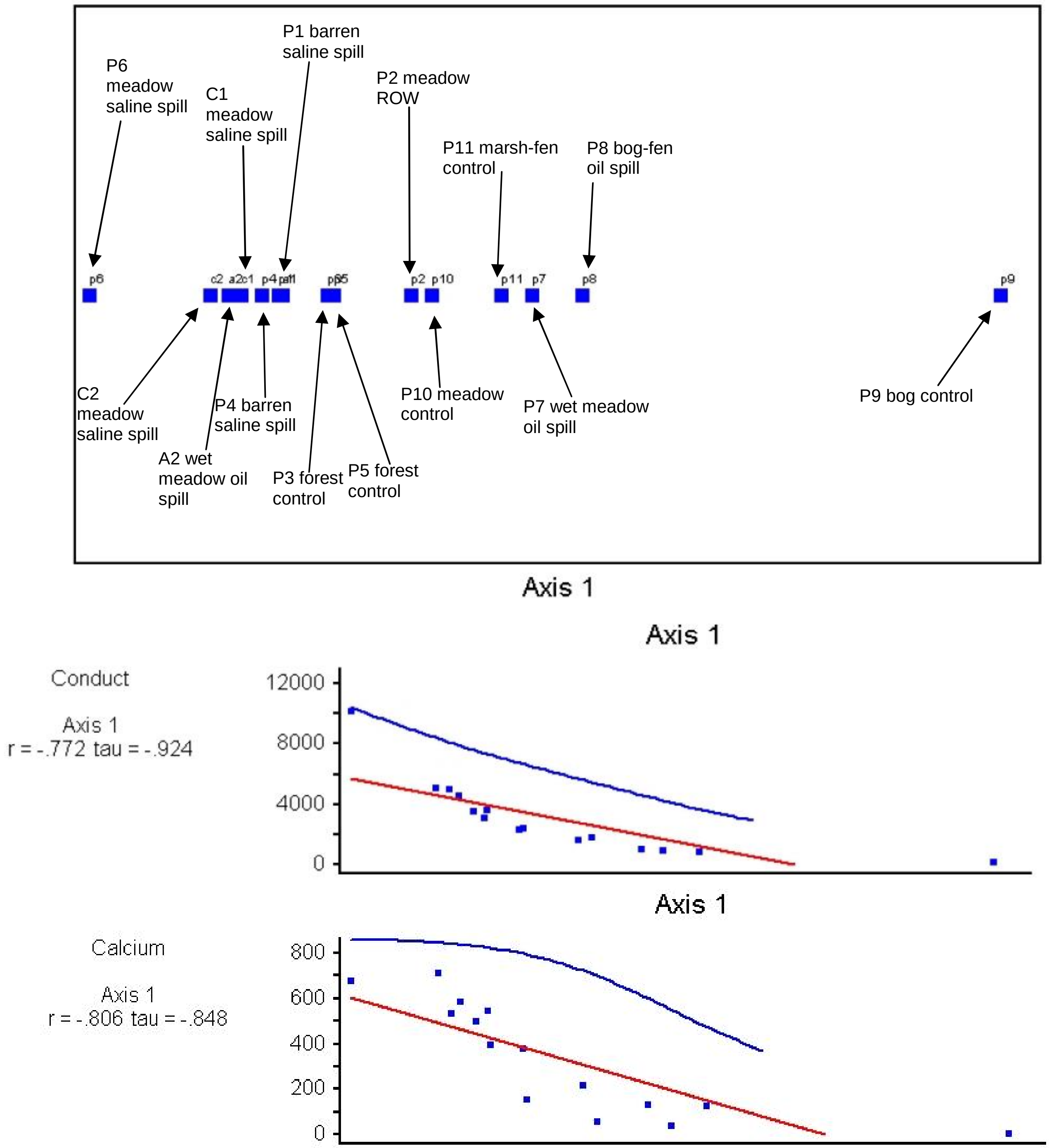
Pace-Spyglass: The differences in chemistry between the bog control and marsh-fen control plots are attributable to the dry, ombrotrophic conditions in the bog and the wet minerotrophic conditions in the marsh-fen.

Apache2: Although Apache did not provide soil information to this investigation and the boundaries of the saline spill were not divulged, the soils and vegetation data indicate that they were located within the spill footprint. A court Agreed Statement of Facts (Kallal 2016) concluded that “chlorides in the produced water were such that the vegetation in the area of the release would have been affected” (Kallal 2016).

Web 9.7. Stress in relation to dimensionality in the NMS ordination of 15 study sites in soil chemistry-space.[a]

	Stress in Real Data, 250 runs			Stress in Randomized Data, Monte Carlo test, 250 runs			
Axes	**Minimum**	**Mean**	**Maximum**	**Minimum**	**Mean**	**Maximum**	**p**
1	4.4	20.7	53.7	0	37.8	53.7	0.012

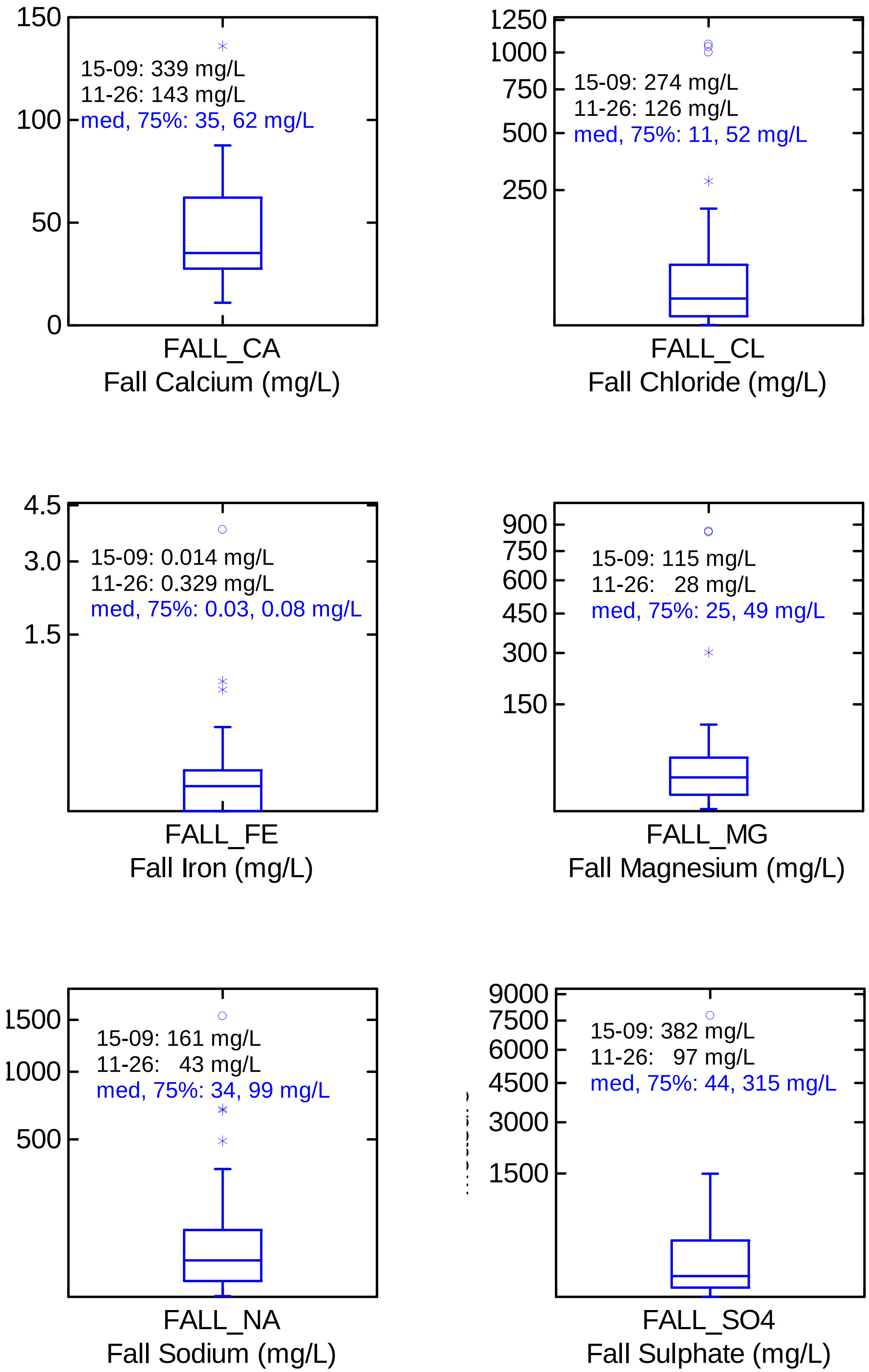
[a] Sorensen distance measure; random starting coordinates; no penalty for ties; 50 iterations of the final solution; 1-dimensional solution final instability = 0.00000



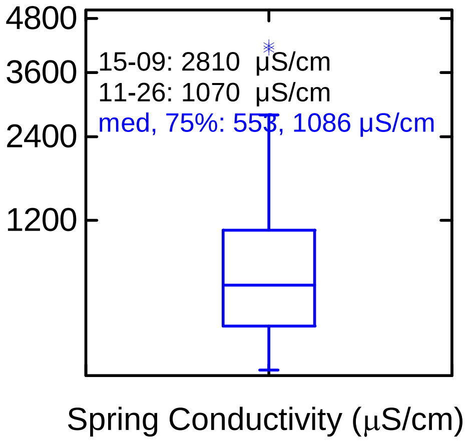
Web 9.8. NMS ordination 1-d solution of 15 study sites in soil chemistry-space.
The bottom two panels plot values of conductivity and calcium concentration in relation to study site position on the x-axis. Axes scaled to percent of maximum. See Web 9.7 for details.

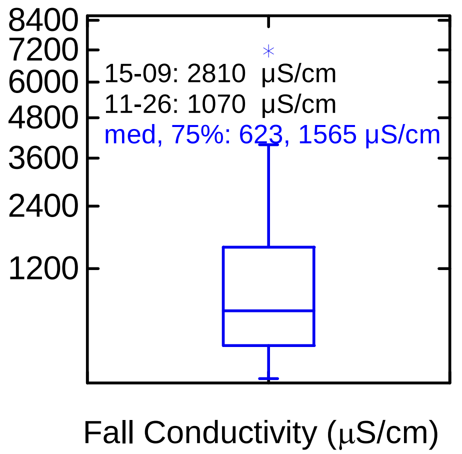
In order to visualize how the sites differ in soil salinity, they were ordinated on the basis of nine soil salinity attributes (conductivity, pH, chloride, calcium, magnesium, sodium, potassium, sulfate, and chloride:sulfate ratio). The Amber oil spill site A2 was also saline. Two other oil spill sites (Plot 7 wet meadow, Plot 8 mixed marsh) occupied the center of the ordination indicating intermediate to low levels of salinity. Two forest controls (Plots 3 and 5) lay to left of ordination center and relatively near their adjacent spill sites (Plots 1 and 4, respectively). The disturbed meadow ROW site (Plot 2) lay adjacent to the semi-natural meadow "control" (Plot 10), which was also located along a pipeline ROW. A bog control (Plot 9) with low conductivity, low pH, etc. lay on the extreme right. Concentrations of the soil attributes decreased from left to right. The saline spill sites were clustered on the left side of the ordination.

Web 9.9. Pond water quality.



Concentrations of selected water quality parameters at the Apache spill sites 15-09 and 11-26 in relation to the median, 75th percentile, and range of values observed in natural reference wetland ponds (n = 50 ponds; original data from Rooney et al. 2011). For all graphs except calcium, y-axis is power-transformed (power = 0.50) to better show high values. Boxes present the interquartile range; horizontal lines within the boxes are medians; error bars represent values 1.5 times the interquartile range; asterisks lie between 1.5 and 3 times the interquartile range; circles are outliers.





Web 9.9 continued—
Electrical conductivity at the Apache spill site ponds 15-09 and 11-26 in relation to median, 75th percentile, and range of spring and fall conductivity values observed in natural reference wetland ponds (n = 48 ponds for spring conductivity, n = 50 for fall conductivity; original data from Rooney et al. 2011). Y-axis is power-transformed (power = 0.5) to better show high values.

Web 9.10. Water quality in the excavated ponds at the two Apache saline spill sites compared to reference values.

	Units	Apache Spill (15-09)	Apache Spill 2 (11-26)	Natural Reference water bodies (median) or Canadian Water Quality Guidelines
pH	---	8.75	8.28	---
Conductivity	µS/cm	2810	1070	862[a], 623[b]
Alkalinity	$CaCO_3$ mg/L	49.2	114.3	210 [a]
Potassium	mg/L	8.2	5.7	17.4 [a]
Lithium	mg/L	0.17	0.06	irrigation water guideline 2.5 mg/L [c]
Magnesium	mg/L	114.5	28.3	34 [a], 25 [b]
Manganese	mg/L	0.003	0.442	esthetic objective for drinking water 0.05 mg/L; irrigation water guideline 0.2 mg/L [c]
Barium	mg/L	0.030	0.050	---
Copper	mg/L	0.053	0.024	aquatic life guideline 0.002-0.004 mg/L [c]
Selenium	mg/L	0.002	0.0	aquatic life guideline 0.001 mg/L [c]
Iron	mg/L	0.014	0.329	0.03 [a,b]
Molybdenum	mg/L	0.006	0.001	aquatic life guideline 0.073 mg/L [c]
Vanadium	mg/L	0.004	0.002	irrigation water guideline 0.1 mg/L [c]
Strontium	mg/L	1.30	0.50	---
Sodium	mg/L	161.1	42.7	54 [a], 34 [b]
Arsenic	mg/L	0.002	0.005	aquatic life guideline 0.005 mg/L [c]
Calcium	mg/L	339.0	143.2	37 [a], 35 [b]
Sulfur	mg/L	473.3	105.1	---
Chloride	mg/L	273.8	126.1	12.1 [a], 11 [b]
Bromide	mg/L	0.9	0.5	---
Sulfate	mg/L	382.3	96.7	101 [a], 44 [b]

[a] medians from Timoney (2015) from 39 reference sites
[b] medians from Rooney et al. (2011) from 50 reference sites
[c] guidelines from Environment Canada (2002)

Comments:

I placed the water quality in the Apache ponds in context by comparing values with water quality guidelines (Environment Canada 2002) and with values observed in natural wetland ponds (Web 9.9). For about one-half of the indicators, no Canadian water quality guidelines exist. I attempted, without success, to procure ancillary data held by industry or the regulator that would help to characterize the water quality at the two excavated ponds. Lacking those data (which exist), we have only a single water sample at each pond for a small number of analytes.

Reaction (pH) indicates alkaline conditions at pond 15-09 and weakly alkaline conditions at pond 11-26. Conductivity is elevated above normal at both ponds, strongly so at pond 15-09. Magnesium concentration is elevated at pond 15-09. Manganese is elevated at pond 11-26 relative to community drinking water and irrigation water. Copper is elevated at both ponds relative to the freshwater aquatic life guideline. Selenium is elevated at pond 15-09 relative to the freshwater aquatic life guideline. Iron at pond 11-26 is strongly-elevated above the median observed in natural ponds. Arsenic at pond 11-26 is equal to the freshwater aquatic life guideline. Calcium at pond 15-09 is strongly-elevated, and that at pond 11-26 elevated above the median calcium concentration observed in natural ponds. Chloride at ponds 15-09 and 11-26 are strongly-elevated above the median chloride concentration observed in natural ponds. Sodium at pond 15-09 is elevated, and that at pond 11-26 is slightly elevated above the median sodium concentration observed in natural ponds. Sulfate at pond 15-09 is strongly-elevated, and that at pond 11-26 is elevated above the median sulfate concentration observed in natural ponds.

Web 9.11. Notes on the Nuvista water chemistry results

A report of post-spill pond water samples assayed on 19 May 2016 by PGL Environmental Consultants was provided to me by the Dene Tha First Nation.

Metal concentrations were of concern for:
arsenic (maximum 37.7 µg/L, 7.5 times the freshwater aquatic life guideline)
barium (max 1410 µg/L, 1.4 times the maximum acceptable concentration (MAC) in drinking water)
chromium (max 87.8 µg/L, 1.6 times the MAC in drinking water)
copper (max 107 µg/L, 26 to 53 times the freshwater aquatic life guideline)
iron (max 90,100 µg/L, 300 times the freshwater aquatic life guideline)
lead (max 50.8 µg/L, 7-51 times the freshwater aquatic life guideline, and 5 times the MAC in drinking water),
manganese (max 1420 µg/L, 28 times the aesthetic objective for drinking water)
selenium (max 3.7 µg/L, 3.7 times the freshwater aquatic life guideline)
silver (max 0.91 µg/L, 9 times the freshwater aquatic life guideline)
uranium (max 25.6 µg/L, 1.4 times the interim MAC in drinking water)
vanadium (max 219 µg/L, 2.2 times the livestock water and irrigation water guidelines)
zinc (max 660 µg/L, 22 times the freshwater aquatic life guideline).

According to the Dene Tha, some contaminated materials were moved off-site and other materials were sent to High Level, Alberta. A wildlife fence was placed around the perimeter of the main post-spill excavation which measured 4430 m^2; there were also two smaller excavations of 270 m^2 and 135 m^2.

Without baseline data, it’s not possible to quantify the degree to which concentrations of the analytes have been elevated above background.

Web 10. Data on environment, soils, and vegetation for the four study regions

The following sections provide data tables and figures that document the physical and biological effects of fossil fuel industry activities in four study regions.

Web 10.1-10.8 report on northwestern Alberta.
Web 10.9-10.13 report on north-central and northeastern Alberta (Purdy data).
Web 10.14-10.22 report Canol Road, Northwest Territories (Kershaw et al. data).
Web 10.23-10.27 report on Rumsey Block, Alberta (Elsinger data).
Web 10.28. Thirty vascular plants whose abundance increases as a result of fossil fuel industry activities in northern Alberta.

Web 10.1 Spill effects and vegetation of the study sites in northwestern Alberta

Web 10.1.1. Summary of spill effects according to the AER compared to the field data.

Spill	AER		Fieldwork	
	Cleanup Date	**Wildlife/Livestock/ Habitat Impact?**	**Soil Impact?**	**Vegetation Impact?**
Plot 1, Barnwell saline spill	Not provided	"No affect"	Yes	Yes
Plot 4 15-09 Apache saline spill	Not provided	"No affect"	Yes	Yes
Plot 6, BP Zama saline spills	Uncertain	None found	Yes	Yes
Plot 7, Beaver Pond oil spill	No record	No record	None found	None found
Plot 8, Pace-Spyglass oil spill	12 September 2012	"No affect"	Yes	Yes
Site A, Amber oil spill and disturbance	Uncertain	None found	Yes	Yes
Site B, Old Man Creek oil spill	No record	No record	Unknown	Unknown
Site C, 11-26 Apache2 saline spill [a]	28 February 2015	"No affect" [a]	Yes	Yes
Nuvista saline and oil spill	Not provided	"No affect"	Yes, soil was removed	Unknown

[a] Although I requested in the FOIP, the AER declined to provide information on this spill. There were effects on habitat and wildlife because Apache pled guilty to causing detrimental effects (Kallal 2016) and the case is closed, yet the FIS database indicates "No affect"

Comments:
I observed residual contamination, soil impairment, shifts in vegetation species composition, and suppression of native plant species richness at the industrially-disturbed sites. These results differed from the regulator's data, which reported completion of cleanup operations and no effects on habitat or wildlife.

Web 10.1.2 Vegetation of the study sites in northwestern Alberta.

Site	Vegetation	Total Plant Cover %
Plot 1 (saline spill)	herb barren [a]	1
Plot 2 (disturbed ROW)	shrub/common horsetail – timothy weedy meadow	72
Plot 3 (control)	white spruce – paper birch/prickly rose/feather moss forest	118
Plot 4 (saline spill)	foxtail barley barren [a]	5
Plot 5 (control)	black spruce – aspen/prickly rose forest	71
Plot 6 (saline spill)	foxtail barley – Nuttall's salt-meadow grass dry weedy meadow	19
Plot 7 (oil spill)	bluejoint reedgrass – water sedge wet meadow	41
Plot 8 (oil spill)	water sedge – common cattail/marsh horsetail – rush/*Leptobryum pyriforme* mixed marsh	106
Plot 9 (control)	black spruce/Labrador tea/reindeer lichen bog forest	183
Plot 10 ("control")	fowl bluegrass/dandelion weedy meadow	83
Plot 11 (control)	dwarf birch/common cattail – water sedge/common bladderwort/*Sanionia uncincata* marsh-fen transition	105
Site A1 (disturbed battery)	foxtail barley – alsike clover weedy dry meadow	84
Site A2 (oil spill)	alsike clover – common horsetail – foxtail barley weedy wet meadow	81
Site C (saline spill)	common horsetail – sweet-clover – foxtail barley weedy mixed meadow	~50 (variable)

[a] "Barren" is a plant community with total plant cover ≤ 5%.

Web 10.2. Plant taxa found at the northwestern Alberta study sites, sorted by scientific name.

Common names are from the Alberta Conservation Information Management System (ACIMS 2013). Taxa are categorized as to native (n) or exotic (e), weedy disturbance indicators (yes, no), and by plant group (v = vascular plants, b = bryophytes, l = lichens).

Scientific Name	Common Name from ACIMS	native or exotic	weedy (yes, no)	group (v, b, l)
Achillea millefolium	common yarrow	n	n	v
Achillea sibirica	many-flowered yarrow	n	y	v
Agrostis scabra	rough hair grass (tickle grass)	n	y	v
Alopecurus aequalis	short-awned foxtail	n	y	v
Alopecurus arundinaceus	creeping foxtail	e	n	v
Amblystegium serpens	moss	n	n	b
Artemisia biennis	biennial sagewort	n	y	v
Atriplex subspicata	spearscale saltbush	n	y	v
Aulacomnium palustre	tufted moss	n	n	b
Barbula convoluta	convolute screw moss	n	y	b
Beckmannia syzigachne	slough grass	n	y	v
Betula neoalaskana	Alaska birch	n	n	v
Betula papyrifera	white birch	n	n	v
Betula pumila	dwarf birch	n	n	v
Brachythecium salebrosum	moss	n	n	b
Brachythecium turgidum	moss	n	n	b
Bromus ciliatus	fringed brome	n	n	v
Bromus inermis	smooth brome	e	y	v
Bryoerythrophyllum recurvirostre	red leaf moss	n	n	l
Bryoria fuscescens	old man's beard	n	n	b
Bryum	moss	n	n	b
Bryum caespiticium	moss	n	y	b
Bryum pseudotriquetrum	moss	n	n	b
Calamagrostis canadensis	bluejoint	n	y	v
Calamagrostis inexpansa	northern reed grass	n	n	v
Caltha natans	floating marsh-marigold	n	n	v
Campylium chrysophyllum	goldenleaf campylium moss	n	n	b
Campylium hispidulum	campylium moss	n	n	b
Campylium stellatum	yellow starry fen moss	n	n	b
Carex aenea	silvery-flowered sedge	n	n	v
Carex aquatilis	water sedge	n	n	v
Carex canescens	hoary sedge	n	n	v
Carex diandra	two-stamened sedge	n	n	v
Carex disperma	two-seeded sedge	n	n	v
Catinaria atropurpurea	lichen	n	n	l
Cephalozia	liverwort	n	n	b
Cephalozia bicuspidata	liverwort	n	n	b
Ceratodon purpureus	purple horn-toothed moss	n	y	b
Chamaedaphne calyculata	leatherleaf	n	n	v
Chenopodium album	lamb's-quarters	e	y	v

Cicuta virosa	narrow-leaved water-hemlock	n	n	v
Cladonia	reindeer lichen	n	n	l
Cladonia chlorophaea	mealy pixie-cup lichen	n	n	l
Cladonia cornuta	bighorn cladonia	n	n	l
Cladonia deformis	lesser sulphur-cap lichen	n	n	l
Cladonia gracilis	smooth cladonia	n	n	l
Cladonia macilenta var. *bacillaris*	cup lichen	n	n	l
Cladonia mitis	reindeer lichen	n	n	l
Cladonia multiformis	sieve lichen	n	n	l
Cladonia pleurota	red-fruited pixie-cup lichen	n	n	l
Cladonia scabriuscula	mealy forked cladonia	n	n	l
Cladonia sulphurina	greater sulphur-cup	n	n	l
Cornus canadensis	bunchberry	n	n	v
Cornus stolonifera	red-osier dogwood	n	n	v
Dicranum fragilifolium	cushion moss	n	n	b
Dicranum fuscescens	fuscous moss	n	n	b
Dicranum polysetum	wavy dicranum moss	n	n	b
Drepanocladus aduncus	brown moss	n	n	b
Elymus trachycaulus	slender wheatgrass	n	y	v
Epilobium angustifolium	common fireweed	n	y	v
Epilobium palustre	marsh willowherb	n	n	v
Equisetum arvense	common horsetail	n	y	v
Equisetum palustre	marsh horsetail	n	n	v
Equisetum sylvaticum	woodland horsetail	n	n	v
Eurhynchium pulchellum	moss	n	n	b
Evernia mesomorpha	boreal oakmoss lichen	n	n	l
Festuca rubra	red fescue (see notes in Web 10.3)	e	y	v
Festuca trachyphylla	hard fescue	e	n	v
Flavocetraria nivalis	crinkled snow lichen	n	n	l
forb	forb	n	n	v
Fragaria virginiana	wild strawberry	n	n	v
Funaria hygrometrica	cord moss	n	y	b
Galium labradoricum	Labrador bedstraw	n	n	v
Geocaulon lividum	northern bastard toadflax	n	n	v
grass	grass	n	n	v
Herzogiella turfacea	moss	n	n	b
Hieracium umbellatum	narrow-leaved hawkweed	n	y	v
Hippuris vulgaris	common mare's-tail	n	n	v
Hordeum jubatum	foxtail barley	n	y	v
Hylocomium splendens	stair-step moss	n	n	b
Hypnum pratense	moss	n	n	b
Hypogymnia physodes	hooded tube lichen	n	n	l
Jamesoniella autumnalis	liverwort	n	n	b
Juncus alpinoarticulatus	alpine rush	n	n	v
Juncus bufonius	toad rush	n	y	v
Ledum groenlandicum	common Labrador tea	n	n	v

Lemna minor	common duckweed	n	n	v
Lemna trisulca	ivy-leaved duckweed	n	n	v
Leptobryum pyriforme	moss	n	y	b
Linnaea borealis	twinflower	n	n	v
Lophozia	liverwort	n	n	b
Matricaria matricarioides	pineappleweed	e	y	v
Matricaria perforata	scentless chamomile	e	y	v
Medicago sativa	alfalfa	e	n	v
Melanohalea elegantula	elegant camouflage lichen	n	n	l
Melanohalea exasperatula	lustrous camouflage lichen	n	n	l
Melanohalea septentrionalis	northern camouflage lichen	n	n	l
Melilotus alba	white sweet-clover	e	y	v
Melilotus officinalis	yellow sweet-clover	e	y	v
Mitella nuda	bishop's-cap	n	n	v
Moneses uniflora	one-flowered wintergreen	n	n	v
Mylia anomala	liverwort	n	n	b
Orthilia secunda	one-sided wintergreen	n	n	v
Oxycoccus microcarpus	small bog cranberry	n	n	v
Parmelia sulcata	hammered shield lichen	n	n	l
Parnassia palustris	northern grass-of-parnassus	n	n	v
Peltigera aphthosa	studded leather lichen	n	n	l
Peltigera canina	dog lichen	n	n	l
Peltigera malacea	veinless pelt lichen	n	n	l
Phalaris arundinacea	reed canary grass	n	y	v
Phleum pratense	timothy	e	y	v
Picea glauca	white spruce	n	n	v
Picea mariana	black spruce	n	n	v
Plagiomnium cuspidatum	moss	n	n	b
Plagiomnium ellipticum	moss	n	n	b
Plantago major	common plantain	e	y	v
Plantanthera	bog orchid	n	n	v
Pleurozium schreberi	Schreber's moss	n	n	b
Poa palustris	fowl bluegrass	n	y	v
Pohlia nutans	copper wire moss	n	y	b
Polygonum monspeliense	knotweed	e	y	v
Polytrichum juniperinum	juniper hair-cap moss	n	n	b
Populus balsamifera	balsam poplar	n	n	v
Populus tremuloides	aspen	n	y	v
Potentilla norvegica	rough cinquefoil	n	y	v
Potentilla palustris	marsh cinquefoil	n	n	v
Ptilidium ciliare	liverwort	n	n	b
Puccinellia nuttalliana	Nuttall's salt-meadow grass	n	y	v
Pylaisiella polyantha	moss	n	n	b
Ramalina dilacerata	punctured ramalina	n	n	l
Ranunculus macounii	Macoun's buttercup	n	n	v
Rhinanthus minor	yellow rattle	n	y	v

Rhizomnium pseudopunctatum	moss	n	n	b
Ribes hudsonianum	northern black currant	n	n	v
Ribes oxyacanthoides	northern gooseberry	n	n	v
Rosa acicularis	prickly rose	n	n	v
Rubus arcticus	dwarf raspberry	n	n	v
Rubus chamaemorus	cloudberry	n	n	v
Rubus idaeus	wild red raspberry	n	n	v
Rubus pubescens	dewberry	n	n	v
Rumex triangulivalvis	narrow-leaved dock	n	n	v
Salix arbusculoides	shrubby willow	n	n	v
Salix athabascensis	Athabasca willow	n	n	v
Salix bebbiana	beaked willow	n	n	v
Salix discolor	pussy willow	n	n	v
Salix pedicellaris	bog willow	n	n	v
Sanionia uncinata	brown moss	n	n	b
Scutellaria galericulata	marsh skullcap	n	n	v
Solidago	goldenrod	n	n	v
Sonchus uliginosus	smooth perennial sow-thistle	e	y	v
Sphagnum fuscum	rusty peat moss	n	n	b
Sphenopholis intermedia	slender wedge grass	n	n	v
Splachnum ampullaceum	flagon-fruited splachnum moss	n	n	b
Symphyotrichum ciliolatum	Lindley's aster	n	n	v
Taraxacum officinale	common dandelion	e	y	v
Tetraphis pellucida	moss	n	n	b
Tomentypnum nitens	golden moss	n	n	b
Trapeliopsis granulosa	granular mottled-disk lichen	n	n	l
Trifolium hybridum	alsike clover	e	y	v
Trifolium pratense	red clover	e	y	v
Tuckermannopsis sepincola	chestnut wrinkle-lichen	n	n	l
Typha latifolia	common cattail	n	y	v
Usnea filipendula	fishbone beard lichen	n	n	l
Usnea scabrata	straw beard lichen	n	n	l
Utricularia vulgaris	common bladderwort	n	n	v
Vaccinium vitis-idaea	bog cranberry	n	n	v
Viburnum edule	low-bush cranberry	n	n	v
Vicia americana	wild vetch	n	n	v
Viola	violet	n	n	v
Vulpicida pinastri	wrinkle lichen	n	n	l

Web 10.3. Comments on the plant species observed in northwestern Alberta

One-hundred and seventy taxa were documented from 14 field sites; this is relatively few plant taxa. Reasons for the relatively small number of taxa include: (1) taxa observed outside plot boundaries were excluded; (2) the brevity of the fieldwork (multiple observations over various seasons and years are required to document a complete flora); (3) the occurrence of small, stressed, and unidentifiable sprigs and seedlings; and (4) focus on industrially-disturbed sites and natural sites immediately adjacent to the disturbances, which lowered the chances of finding native species. There were 123 species observed at the five natural plots and 75 species observed at the nine industrial plots. The probable number of species based on bootstrapping was estimated at 259 species for all sites, 193 species for natural sites, and 116 species for industrial sites (first-order jackknife). Industrial sites supported far fewer species than did natural sites.

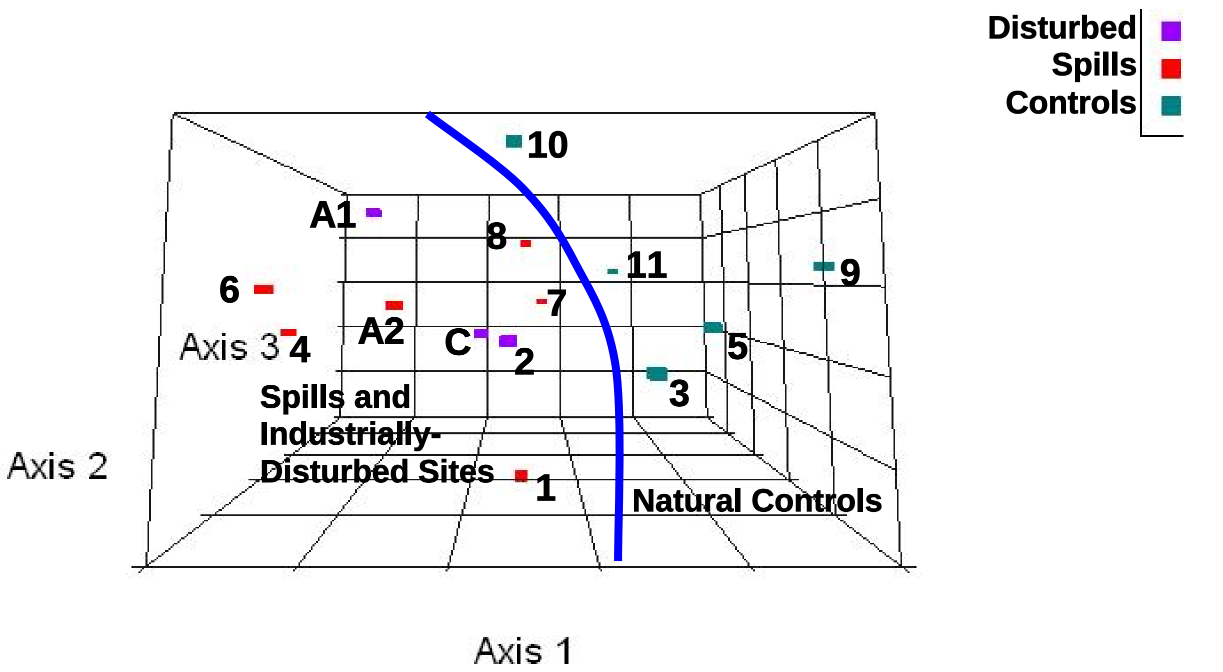
Species observed outside plot boundaries, or present during the June plot establishment but absent during July sampling, were excluded from the 170 taxa, as follows: Plot 1: *Chenopodium capitatum;* Plot 2: *Polemonium acutiflorum;* Plot 4: *Erysimum cheiranthoides* (also, possible *Aster* seedlings observed in June were absent in July); Plot 6: *Geranium bicknellii, Dracocephalum parviflorum*; *Bryum argenteum* and *Weissia controversa, Campylium hispidulum, Pohlia nutans*, and *Bryum caespiticium* documented from Plot 6 in the June 2016 visit had been extirpated from the plot by the time of the July 2016 visit due to an incursion of heavy machinery; Plot 8: *Sium suave;* Site C (Apache saline spill 11-26): species excluded from the plant composition list because they were planted by a reclamation crew included putative *Larix laricina, Picea mariana, Pinus contorta,* and "*Salix*". Both the *Larix* and the *Picea* were morphologically dissimilar to their putative species. Although I requested confirmation of the species planted on behalf of Apache, I received no information. Field observations and photographs by Dene Tha First Nation members in September 2018 demonstrated that plant species intentionally introduced at the other Apache saline spill (15-09, near Plot 4) were struggling to survive in the salt-contaminated soil.

In most cases, the classification of vascular plant taxa into native vs. exotic elements was straightforward. There were, however, some exceptions. *Hordeum jubatum* (foxtail barley) is classified as a native plant. The taxon may, however, be composed of native and introduced elements and can be found across a wide range of natural and anthropogenic sites that range in salinity and level of disturbance. In many areas, foxtail barley is seen as a "troublesome" weed indicative of soil and/or site degradation or overgrazing.

Elymus trachycaulus (slender wheatgrass) is problematic as a "native" species in this dataset. Slender wheatgrass is a common native plant species in Alberta that is found across a range of dry to mesic vegetation types ranging from grassland to shrubland and open forests. However, slender wheatgrass has been modified through selective breeding programs and is widely planted in reclamation. In form, the agronomic varieties of slender wheatgrass are larger and more robust than are the native elements. Floristic keys, unfortunately, don't differentiate the native varieties from cultivars. All six slender wheatgrass occurrences in this dataset were probably introduced by human agency. The word "probably" is necessary because my inquiries to the energy companies and their contractors as to the use of *Elymus trachycaulus* and other reclamation species were not answered.

Festuca rubra (red fescue) is yet another example of a problematic "native" element. It's a circumboreal species composed of native and introduced elements. Its single occurrence likely resulted from human agency. The Alberta Native Plant Council classifies red fescue as an invasive agronomic species.

One other exotic grass species merits mention. Hard fescue (*Festuca trachyphylla*) was found on the disturbed pipeline corridor at the Zama saline spill site. This species is sometimes used in pipeline corridor reclamation. Its occurrence highlights one of the difficulties of documenting species in disturbed areas. We find introduced species and cultivars that are absent from plant keys. We can ask the company responsible for the site what was planted, if the company still exists, but it's unlikely to know and unlikely to answer (see Web 14.3).



Web 10.4. NMS 3-d ordination of 14 study sites in species-space.
Spill sites are colored red, industrially-disturbed sites are colored purple, and natural control sites are colored green. The compositional break between natural vegetation and the vegetation of spills and industrially-disturbed sites, denoted by the blue line, demonstrates that the vegetation created by the fossil fuel industry differs from natural vegetation. Axes scaled to percent of minimum and maximum.

Comments:
The fact that three ordination axes were significant but that soil attributes were correlated primarily with axis 1 indicates that other factors play a role in determining vegetation composition. Other factors known to help explain vegetation composition include moisture regime, time since disturbance, disturbance type and intensity, landform, and animal effects such as browsing, grazing, and trampling.

Web 10.5. Stress in relation to dimensionality in the NMS ordination of 14 study sites in species-space. (170 plant taxa) [a]

Axes	Stress in Real Data, 250 runs Minimum	Mean	Maximum	Stress in Randomized Data, Monte Carlo test, 250 runs Minimum	Mean	Maximum	p
1	22.8	30.3	52.6	30.4	46.9	53.4	0.004
2	12.3	13.5	24.7	17.2	24.0	35.0	0.004
3	5.7	6.8	12.1	9.9	14.3	25.0	0.004
4	3.5	3.8	8.7	5.3	8.9	19.0	0.004
5	1.6	2.2	6.5	0.4	5.8	15.5	0.008
6	0.1	0.5	3.9	0.1	3.5	8.2	0.004

[a] Sorensen distance measure; random starting coordinates; no penalty for ties; 41 iterations of the final solution; 3-dimensional solution; final instability = 0.00000

Web 10.6. Correlations of species abundance with the three NMS plot ordination axes in species-space.
Pearson correlations significant at α ≤ 0.05 are bolded. Axis 1 is a disturbance gradient; axis 2 is a moisture gradient; axis 3 is a complex disturbance gradient.

	Correlations with Axes	**1**	**2**	**3**
n plots	**Species (ACIMS common name if unequivocal one exists)**	**r**	**r**	**r**
4	*Bryoria fuscescens*	**-0.552**	0.147	0.121
2	*Bryum caespiticium*	-0.02	-0.106	**0.583**
4	water sedge	-0.238	**-0.861**	0.195
2	leatherleaf	**-0.593**	-0.219	0.173
2	*Cladonia macilenta* var. *bacillaris*	**-0.655**	0.245	0.03
2	*Cladonia mitis*	**-0.55**	0.147	0.123
4	*Evernia mesomorpha* (boreal oakmoss lichen)	**-0.771**	0.153	-0.012
4	*Hypogymnia physodes* (hooded tube lichen)	**-0.559**	0.149	0.121
2	Labrador tea	**-0.554**	0.153	0.119
4	*Parmelia sulcata* (shield lichen)	**-0.771**	0.153	-0.012
2	black spruce	**-0.546**	0.236	-0.027
5	fowl bluegrass	0.002	0.202	**0.544**
2	*Ptilidium ciliare*	**-0.556**	0.388	-0.04
2	Lindley's aster	-0.004	0.165	**0.568**
2	common dandelion	0.001	0.2	**0.541**
3	*Tuckermannopsis sepincola* (chestnut wrinkle lichen)	**-0.635**	0.051	0.038
3	common cattail	-0.248	**-0.571**	0.221
2	*Usnea scabrata* (straw beard lichen)	**-0.577**	0.103	0.133

Web 10.7. Indicator species with significant p-values by group (disturbed, undisturbed).
Sorted by indicator significance p-value.

Species (ACIMS common name if unequivocal one exists)	Group	Observed Indicator Value	Random Mean	Random s.d.	p
white sweet-clover	disturbed	99.5	37.3	16.3	0.004
yellow sweet-clover	disturbed	96.9	36.6	16.3	0.006
slender wheatgrass	disturbed	69.6	34.2	13.0	0.024
rough hair-grass (tickle grass)	disturbed	63.2	31.1	15.0	0.044
common yarrow	disturbed	63.2	29.2	13.5	0.050
Bryoria fuscescens	control	80	38.9	15.7	0.012
Hypogymnia physodes (hooded tube lichen)	control	80	38.3	15.8	0.012
Evernia mesomorpha (boreal oakmoss lichen)	control	80	28.2	14.9	0.018
Parmelia sulcata (shield lichen)	control	80	28.2	14.9	0.018
Sanionia uncinata	control	80	38.2	16.4	0.024
Tuckermannopsis sepincola (chestnut wrinkle lichen)	control	60	26.8	13.6	0.028
Cladonia cornuta (bighorn lichen)	control	60	25.7	13.6	0.030
Ramalina dilacerata (punctured ramalina)	control	60	26.7	14.2	0.036
Vulpicida pinastri	control	60	26.7	14.2	0.036

Web 10.7.1 Plant species indicators at industry disturbances in northwestern Alberta.
See Web 10.2 for species names.

Indicator Type	Species
Indicators of Disturbance	white sweet-clover, yellow sweet-clover, slender wheatgrass, rough hair (tickle) grass, common yarrow
Tolerators, Exotic Vascular Plants	alsike clover, smooth brome, common dandelion, smooth perennial sow-thistle, creeping foxtail, common plantain, pineapple weed, scentless chamomile, knotweed, red clover, red fescue, timothy
Tolerators, Native Vascular Plants	foxtail barley, common horsetail, marsh horsetail, fowl bluegrass, water sedge, fireweed, Nuttall's salt-meadow grass (Figure 10.3), common vetch, common cattail, many-flowered yarrow, short-awned foxtail, slough grass, narrow-leaved hawkweed, alpine rush, toad rush, aspen, yellow rattle, biennial sagewort, spearscale saltbush, reed canary grass
Tolerators, Bryophytes	*Leptobryum pyriforme, Barbula convoluta, Bryum caespiticium, Funaria hygrometrica, Pohlia nutans, Ceratodon purpureus*
Tolerators, Lichens	none found

Web 10.8. Pearson correlations of soil attributes with the three NMS ordination axes of plots in species-space. Correlations significant at $\alpha \leq 0.05$ are bolded.[a]

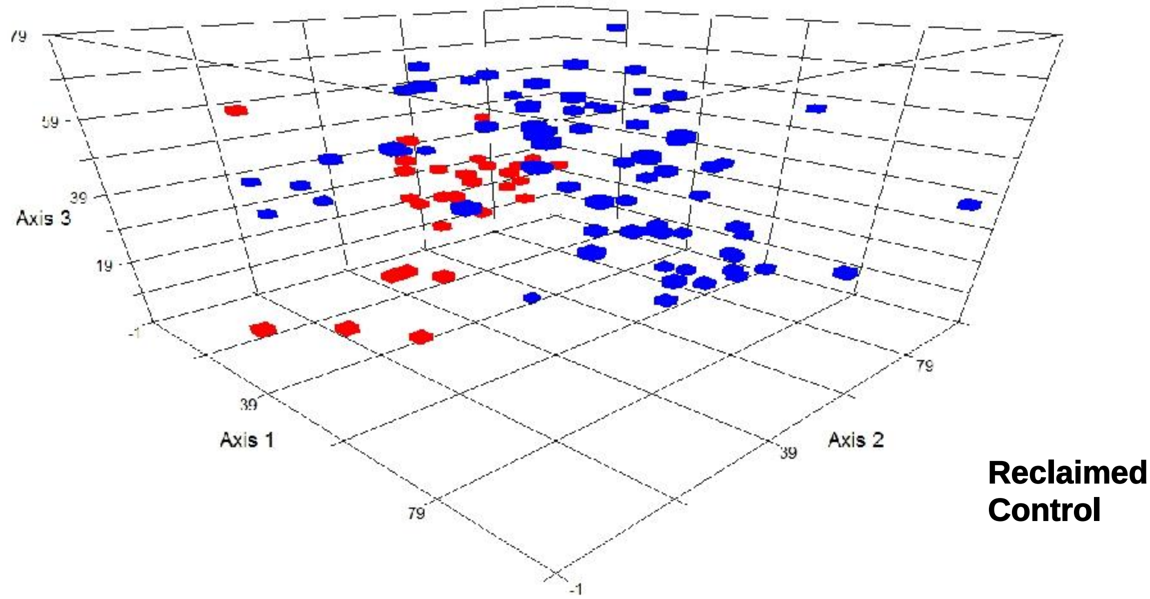
Correlations with Axes Attribute	1 r	2 r	3 r
Chloride	-0.504	-0.091	-0.105
Conductivity	**-0.701**	-0.026	0.18
pH	-0.519	-0.232	0.355
Calcium	**-0.723**	0.027	0.528
Magnesium	**-0.699**	0.196	0.43
Sodium	-0.485	-0.071	-0.062
Potassium	**-0.661**	0.052	0.168
Sulfate	**-0.665**	0.108	0.48
Cl:SO4 ratio	0.008	-0.350	-0.315
F2	-0.238	-0.083	0.115
F3	-0.244	-0.013	0.147
F4	-0.247	-0.009	0.148
F1	0.059	-0.377	-0.185
Benzene	0.059	-0.377	-0.185
Toluene	0.216	**-0.568**	-0.021
Ethylbenzene	0.041	-0.379	-0.175
m- and p-Xylene	0.059	-0.377	-0.185
o-Xylene	0.014	-0.378	-0.158

[a] NMS found a 3-d solution with final stress of 3.9 and final instability of 0.00000 after 91 iterations; all three axes were significant at $p = 0.004$.

Web 10.9. Stress in relation to dimensionality in the NMS ordination of 107 study sites in species-space (165 plant taxa, north-central and northeastern Alberta, Purdy data).[a]

	Stress in Real Data, 250 runs			Stress in Randomized Data, Monte Carlo test, 250 runs			
Axes	**Minimum**	**Mean**	**Maximum**	**Minimum**	**Mean**	**Maximum**	**p**
1	31.7	33.0	43.5	42.2	50.5	53.3	0.004
2	20.0	21.3	24.0	31.9	33.7	35.6	0.004
3	14.6	15.0	16.7	24.0	25.4	26.3	0.004

[a] Sorensen distance measure; random starting coordinates; no penalty for ties; 86 iterations of the final solution; 3-dimensional solution; final instability = 0.00000



Web 10.10. NMS ordination of 107 plots in species-space for northeastern and north-central Alberta. Natural reference control plots in blue, reclaimed plots in red. Note the clear difference in plant species composition that exists between natural sites and reclaimed sites. See also Purdy et al. (2005).

Web 10.11. Pearson correlations of soil attributes with the three NMS plot ordination axes in species-space (north-central and northeastern Alberta).

Correlations significant at α ≤ 0.001 are bolded. Only those attributes correlated significantly with one or more axes are listed; Purdy data, 165 taxa in 107 plots, 75 natural control and 32 reclaimed sites.

Correlations with axes	1	2	3
Attribute	r	r	r
Calcium at 10 cm	**0.479**	-0.24	0.151
Potassium at 10 cm	**0.342**	**-0.338**	-0.267
Sodium at 10 cm	**0.558**	-0.276	0.227
SAR at 10 cm	**0.586**	-0.261	0.162
Chloride at 10 cm	**0.537**	-0.248	0.241
Sulphate at 10 cm	0.319	**-0.498**	0.182
Electrical Conductivity at 10 cm	**0.584**	-0.3	0.215
Calcium at 80 cm	**0.338**	-0.144	0.139
Potassium at 80 cm	**0.401**	-0.305	-0.223
Sodium at 80 cm	**0.536**	-0.183	0.089
SAR at 80 cm	**0.605**	-0.167	-0.023
Chloride at 80 cm	**0.475**	-0.155	0.072
Electrical Conductivity at 80 cm	**0.538**	-0.142	0.057

Web 10.12. Indicator species of the treatments, north-central and northeastern Alberta.
Sorted by indicator significance p-value then by indicator value.

Species (ACIMS common name)	Group	Observed Indicator Value	Random Mean	s.d.	p
water sedge	reclaimed	66.6	17.9	3.74	0.0001
small bottle sedge	reclaimed	43.2	10.9	3.31	0.0001
bluejoint reedgrass	reclaimed	41.8	17.8	3.94	0.0001
Pumpelly brome	reclaimed	28.1	7.2	2.54	0.0001
bird's-foot trefoil	reclaimed	28.1	7.4	2.72	0.0001
common cattail	reclaimed	40.5	16	4.01	0.0002
shining willow	reclaimed	29.2	10.2	3.16	0.0002
meadow horsetail	reclaimed	21.9	6.1	2.38	0.0003
white sweet-clover	reclaimed	31.7	12.2	3.58	0.0004
fireweed	reclaimed	37.8	16.8	3.85	0.0005
bog willow	reclaimed	18.8	6.1	2.26	0.0005
yellow sweet-clover	reclaimed	25.9	11.1	3.47	0.0020
sandbar willow	reclaimed	15.4	5.8	2.25	0.0028
swamp horsetail	reclaimed	17.2	7.2	2.59	0.0041
slough grass	reclaimed	16.6	7.3	2.63	0.0050
pale persicaria	reclaimed	15.2	6.1	2.42	0.0059
common mare's-tail	reclaimed	12.5	4	1.86	0.0062
tufted loosestrife	reclaimed	14.3	5.6	2.26	0.0073
marsh cinquefoil	reclaimed	12.5	4	1.92	0.0074
fowl bluegrass	reclaimed	31.3	19	3.82	0.0101
western dock	reclaimed	23.6	13.7	3.61	0.0155
velvet-fruited willow	reclaimed	11.6	6.1	2.37	0.0206
rough cinquefoil	reclaimed	12.4	6.5	2.39	0.0234
hoary willow	reclaimed	9.4	3.5	1.53	0.0252
water smartweed	reclaimed	9.4	3.3	1.72	0.0264
marsh grass-of-parnassus	reclaimed	9.4	3.5	1.57	0.0272
western willow aster	control	38.7	17.9	3.71	0.0003
slender wheatgrass	control	33.3	15.9	3.52	0.0007
Nuttall's salt-meadow grass	control	38.7	18.4	4.06	0.0009
tufted white prairie aster	control	30.7	14.8	3.47	0.0016
baltic rush	control	32	15.6	3.72	0.0021
sea milkwort	control	25.3	13.1	3.53	0.0056
red goosefoot	control	25.3	13.1	3.53	0.0064
silverweed	control	24	12.5	3.42	0.0074
seaside arrow-grass	control	29	16.6	3.76	0.0102
common yarrow	control	27.3	15.9	3.62	0.0136
western sea-blite	control	18.7	10	2.91	0.0185
awned sedge	control	18.7	10.7	3.34	0.0262
saline plantain	control	17.3	9.9	3.15	0.0278
many-flowed yarrow	control	14.7	8.3	2.7	0.0302
prickly rose	control	19	11.4	3.34	0.0413

Canada thistle	control	14.7	8.4	2.76	0.0482
salt grass	control	14.7	8.6	2.89	0.0522
red clover	control	13.3	7.8	2.66	0.0522
salt-marsh sand spurry	control	14.7	8.6	2.87	0.0524

Comments:
Indicator species can be regionally specific. For example, although slender wheatgrass indicated industrially-disturbed sites in northwestern Alberta, it indicated natural sites in northeastern and north-central Alberta. Post-disturbance intentional seeding may account for the prevalence of this grass in disturbed sites in northwestern Alberta whereas in northeastern Alberta, its occurrences were probably unaided by human agency. Similarly, Canada thistle indicated disturbed natural meadows influenced by cattle grazing in northeastern and north-central Alberta, not industrially-disturbed sites as it can elsewhere. Disturbances such as spills, topsoil stripping and excavating, soil compaction, intentional seeding, and cattle grazing can all exert long-term effects on ecosystems. Therefore, whenever we identify and interpret the meaning of indicator species, we need to know site histories.

Web 10.12.1. Species richness and family assemblages for the north-central, northeastern, and northwestern Alberta vegetation data

I used bootstrapping to estimate the total vascular plant species richness in the natural saline control and industrially-reclaimed vegetation. The input data used 107 plots composed of 165 species. There were 75 natural control plots with 155 observed species and 32 industrially-reclaimed plots with 81 observed species. Total vascular plant richness was estimated to be 161 species in naturally saline controls and 100 species in industrially-reclaimed vegetation (first-order jacknife estimates). The bootstrapped total vascular plant richness for all plots was 165, equal to the number of observed species, indicating that the researchers did an excellent job of documenting the flora.

Industrial reclamation significantly lowered vascular plant species richness. It also lowered the total number of plant families. Overall, 35 plant families were observed. At industrially-reclaimed sites, 26 families were observed; at naturally saline sites, 34 families were observed.

In northwestern Alberta's natural communities, the grass, composite, and bean families comprised only 5 %, 4 %, and 0 % of the total flora, whereas in industrially disturbed vegetation the grass, composite, and bean families comprised 24 %, 16 %, and 12 % of the total flora. By "total flora" I mean the flora including vascular plants, mosses, liverworts, and lichens.

In north-central and northeastern Alberta's naturally saline communities, the grass, composite, and bean families comprised 18 %, 15 %, and 4.5 % of the vascular flora whereas in industrially reclaimed sites, the grass, composite, and bean families comprised 14 %, 9 %, and 4.9 % of the vascular flora.

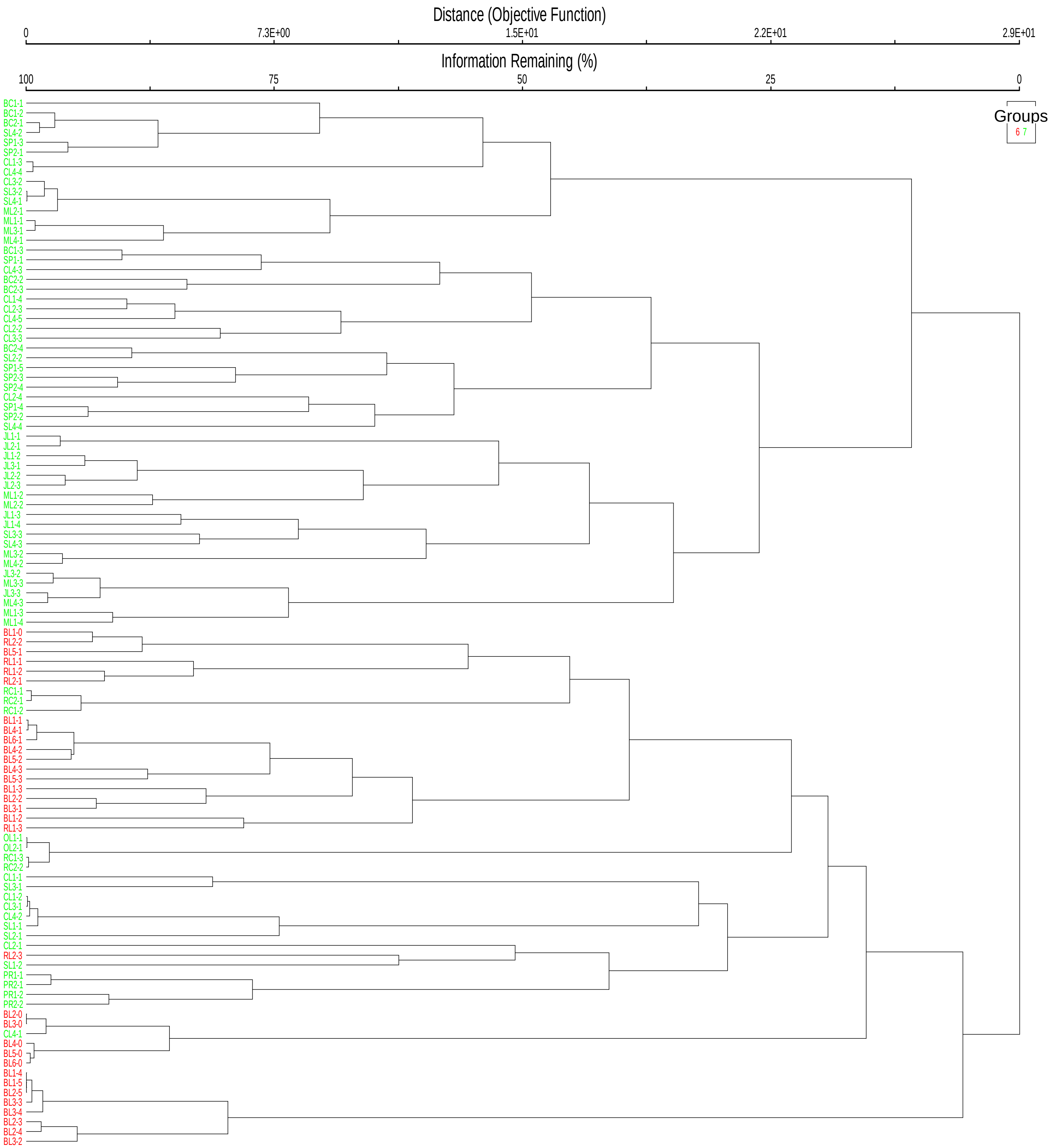
In the southeastern United States, one-half of the flowering plant species that are potentially tolerant of salts and hydrocarbons are grasses, followed by species from the composite (12 %) and goosefoot families (7 %) (Vavrek et al. 2004).

Although various studies have observed that industrial disturbance causes an increased proportion of species from the grass, composite, goosefoot, and other families, all rules have exceptions. In the case of naturally saline plant communities in north-central and northwestern Alberta, the effects of industrial site reclamation reverse this pattern. The reason appears to be straightforward. Naturally saline plant communities have by their nature a high proportion of halophytes and therefore the grass, composite, and goosefoot families are well-represented. When these communities are disturbed, many native halophytes are extirpated because they are not adapted to industrial disturbance (examples: *Atriplex, Almutaster, Chenopodium salinum, Distichlis, Grindelia, Muhlenbergia, Salicornia, Spartina*). Therefore, the net effect of disturbance is to decrease the proportion of species from those families. Conversely, other families increase in relative importance such as the rose and willow families, which contain species well-adapted to disturbance (*Fragaria, Geum, Potentilla, Rubus, Salix*). Web 10.12.2 summarizes the results for north-central and northeastern Alberta.

Web 10.12.2. Changes in the proportion of species, species occurrences, relative cover (which sums to 100 %), and absolute % cover by vascular plant families in naturally saline and industrially reclaimed sites in north-central and northeastern Alberta.

		Naturally Saline				Reclaimed				Change (Reclaimed - Natural)			
Family	Common Name	% Species	% Occur-rences	% Relative Cover	% Abso-lute Cover	% Species	% Occur-rences	% Relative Cover	% Abso-lute Cover	% Species	% Occur-rences	% Relative Cover	% Abso-lute Cover
Apiaceae	Carrot	1.9	1.8	0.89	0.78	2.5	1.5	0.46	0.5	0.5	-0.2	-0.4	-0.3
Asteraceae	Composite	14.8	20.2	14.77	12.88	8.6	7.7	6.39	6.5	-6.2	-12.5	-8.4	-6.4
Betulaceae	Birch	2.6	0.8	0.65	0.57	3.7	1.3	0.97	1.0	1.1	0.4	0.3	0.4
Brassicaceae	Mustard	0.6	0.2	0.05	0.04	0.0	0.0	0.00	0.0	-0.6	-0.2	0.0	0.0
Caprifoliaceae	Honey-suckle	1.3	1.0	0.73	0.63	0.0	0.0	0.00	0.0	-1.3	-1.0	-0.7	-0.6
Caryophyllaceae	Pink	2.6	1.5	1.11	0.97	2.5	1.0	0.14	0.1	-0.1	-0.5	-1.0	-0.8
Chenopodiaceae	Goosefoot	4.5	5.2	3.52	3.07	0.0	0.0	0.00	0.0	-4.5	-5.2	-3.5	-3.1
Cornaceae	Dogwood	0.6	0.3	0.19	0.17	1.2	0.3	0.23	0.2	0.6	0.0	0.0	0.1
Cupressaceae	Cypress	0.6	0.5	0.31	0.27	0.0	0.0	0.00	0.0	-0.6	-0.5	-0.3	-0.3
Cyperaceae	Sedge	9.0	6.8	9.94	8.67	7.4	12.8	20.74	21.1	-1.6	6.0	10.8	12.4
Elaeagnaceae	Oleaster	1.3	0.8	0.76	0.67	0.0	0.0	0.00	0.0	-1.3	-0.8	-0.8	-0.7
Equisetaceae	Horsetail	1.3	0.6	0.23	0.20	3.7	4.1	2.84	2.9	2.4	3.5	2.6	2.7
Fabaceae	Bean	4.5	3.4	2.26	1.97	4.9	7.9	7.67	7.8	0.4	4.6	5.4	5.8
Grossulariaceae	Currant	1.9	1.6	0.57	0.50	3.7	0.8	0.17	0.2	1.8	-0.8	-0.4	-0.3
Hippuridaceae	Mare's-tail	0.0	0.0	0.00	0.00	1.2	1.0	0.34	0.3	1.2	1.0	0.3	0.3
Iridaceae	Iris	0.6	0.2	0.08	0.07	0.0	0.0	0.00	0.0	-0.6	-0.2	-0.1	-0.1
Juncaceae	Rush	0.6	2.2	2.79	2.43	0.0	0.0	0.00	0.0	-0.6	-2.2	-2.8	-2.4
Juncaginaceae	Arrow-grass	1.3	2.4	1.80	1.57	1.2	0.5	0.15	0.2	-0.1	-1.9	-1.6	-1.4
Lamiaceae	Mint	2.6	2.1	1.49	1.30	2.5	0.8	0.34	0.3	-0.1	-1.3	-1.2	-1.0
Liliaceae	Lily	0.6	0.7	0.50	0.43	0.0	0.0	0.00	0.0	-0.6	-0.7	-0.5	-0.4
Lycopodiaceae	Club-moss	0.6	0.7	0.27	0.23	1.2	0.3	0.08	0.1	0.6	-0.4	-0.2	-0.2
Onagraceae	Evening Primrose	2.6	2.2	1.19	1.04	2.5	3.8	2.75	2.8	-0.1	1.6	1.6	1.8
Pinaceae	Pine	0.6	0.7	0.57	0.50	1.2	0.5	0.11	0.1	0.6	-0.2	-0.5	-0.4
Plantaginaceae	Plantain	1.3	1.5	3.63	3.17	0.0	0.0	0.00	0.0	-1.3	-1.5	-3.6	-3.2
Poaceae	Grass	18.1	21.9	35.32	30.80	13.6	23.6	30.21	30.8	-4.5	1.7	-5.1	-0.1
Polygonaceae	Knotweed	2.6	1.8	0.86	0.75	4.9	5.1	2.32	2.4	2.4	3.4	1.5	1.6
Primulaceae	Primrose	1.9	2.5	2.37	2.07	1.2	1.3	0.37	0.4	-0.7	-1.2	-2.0	-1.7
Ranunculaceae	Buttercup	2.6	2.3	1.12	0.98	2.5	1.5	0.23	0.2	-0.1	-0.8	-0.9	-0.7
Rosaceae	Rose	5.8	6.8	5.44	4.75	9.9	4.6	2.95	3.0	4.1	-2.2	-2.5	-1.7
Rubiaceae	Madder	1.3	1.7	1.15	1.01	2.5	1.5	0.66	0.7	1.2	-0.1	-0.5	-0.3
Salicaceae	Willow	7.1	4.0	3.36	2.93	14.8	13.3	10.51	10.7	7.7	9.3	7.2	7.8
Saxifragaceae	Saxifrage	0.0	0.0	0.00	0.00	1.2	0.8	0.17	0.2	1.2	0.8	0.2	0.2
Scrophulariaceae	Lousewort	0.6	0.3	0.11	0.10	0.0	0.0	0.00	0.0	-0.6	-0.3	-0.1	-0.1
Typhaceae	Cattail	0.6	0.8	1.68	1.47	1.2	3.8	9.22	9.4	0.6	3.0	7.5	7.9
Urticaceae	Nettle	0.6	0.5	0.27	0.23	0.0	0.0	0.00	0.0	-0.6	-0.5	-0.3	-0.2

Web 10.13. Cluster analysis of 107 plots, north-central and northeastern Alberta.
Distance measure = Sorensen, linkage method = flexible beta, value = -0.25. Percent chaining = 1.6. Green sites are natural controls, red sites are industrially-disturbed reclaimed sites. The cluster diagram groups demonstrate the clear division between natural control and industrially-disturbed plant communities.

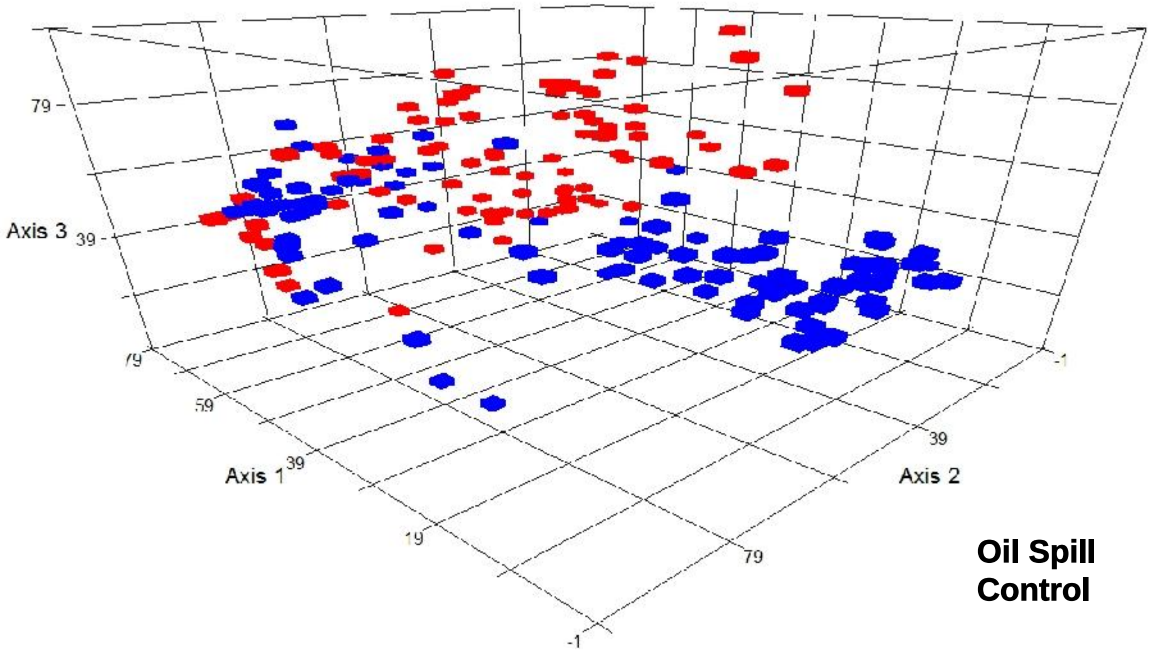


Web 10.13. continued—

Comments:

At this scale of plotting, the cluster diagram is simply intended to show the clear compositional breaks in the communities from natural sites (in green) and industrially-reclaimed sites (in red). If there were not major differences in community composition, the green and red sites would be positioned at random rather than in clusters.

Of the 11 community types found at natural sites, two were observed less often than expected by chance. These were the water sedge – small bottle sedge marsh and the common cattail – slough grass marsh; these types are indicators of industrial disturbance. Conversely, four types were observed more often than expected by chance at natural control sites: a meadow community of reed canary grass, awned sedge, common horsetail, wool-grass, and Bebb's sedge; a naturally-disturbed wet meadow of great bulrush (*Schoenoplectus acutus*) and Canada thistle; a naturally-disturbed meadow of wild strawberry, narrow-leaved hawkweed, baltic rush, and Kentucky bluegrass; and a naturally-disturbed meadow indicated by bluejoint reedgrass, Sartwell's sedge, and small bedstraw.



Web 10.14. NMS ordination of 195 plots in species-space (Canol data, erect deciduous shrub tundra and decumbent shrub tundra sites).
Species are limited to those that occurred ≥ five times (73 taxa). Natural reference control plots in blue, oil spill plots in red.

Web 10.15. Stress in relation to dimensionality in the NMS ordination of 195 study sites in species-space.
(73 taxa, Canol data).[a,b]

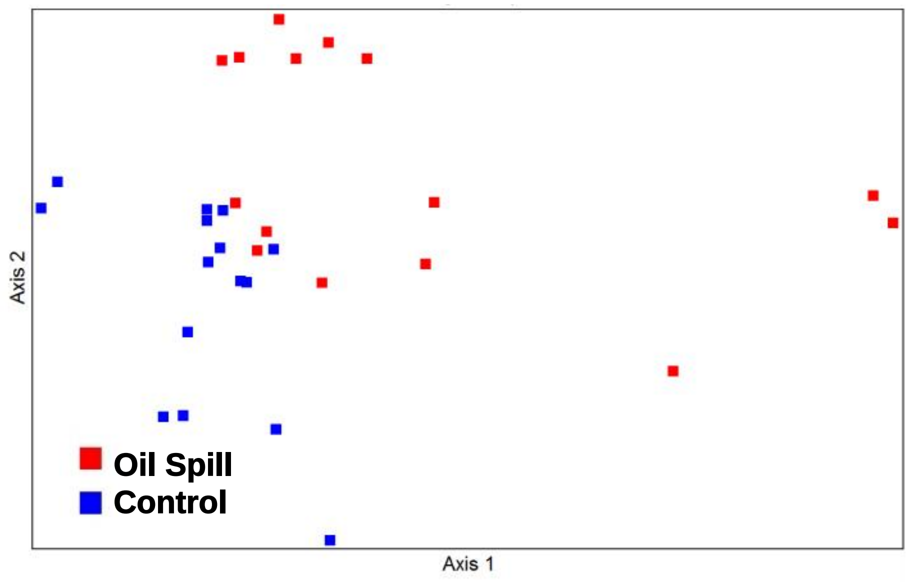
Note: The Canol plots were clustered in two areas, the first near 63º 17’ 52’’ N, 129º 49’ 30’’ W (Canol 1), and the second near 64º 20’ 15” N, 128º 5’ 56” W (Canol 2).

	Stress in Real Data, 250 runs			Stress in Randomized Data, Monte Carlo test, 250 runs			
Axes	**Minimum**	**Mean**	**Maximum**	**Minimum**	**Mean**	**Maximum**	**p**
1	36.2	50.4	57.3	47.7	51.8	57.4	0.004
2	18.9	20.5	41.5	28.9	31.4	41.6	0.004
3	12.4	13.8	32.6	20.8	21.9	23.3	0.004

[a] Sorensen distance measure; random starting coordinates; no penalty for ties; 88 iterations of the final solution; 3-dimensional solution; final instability = 0.00000
[b] Sedge meadows are not included; ordination included only taxa that occurred >/= 5 times

Web 10.16. Pearson correlations of the taxa with the three NMS plot ordination axes in species-space, Canol data. Correlations significant at α ≤ 0.001 are bolded. Only those cover types correlated significantly with one or more axes are listed. Sedge meadows and species that occurred </= 5 times were not included in the ordination.

Correlations with axes	**1**	**2**	**3**
Attribute	**r**	**r**	**r**
tar residue	0.147	0.157	**-0.310**
Asahinea chrysantha	0.162	**0.248**	0.130
Betula glandulosa (0-30 cm tall)	**-0.276**	0.208	**-0.241**
Betula glandulosa (30-100 cm tall)	**-0.444**	0.135	-0.137
biotic crust (cryptogamic crust)	**0.311**	**-0.404**	**0.485**
bryophytes miscellany	0.219	-0.119	**0.382**
Carex petricosa	0.125	**0.270**	0.020
Carex rupestris	**0.237**	0.193	0.075
Carex scirpoidea	0.182	**0.365**	0.043
Cetraria ericetorum	0.215	**0.400**	-0.002
Cetraria islandica	-0.100	-0.064	**0.344**
Cladonia arbuscula	**-0.299**	-0.016	0.128
Cladonia cups	-0.165	**-0.252**	**0.336**
Cladonia	**-0.240**	-0.074	0.003
Cladonia rangiferina	**-0.239**	0.077	-0.122
Cladonia stellaris	**-0.906**	-0.002	-0.077
crustose lichens	0.175	**-0.279**	-0.204
Dryas integrifolia	0.459	**0.468**	0.012
lichens miscellany	0.153	-0.198	**0.258**
mineral soil	**0.438**	**-0.577**	**-0.434**
organic matter	**0.381**	**0.790**	0.042
Oxytropis nigrescens	0.146	**0.318**	0.043
Polytrichum commune	**-0.238**	0.003	0.051
Polytrichum juniperinum	-0.152	-0.175	**0.530**
Rhododendron lapponicum	0.138	**0.248**	-0.040
Rhytidium rugosum	-0.033	0.183	**-0.292**
Stereocaulon	-0.179	-0.017	**0.256**
Thamnolia	**0.252**	0.056	-0.036
Vaccinium uliginosum	-0.042	**0.241**	**-0.276**



Web 10.17. NMS ordination of 30 sedge meadow tundra plots in species-space (Canol data). Natural reference control plots in blue, oil spill plots in red. Note the clear compositional break between oil spill and control plots.

Web 10.18. Stress in relation to dimensionality in the NMS ordination of 30 sedge meadow sites in species-space (37 taxa, Canol data).a

	Stress in Real Data, 250 runs			Stress in Randomized Data, Monte Carlo test, 250 runs			
Axes	**Minimum**	**Mean**	**Maximum**	**Minimum**	**Mean**	**Maximum**	**p**
1	21.4	35.9	55.8	21.5	38.3	55.8	0.004
2	10.5	12.4	39.2	11.7	16.1	39.2	0.004

[a] Sorensen distance measure; random starting coordinates; no penalty for ties; 69 iterations of the final solution; 2-dimensional solution; final instability = 0.00000

Web 10.19. Pearson correlations of the taxa with the two NMS plot ordination axes in species-space, Canol data, sedge meadows.

Correlations significant at $\alpha \leq 0.05$ are bolded. Only those cover types correlated significantly with one or more axes are listed.

Correlations with axes	1	2
Attribute	**r**	**r**
Andromeda polifolia	**-0.45**	-0.112
biotic crust	0	**-0.573**
Cladonia cornuta	**0.357**	-0.209
Cladonia stellaris	**0.391**	0.003
crustose lichen	**0.577**	0.042
Luzula confusa	**0.572**	0.016
Lycopodium selago	-0.046	**-0.355**
mineral soil	**0.925**	0.158
oil residue	-0.03	**0.754**
organic matter	**-0.791**	**0.513**
Oxycoccus microcarpus	-0.248	**-0.361**
Polytrichum juniperinum	**0.418**	-0.203
Sphagnum	-0.269	**-0.43**
water	**-0.359**	0.085

Web 10.20. Indicator species analysis of the treatments (116 taxa, bare mineral soil, etc.) in the 225 plots in the Canol study area.

Sorted by indicator significance p-value.

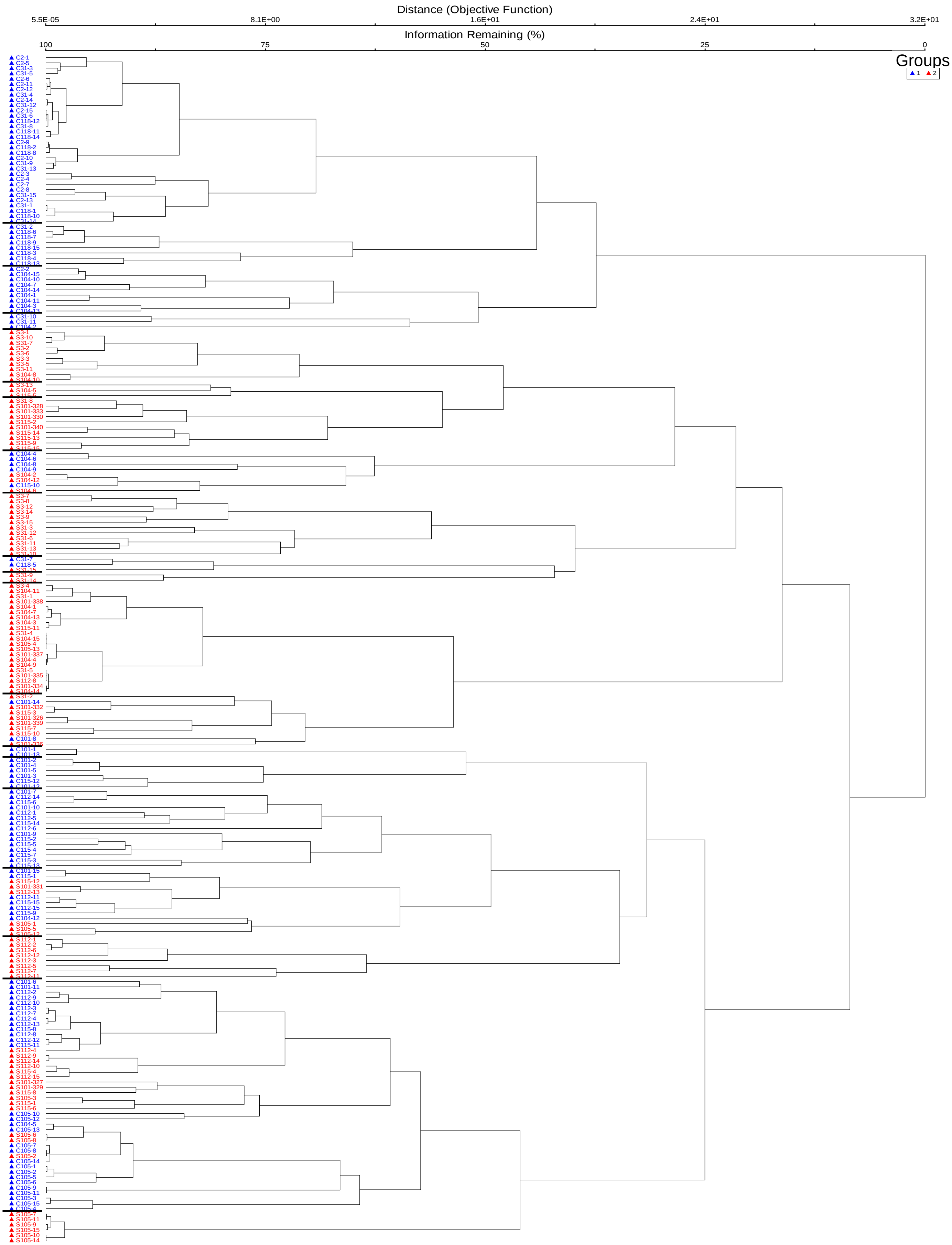
Taxa	Group	Observed Indicator Value	Random Mean	s.d.	p
Alectoria ochroleuca	control	37.3	13.7	2.3	0.0001
Asahinea chrysantha	control	17.5	6.6	1.6	0.0001
Betula glandulosa (0-30 cm tall)	control	31.3	14.8	2.2	0.0001
Betula glandulosa (30-100 cm tall)	control	29.6	11.2	2.0	0.0001
Cetraria cucullata	control	38.1	21.1	2.7	0.0001
Cetraria ericetorum	control	35	14.5	2.2	0.0001
Cetraria nivalis	control	43.7	23.5	3.9	0.0001
Cladonia rangiferina	control	28.9	14.0	2.8	0.0001
Cladonia stellaris	control	54.8	25.5	2.6	0.0001
Dactylina arctica	control	19.7	8.4	2.0	0.0001
Rhododendron lapponicum	control	19.2	7.2	1.8	0.0001
Silene acaulis	control	14.2	5.6	1.5	0.0001
Vaccinium uliginosum	control	20.0	7.9	1.9	0.0001
Masonhalea richardsonii	control	13.1	5.9	1.6	0.0004
Thamnolia	control	24.1	13.3	2.3	0.0008
Carex scirpoidea	control	15.8	8.1	1.7	0.0013
Oxytropis nigrescens	control	8.3	3.6	1.1	0.0013
Andromeda polifolia	control	10.8	4.8	1.4	0.0017
Cladonia arbuscula	control	34.9	23.9	3.1	0.0034
Cetraria sepincola (Tuckermannopsis sepincola)	control	7.5	3.6	1.2	0.0036
Carex petricosa	control	8.9	4.2	1.3	0.0039
Carex rupestris	control	22	13.5	2.31	0.0040
Cassiope tetragona	control	12.0	6.4	1.8	0.0064
Rhytidium rugosum	control	7.5	3.4	1.2	0.0078
Ledum decumbens	control	11.2	6.3	1.6	0.0099
Sphagnum	control	5	2.5	1.0	0.0293
organic matter	control	56.0	51.3	2.1	0.0298
Oxytropis	control	5.0	2.8	1.0	0.0320
Pleurozium schreberi	control	5.0	2.5	1.0	0.0312
Vaccinium vitis-idaea	control	17.1	12.6	2.3	0.0491
oil residue	oil spill	16.2	5.6	1.5	0.0001
biotic crust (cryptogamic crust)	oil spill	53.4	24.9	2.7	0.0001
bryophytes miscellany	oil spill	56.9	28.9	3.3	0.0001
lichens miscellany	oil spill	38.3	16.9	2.8	0.0001
mineral soil	oil spill	69.5	29.8	2.8	0.0001
Polytrichum piliferum	oil spill	12.4	4.7	1.5	0.0001
tarry residue	oil spill	10.5	3.9	1.2	0.0002
Polytrichum juniperinum	oil spill	27.2	15.4	2.6	0.0008
Cladonia cups	oil spill	32.3	22	2.8	0.0031
Carex membranacea	oil spill	18.3	10.7	2.0	0.0033
Potentilla fruticosa	oil spill	6.7	2.9	1.1	0.0050

Eriophorum angustifolium	oil spill	9.4	5.2	1.5	0.0145
Carex brunnescens	oil spill	4.8	2.3	1.0	0.0190
Androsace chamaejasme	oil spill	15.6	10.4	2.1	0.0229
Antennaria densifolia	oil spill	7.1	3.9	1.3	0.0280
anthropogenic debris	oil spill	3.8	1.9	0.8	0.0471
Salix arbusculoides	oil spill	3.8	1.9	0.9	0.0475
Leymus innovatus (Elymus innovatus)	oil spill	3.8	1.9	0.8	0.0493

Comments:
Spill indicators included anthropogenic residues (oil, tar, debris), bare mineral soil, three bryophytes, two lichens, cryptogamic crust, and eight vascular plant species. Natural control indicators comprised four groups: 14 species of vascular plants, 12 lichens, three bryophytes, and organic matter.

No exotic species were found in the study plots, although some exotic species exist nearby (e.g., common dandelion, common wheat) associated with horses and human activities. The lack of exotic species in the plots is attributable to the isolated northern alpine location, inimical to most exotic species, and to the lack of reclamation activities that would have introduced species.

Web 10.21. Cluster analysis of 225 Canol plots.
Distance measure = Sorensen, linkage method = flexible beta, value = -0.25. Percent chaining = 0.9. Blue sites are natural controls, red sites are crude oil spills. Note the clear division between natural control and crude oil spill plant communities. Cluster groups are marked by bold black lines.



Web 10.22. Indicator cover types for the 20 plant community assemblages identified by cluster analysis, Canol data. Sorted by indicator value.

Taxa	Community Group	Observed Indicator Value	Random Mean	s.d.	p
tar residue	166	98.3	10.8	8.3	0.0001
Polytrichum piliferum	54	91.5	11.2	8.8	0.0001
Stereocaulon	37	87.3	12.2	8.8	0.0001
Rhytidium rugosum	61	83.3	11.2	9.3	0.0007
oil residue	142	82.7	10.9	8.1	0.0001
Asahinea chrysantha	67	78.6	11.2	7.9	0.0001
Vaccinium uliginosum	61	75.4	11.7	8.8	0.0004
Betula glandulosa (30-100 cm)	32	74.3	11.1	7.0	0.0001
Umbilicaria	94	74.2	11.1	9.2	0.0015
Cetraria nivalis	40	73.7	16.1	9.6	0.0002
lichens miscellany	28	70.8	13.1	8.5	0.0003
crustose lichens	94	65.6	12.4	7.4	0.0001
Polytrichum juniperinum	22	59	12.2	7.5	0.0007
Pleurozium schreberi	32	48.4	10.7	9.1	0.0035
Betula glandulosa (>100 cm)	32	48.3	11.4	9.2	0.0077
Cladonia rangiferina	32	45.1	14	9.6	0.0182
bryophytes miscellany	53	43.1	13.5	6.5	0.0050
Vaccinium vitis-idaea	2	37.4	11.8	7.6	0.0174
anthropogenic debris	166	37.4	10.4	9.2	0.0302
biotic crust (cryptogamic crust)	16	37.1	11	4.8	0.0005
Betula glandulosa (<30 cm)	62	35.5	10.6	5.8	0.0061
exposed mineral soil	19	34.7	11.3	4.3	0.0001
Cladonia stellaris	1	32.4	10.7	4.3	0.0001
Andromeda polifolia	66	31.8	11.2	8.8	0.0325
Alcetoria ochroleuca	67	31.7	11.2	7.0	0.0199
Cladonia cups	22	31.3	12.3	6.6	0.0297
Carex rupestris	67	30.3	11.3	6.9	0.0236
Silene acaulis	67	29.8	11.2	8.6	0.0421
Androsace chamaejasme	53	28	11.6	7.8	0.0481
Kobresia simpliciuscula	47	25.7	10.8	7.5	0.0406
Cetraria ericetorum	62	25.1	10.7	5.9	0.0388
organic matter	142	19.9	9.5	1.6	0.0001
Dryas integrifolia	75	19.8	9.8	4.6	0.0479

Web 10.23. Pipelines, Rumsey Block indicator species analysis for species with significant p-values by group. Sorted by indicator significance (p-value).

The industrial sites were divided into pipeline ROWs and well pads with complex treatment histories. Construction methods included minimal disturbance, unknown, “full build”, bucket-width topsoil stripping, ditchwitching, and ploughing-in. Pipelines were constructed between 1976 and 2000. Revegetation methods for industrial sites included natural recovery, unknown, three Rumsey seed mixtures, an agricultural species mixture, a “native mixture”, and sites initially seeded to an agricultural mix, then reworked and seeded to a Rumsey mixture. Sites also differed in cattle grazing pressure and age. Finally, the possibility of spills at the pipeline and well sites cannot be ruled out.

Pipeline Disturbed vs. Controls		**Observed**	**Random**		
Species (ACIMS common name if unequivocal one exists)	**Group**	**Indicator Value**	**Mean**	**s.d.**	**p**
Elymus lanceolatus (northern wheat grass, formerly *Agropyron dasystachyum*)	disturbed	75.7	55.4	6.32	0.005
Elymus trachycaulus (awned wheat grass, bearded wheat grass, formerly *Agropyron subsecundum*)	disturbed	70.7	46.9	8.04	0.010
Pascopyrum smithii (western wheat grass, formerly *Agropyron smithii*)	disturbed	64.6	41.8	7.59	0.011
pasture sagewort	disturbed	62.8	52.9	4.42	0.027
prairie crocus	control	76.5	38	6.89	0.0001
plains rough fescue	control	78.8	52.4	5.32	0.0001
tufted fleabane	control	48.2	32.3	7.22	0.034
Heterostipa curtiseta (western porcupine grass, formerly *Stipa curtiseta*)	control	59.3	52.8	3.25	0.044
Pipeline Construction Method vs. Controls		**Observed**	**Random**		
plains muhly	ditchwitch	44.6	23.6	14.13	0.045
bastard toadflax	ditchwitch	59.9	33.2	13.21	0.051
field mouse-ear chickweed	ploughed-in	75.2	35.2	11.45	0.0004
intermediate oat grass	ploughed-in	44	21.6	14.15	0.045
plains rough fescue	control	44.7	31	5.7	0.020
prairie crocus	control	55	30.3	10.24	0.025
Pipeline Revegetation Method vs. Controls		**Observed**	**Random**		
Nasella viridula (green needle grass, formerly *Stipa viridula*)	agronomic	66.6	29.9	13.62	0.038
Heterostipa curtiseta (western porcupine grass, formerly *Stipa curtiseta*)	agronomic	38	31.4	3.39	0.043
Carex stenophylla (low sedge, formerly *Carex eleocharis*)	Rumsey mix 1983	65.7	35.8	6.5	0.0002
pasture sagewort	Rumsey mix 1983	47.7	33.5	4.93	0.009
plains rough fescue	control	57.8	34.9	5.94	0.0005
prairie crocus	control	67.5	31.4	10.17	0.001

Web 10.24. Well sites, Rumsey Block indicator species analysis for species with significant p-values by group. Sorted by indicator significance (p).

Well Site Disturbed vs. Controls **Species (ACIMS common name if unequivocal one exists)**	**Group**	**Observed Indicator Value**	**Random Mean**	**s.d.**	**p**
smooth brome	disturbed	54	21.6	4.57	0.0001
Kentucky bluegrass	disturbed	74.4	44.5	4.44	0.0001
common dandelion	disturbed	65	27.8	5.75	0.0001
Elytrigia repens var. *repens* (quack grass, formerly *Agropyron repens, Elymus repens*)	disturbed	32.8	14	4.14	0.0003
Elymus trachycaulus (slender wheat grass, formerly *Agropyron trachycaulum*)	disturbed	34	16.1	4.1	0.001
Pascopyrum smithii (western wheat grass, formerly *Agropyron smithii*)	disturbed	61.1	43.3	5	0.004
Cirsium spp. (thistles, including undesirable exotic Canada thistle)	disturbed	33.2	18.7	4.46	0.007
Nasella viridula (green needle grass, formerly *Stipa viridula*)	disturbed	44.3	28.9	5.45	0.015
sheep fescue	disturbed	28	16.8	4.62	0.024
gumweed	disturbed	18.7	9.5	3.37	0.027
yellow sweet-clover	disturbed	19.1	11.5	3.74	0.047
Thinopyrum intermedium (intermediate wheat grass, formerly *Agropyron intermedium*)	disturbed	13.9	6.7	2.67	0.051
prairie crocus	control	61.3	26.1	4.88	0.0001
blue grama	control	41.7	15.3	4.01	0.0001
Carex stenophylla (low sedge, formerly *Carex eleocharis*)	control	73.8	39	4.51	0.0001
tufted fleabane	control	57.8	23	4.64	0.0001
plains rough fescue	control	82.8	38.8	4.37	0.0001
Hooker's oat grass	control	38.6	15.1	3.93	0.0001
June grass	control	72	41.7	4.47	0.0001
prairie rose	control	38.9	14.3	3.84	0.0001
low goldenrod	control	52.3	26.7	4.68	0.0001
Heterostipa curtiseta (western porcupine grass, formerly *Stipa curtiseta*)	control	83.9	43.3	4.01	0.0001
bastard toadflax	control	45.1	19.6	4.18	0.0002
field mouse-ear chickweed	control	63.5	42.3	4.34	0.001
sun-loving sedge	control	46.9	26.6	4.59	0.002
pasture sagewort	control	59.4	42.4	4.36	0.002
golden bean	control	36.1	21.3	4.4	0.007
buckbrush	control	22	10.9	3.33	0.008
plains wormwood	control	19.4	8.8	3.24	0.011
owl-clover	control	13.9	6.8	2.74	0.053

Web 10.25. Vascular plant species richness and total cover in the Rumsey Block well pads, pipelines, and controls.

Treatment (sites)	Species Richness (median n), Total Cover (median %) Native Species	Exotic Species	Total Species	Comments [a]
Well Pads (36)	14.0, 60.3 %	4.0, 36.9 %	18.5, 99.9 %	strongly reduced richness and total cover of native species, more exotic species and higher exotic cover on well pads
Well Controls (36)	22.0, 96.7 %	2.0, 1.8 %	24.0, 99.9 %	
Pipelines (17)	20.0, 94.7 %	2.0, 4.5 %	23.0, 100.0 %	reduced richness of native species, more exotic species on pipelines; no significant differences in cover
Pipeline Controls (17)	23.0, 98.2 %	1.0, 1.2 %	23.0, 100.0 %	

[a] Species richness, Mann-Whitney tests for differences; wells vs. controls, for native species $U = 132$, $p < 0.0001$, for exotic species $U = 1115$, $p < 0.0001$, for total species, $U = 203$, $p < 0.0001$; pipelines vs. controls, for native species, $U = 80$, $p = 0.026$, for exotic species $U = 178$, $p = 0.243$, for total species, $U = 109$, $p = 0.211$

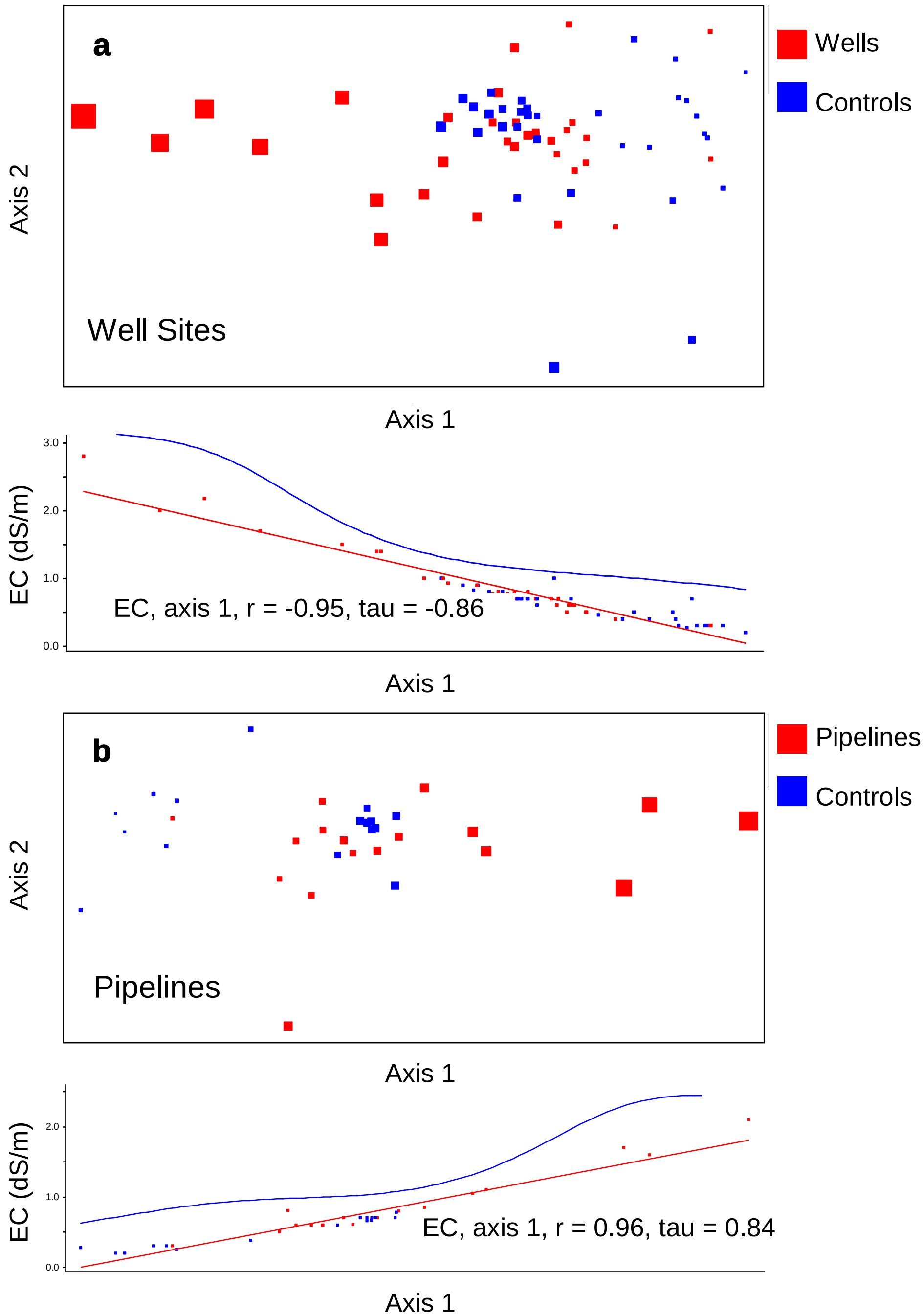
Total cover, Mann-Whitney tests; wells vs. controls, for native cover $U = 147$, $p < 0.0001$, for exotic cover $U = 1158$, $p < 0.0001$, for total cover, $U = 550$, $p < 0.243$; pipelines vs. controls, for native cover, $U = 97$, $p = 0.097$, for exotic cover $U = 188$, $p = 0.132$, for total cover $U = 135$, $p = 0.699$

Web 10.26. Summary statistics for soil attributes in the Rumsey Block.
Raw data from Elsinger (2009).

Attribute	Pipelines Disturbed (median)	Pipelines Control (median)	Difference? Mann-Whitney p, result
Bulk Density at 0-2.5 cm (Mg/m^3)[a]	1.03	0.60	0.0004, higher on pipelines
Bulk Density at 2.5-5 cm (Mg/m^3)	1.24	0.94	0.0002, higher on pipelines
Bulk Density at 5-10 cm (Mg/m^3)	1.24	1.07	0.0007, higher on pipelines
Bulk Density at 10-15 cm (Mg/m^3)	1.32	1.19	0.0011, higher on pipelines
Bulk Density at 15-20 cm (Mg/m^3)	1.35	1.29	0.0515, higher on pipelines
Clay (%)	23.0	21.0	0.0403, higher on pipelines
Sand (%)	47.0	48.0	0.2412, no difference
Silt (%)	30.0	32.0	0.4452, no difference
Calcium (mg/L)	106.0	100.0	0.0817, no difference
Electrical Conductivity (µS/cm)	700	600	0.0089, higher on pipelines
Magnesium (mg/L)	35.0	23.0	0.0044, higher on pipelines
Organic Carbon (%)	2.3	3.2	0.0023, lower on pipelines
pH	7.3	6.5	0.0001, higher on pipelines
Potassium (mg/L)	18.0	18.0	0.4886, no difference
SAR	0.3	0.3	0.9303, no difference
Sodium (mg/L)	15.0	9.0	0.1774, no difference
Total nitrogen (%)	0.21	0.29	0.0019, lower on pipelines
	Wells Disturbed (median)	**Wells Control (median)**	**Difference? Mann-Whitney p, result**
Bulk Density at 0-2.5 cm (Mg/m^3)	0.99	0.58	<0.0001, higher on well sites
Bulk Density at 2.5-5 cm (Mg/m^3)	1.17	0.92	<0.0001, higher on well sites
Bulk Density at 5-10 cm (Mg/m^3)	1.17	1.08	0.0058, higher on well sites
Bulk Density at 10-15 cm (Mg/m^3)	1.30	1.18	0.0004, higher on well sites
Bulk Density at 15-20 cm (Mg/m^3)	1.44	1.29	0.0005, higher on well sites
Clay (%)	23.0	20.5	0.0084, higher on well sites
Sand (%)	44.5	48.5	0.0179, lower on well sites
Silt (%)	31.0	30.5	0.3797, no difference
Calcium (mg/L)	102.0	81.5	0.0291, higher on well sites
Electrical Conductivity (µS/cm)	770	700	0.0115, higher on well sites
Magnesium (mg/L)	32.0	27.0	0.0069, higher on well sites
Organic Carbon (%)	2.5	3.4	0.0031, lower on well sites
pH	7.2	6.6	<0.0001, higher on well sites
Potassium (mg/L)	27.0	20.5	0.0113, higher on well sites
SAR	0.3	0.3	0.4253, no difference
Sodium (mg/L)	18.5	10.5	0.0106, higher on well sites
Total nitrogen (%)	0.22	0.30	0.0070, lower on well sites

[a] one Mg = one million g or one metric tonne

Web 10.27. NMS ordination of soil attributes at (a) well sites and (b) pipelines in the Rumsey Block. Soil attributes included measures of bulk density at five depths, clay, silt, sand, calcium, magnesium, potassium, sodium, nitrogen, pH, conductivity, SAR, organic carbon, and organic matter. Well site 2-d solution, final stress 7.7, instability 0.00000. Pipeline 2-d solution, final stress 5.8, instability 0.00000. Values for soil conductivity are overlain and scaled to their values. Note the significant gradient of increasing soil conductivity between controls and both well sites (a) and pipelines (b). The r-value and the tau value are the parametric and non-parametric correlations.



Web 10.28. Thirty common species of vascular plants that are favored by fossil fuel industry disturbances (according to data from ABMI 2018). The species listed are those whose abundance increases the most as a result of the fossil fuel industry, sorted by population effect based on habitat modeling in Alberta's "northern sector".

Species	Common Name	Population Effect %	Comments
Matricaria perforata	scentless chamomile	165	exotic
Rhinanthus minor	yellow rattle	138	weedy
Juncus tenuis	slender rush	133	weedy
Melilotus alba	white sweet-clover	118	exotic
Sonchus asper/oleraceus	annual sow-thistle	95	exotic
Deschampsia cespitosa	tufted hairgrass	80	weedy
Collomia linearis	narrow-leaved Collomia	69	
Avena fatua	wild oat	67	exotic
Carex bebbii	Bebb's sedge	65	weedy
Dactylis glomerata	orchard grass	64	exotic
Matricaria matricarioides	pineappleweed	63	exotic
Crepis tectorum	annual hawk's-beard	60	exotic
Amaranthus retroflexus	red-root pigweed	59	exotic
Melilotus officinalis	yellow sweet-clover	55	exotic
Carex praticola	meadow sedge	54	
Scirpus microcarpus	small-fruited bulrush	52	weedy
Festuca rubra	red fescue	51	exotic
Medicago lupulina	black medick	48	exotic
Capsella bursa-pastoris	shepherd's Purse	47	exotic
Hordeum jubatum	foxtail barley	47	weedy, pollution tolerant
Juncus bufonius	toad rush	46	weedy
Hordeum vulgare	cultivated barley	43	exotic
Rumex triangulivalvis	narrow-leaved dock	42	
Halenia deflexa	spurred gentian	39	
Bromus tectorum	downy chess	39	exotic
Achillea sibirica	many-flowered yarrow	37	weedy
Phalaris arundinacea	reed canary grass	37	weedy, pollution tolerant
Trifolium hybridum	alsike clover	37	exotic
Medicago sativa	alfalfa	36	exotic
Kochia scoparia	summer-cypress	36	exotic

Comments:
These are some of the vascular plant "winners" that benefit from industry disturbances. Note the predominance of exotic and weedy species and the absence of woody plants. As a group, these 30 species are disturbance-adapted and characteristic of open habitats such as weedy meadows, roadsides, and semi-barren areas with recently-disturbed soil.

Web 11. A Journey down the Rabbit Hole

Web 11.1. History of the 14-21 Pace-Spyglass well and spill

AER (2014b) Well History: "The well, known as the Pace Rainbow 14-21 well, was drilled open hole in 1966 by Baily Selburn Oil and Gas Ltd (a subsidiary of Pacific Western Petroleum Ltd [Pacific]) to a depth of 1972.1 metres below kelly bushing (mKB) into the Keg River and Muskeg Formations in the Rainbow Lake Field. The well was abandoned after five drillstem tests indicated no measurable quantities of hydrocarbons. The 14-21 well was re-entered in 1977 when Pacific received AER approval to use the well for water disposal. The re-entry established a 141.0 m open-hole section penetrating both the Keg River and Muskeg Formations. According to the well history supplied by Pace, the well received a total of only 197.1 m3 of injected water from June 1977 to November 1982 and was suspended from November 1982 to May 1993. In 1993, Inuvialuit Oil and Gas Corporation (Inuvialuit) acquired the 14-21 well and returned it to service as a water disposal well. AER records dating back to 1997 indicate that the well and associated facilities were operated by Samson Canada Ltd (Samson) and later sold to Provident Energy Resources Inc. (Provident) on July 1, 2006. Effective June 29, 2010, Pace became a 100 per cent interest holder in the well as a result of a merger between Provident and Midnight Oil Exploration Ltd. The 14-21 well licence transfer from Provident to Pace occurred on June 29, 2011."

This history demonstrates how wells can change ownership many times, which can make it difficult to establish responsibility and liability for spills and reclamation. Further illustrating this point, this well later changed hands and was leased to Spyglass, hence the name for the spill site "Pace-Spyglass". More recently, the license was transferred to SanLing Energy Ltd, an unfortunate development made evident in the book's Postscript.

To summarize, then, we observe the following chain of responsibility and/or ownership for this single well: Baily Selburn Oil and Gas Ltd (subsidiary of Pacific Western Petroleum Ltd) > Inuvialuit Oil and Gas Corporation > Samson Canada Ltd > Provident Energy Resources Inc > Midnight Oil Exploration Ltd > Pace > Spyglass > SanLing Energy Ltd.

Determining responsibility for spills can be like grasping smoke.

Web 11.1.1. Comments on the AER (2014b) report

Pace Oil & Gas Ltd was responsible for a spill discovered on 19 May 2012 attributed to "equipment failure/internal corrosion" of an above-ground pipe at an injection well (at 14-21-108-07 W6). The ultimate source of the crude oil was a production well (at 15-07-108-07 W6).

Quotes from the regulator's report are followed by my comments.

(1) "The incident occurred on Crown land in an area that is characterized by wetlands with flat to mildly rolling topography and varied vegetation cover, including black spruce, sage leaf, and willow."

The vegetation description is uninformative, superficial, and amateur.

(2) "Initial cleanup operations by Pace consisted of delineating the release and renting recovery equipment, including storage tanks, transfer pumps, hoses, containment booms, and swamp matting. During the first two days of the response, the focus was on accessing the site and constructing infrastructure for an efficient response. Once the environmental impact of the release was more clearly understood, the response by Pace, its contractors, and the relevant regulatory agencies during the emergency phase of the incident was significant. By May 31, 2012, a total of 118 individuals were on site and fully engaged in the response."

Because Pace did not own spill recovery equipment, it was forced to rent equipment, which was a factor in the delayed response. There was a 12-day lag between detection of the spill and a full crew being active on site.

(3) "The 14-21 well was suspended immediately following the first report of the incident. However, the AER allowed Pace to put the well back in service to dispose of the water used for site clean-up operations once the failed wellhead fittings were replaced. The well remains in operation."

AER allowed Pace to restart operations at the 14-21 injection well in order "to dispose of water". Disposal was the same operation that was taking place when the spill occurred. Restarting operations at the well prior to determining causality posed unquantified risks. The AER does not specify here where or why the waste crude oil was disposed. Why would crude oil be disposed of? The company was reportedly injecting saline produced water at the 14-21 well. However, the incident resulted in a spill of crude oil at that injection well. No explanation for this discrepancy is provided, nor did they know the composition of the spill until after testing.

(4) “As of September 2012, the site was showing positive signs of vegetative regrowth and results from initial environmental monitoring were showing that site remediation efforts were working. Soil, water, and vegetation will continue to be monitored once Pace completes remediation activities.”

AER concluded in September 2012 that vegetation remediation was working, but the regulator misunderstands a fundamental principle of oil spills. Plant growth after an oil spill can be rapid if a spill does not contain appreciable salts. For some plant species, rapid growth is a stress response, it does not mean that plants are healthy. Furthermore, post-spill vegetation can constitute a mortality sink that draws animals into an area where they are exposed to contaminants. There can be a lag between a spill and ecosystem response; vegetation response can be manifested over years. The AER is not a competent evaluator of vegetation.

(5) “The spill occurred within the 15-day time period between May 4 and May 19, 2012, and may have taken place over a two- to four-day period.”

No one knows when the spill began. The detection date of 19 May may have been two weeks after the release began. Later in the report, AER stated that “By the first week of June, aggressive spill remediation efforts were underway.” This suggests that as much as a month elapsed between the spill and the full-scale response.

(6) “The spill, originating at the disposal well at LSD 14-21 (14-21 well), pooled in an unoccupied beaver dam about 40 metres (m) from the well and migrated almost 500 m downgradient from the source. The area visibly impacted by the spill extended about 475 m from the source and was about 185 m at its widest point.”

Although industry and the regulator stated the spill occurred at an “unoccupied beaver dam”, no evidence was found that the habitat was unoccupied by beaver. Nor are dams “occupied” by beaver; ponds and lodges are occupied. Failure to observe beaver is not equivalent to absence of beaver. Dene Tha First Nation people observed oil-contaminated beavers.

(7) “The initial estimated spill volume reported by Pace to the AER as of 19:30 was 5 to 10 cubic metres (m^3) of an oil-and-water mix. Pace updated this figure to 100 m^3 by about 23:30. Once the depth and lateral extent of the spill were determined, a new volume was estimated at 800 m^3 and accepted by the AER on May 23, 2012. These estimates fluctuated since, according to Pace and based on the use of the well for water disposal, it was possible that a large volume of produced water was associated with the release. This was later proven incorrect by groundwater monitoring and confirmatory sampling conducted by Parkland GEO Ltd (Parkland GEO), who [*sic*] were contracted by Pace for environmental sampling and monitoring. Chloride levels, used to determine salinity, in water samples obtained from the release location were very close to background levels of around 30 parts per million indicating that the release was oil.”

The initial estimate of the spill volume was 80-160 times smaller than the final estimated volume. The company was not aware of the composition of the spill until after field testing. How can a company respond to a spill in a timely and effective manner if it is not aware of its own spill composition?

The failure of AER to impose meaningful enforcement actions after the spill is consistent with its record in handling spills. Lack of meaningful enforcement provides no incentive to companies to improve their environmental performance. AER’s issuance of a cleanup completion date and closing of the audit demonstrate its lack of expertise in assessing environmental impacts.

Web 11.2. Record of relevant correspondence

Web 11.2.1. Correspondence with the AER and the Government of Alberta in regard to confidential review of the initial draft report of this study

In the initial phase of this research, I had completed a study of Alberta spills with an emphasis on spills in northwestern Alberta. Given that the findings should have been of interest to the AER and the Alberta Government, I decided to offer them the opportunity to review the report prior to publication. My rationale for offering a review copy was four-fold. It provided an opportunity to: (1) correct errors; (2) provide alternate explanations for the results; (3) provide data or support for the regulator's views, practices, and performance; and (4) be informed of the results of the study prior to release to the public. A record of the correspondence follows.

1. via email, to Alberta Energy Regulator, 5 December 2016

re: upcoming release of study on environmental impacts of energy industry spills in Alberta
Dear Mr. Protti and Mr. Ellis:
As a courtesy, I am writing to offer AER the opportunity to provide a confidential scientific review of an upcoming publication on the environmental impacts of energy industry spills in Alberta.
If you are interested in being apprised of the findings of this study prior to publication, please indicate so via email. I will then forward a confidentiality agreement. Upon execution of the agreement, I will supply the manuscript for review.

2. via email, to Alberta Premier Notley, 5 December 2016,

re: upcoming release of study on environmental impacts of energy industry spills in Alberta
Dear Premier Notley:
As a courtesy, I am writing to offer AER the opportunity to provide a confidential scientific review of an upcoming publication on the environmental impacts of energy industry spills in Alberta.
If you are interested in being apprised of the findings of this study prior to publication, please indicate so via email. I will then forward a confidentiality agreement. Upon execution of the agreement, I will supply the manuscript for review.

3. via email, from Alberta Energy Regulator, 8 December 2016

re: upcoming release of study on environmental impacts of energy industry spills in Alberta
"Thank you for your correspondence to CEO Ellis and Chair Protti, offering the opportunity for the AER to do a confidential scientific review of your upcoming publication.
On behalf of CEO Ellis, we appreciate and thank you for the offer but the AER will not participate in the proposed review.
We look forward to your work being published and we will certainly take stock of the information it contains.
Kind Regards,
Martin Krezalek
Chief of Staff
Office of the Chief Executive Officer
Alberta Energy Regulator / Edmonton"

4. via email, from Office of the Premier, 9 December 2016

re: upcoming release of study on environmental impacts of energy industry spills in Alberta
"On behalf of Premier Notley, thank you for your email. I have shared your comments and forwarded your email to the ministry of Environment and Parks for consideration.
Best regards,
Sonya
Premier's Correspondence Unit"

I received no further relevant correspondence from the Alberta Government or the AER. The decision to decline review may have stemmed from both the realization that the AER's data and management were not defensible and the need to retain the ability to claim ignorance.

Web 11.2.2. Correspondence regarding high levels of hydrocarbons in the soil at the Pace-Spyglass spill

via email to Ms. Mandy Dumanski, toxicologist, Alberta Energy Regulator, 10 February 2017

“I note from FOIPed materials that a set of soil hydrocarbon analyses from the Pace-Spyglass 14-21, 19 May 2012 spill indicate the following.

1. Soil analyses by Parkland Geo, Table 4
2. Samples taken 23 September 2015, 3 years 4 months after the spill and after the spill was certified by AER as cleaned-up (release cleanup date 12 September 2012)
3. Extremely high levels of BTEX and F1, F2, F3, and F4 hydrocarbons, in some samples, hundreds of times greater than criteria thresholds.
Notes
(a) the spill was of 800 m^3 of crude oil, recovery of 800 m^3 of crude oil (i.e., perfect recovery) reported by AER.
(b) an AER inspection (26-27 August 2015) stated: “No non-compliances were identified during inspection. An inspection on the noted well license was conducted on August 25, 2015. Observations found: Contaminated soil (hydrocarbon soaked) within the immediate surface area of the well. The area within the lease boundary is still matted with swamp mats and could potentially be masking Hydro carbon liquids below the mats. No enforcement was issued for this inspection. the contaminates [*sic*] identified within the well area were direct impacts due to a large Hydro-carbon release that occurred in 2012.”
(c) There are no effective wildlife deterrents in place.

As a toxicologist for AER, please comment on the situation as outlined above. Is the situation at the Pace-Spyglass spill acceptable to the AER?”

On 9 March 2017, I received an anonymous email from AER “Stakeholder Engagement” pertaining to the preceding query on hydrocarbons, and, to another query sent to Mr. Wayne Gilbart regarding data discrepancies in reported numbers of pipeline spills.

The email stated:

“The Alberta Energy Regulator (AER) is in receipt of your e-mails dated February 10 & 14, 2017 to Mandy Dumanski of the AER, and your e-mail dated February 28, 2017 to Wayne Gilbart of the AER in which you raise a number of concerns relating to AER data.

“The AER remains committed to responding to your current information requests and future queries. However, in an effort to effectively facilitate your requests and ensure a timely, coordinated response, the AER is asking that all future engagement from yourself or the organizations you are representing, be submitted to the stakeholder engagement branch by e-mail at stakeholder.engagement@aer.ca. This approach will ensure that the proper subject matter experts are involved with the response back to you, and that your queries are managed in a consistent, timely manner.”

This response is noteworthy in three respects: (1) My previous experiences attempting to obtain information via “Stakeholder Engagement” produced little or no useful information and resulted in long delays. (2) One set of enquiries resulted in being directed, after many emails, to Mr. Wayne Gilbart, a knowledgeable staff person who provided useful information. I therefore directed subsequent queries to Mr. Gilbart. Direct correspondence with Mr. Gilbart, or with any staff outside of “Stakeholder Engagement”, was terminated by the email of 9 March 2017. (3) It fails to note two other outstanding queries, one directed to Mr. Gilbart on 23 February 2017, and one directed to [name withheld] on 10 February 2017 (see, (**c**), below).

Web 11.2.3. Correspondence regarding statements made by the AER in Nikiforuk (2017)

via email to Alberta Energy Regulator, 10 February 2017

In response to a journalist’s questions to the regulator about the results of this study, “…, a public affairs manager with the AER, told the Tyee that it couldn’t verify exactly how Timoney was determining or defining perfect recovery. ‘As Mr. Timoney’s report has not been made publicly available, the AER cannot provide specific responses to the claims made regarding the accuracy of spill reporting data in the province.’ He added that the data set that Timoney used on spill response in the province between 1975 and 2013 ‘provides only a partial picture of spill clean up and damage to habitat as a result of spills in the province’ and doesn’t tell the full story” (Nikiforuk 2017). The regulator’s statements were misleading and prompted a query. The author wrote to the public affairs manager at AER and posed questions; the AER did not respond.

“Dear [name withheld]:
“... I believe that you have supplied misinformation and I am therefore writing to provide you with the opportunity to clarify, correct, or retract your statements. As follows:

“(1) You were quoted: ‘As Mr. Timoney’s report has not been made publicly available, the AER cannot provide specific responses to the claims made regarding the accuracy of spill reporting data in the province.’
Were you aware that I offered Mr. Protti and Mr. Ellis the opportunity for the regulator to review the manuscript in early December 2016?
If you were aware, it is misleading to imply that the regulator cannot make specific comments on the report when, in fact, it was made available to the regulator and the regulator declined the opportunity. The regulator cannot both decline to view information and plead ignorance of that information.
If you were not aware, it demonstrates a failure of the regulator to provide a spokesperson with relevant information.
Your response?

“(2) The article stated: “He [name withheld] added that the data set that Timoney used on spill response in the province between 1975 and 2013 ‘provides only a partial picture of spill clean up and damage to habitat as a result of spills in the province’ and doesn’t tell the full story”.
Were you aware that I submitted a FOIP to AER in September 2016 which included a request for all relevant chemical, biological, and environmental monitoring data and reports for the spills studied during the fieldwork?
As of this writing..., detailed environmental records from only one spill have been received.
You cannot justifiably contend that I was ignorant of information when I requested the information and have been denied, to date, access to most of the information or informed that no such records existed.
Your response?

“(3) The article stated, referring to your comments, that prior to 2013 the regulator tracked only what was in its mandate and impacts on wildlife and wildlife habitat were not under its jurisdiction. You then stated: “If the spill caused damage to a sensitive area or wildlife/livestock outside of the regulator’s jurisdiction, it may have been marked (for lack of a better option in the system) as not affected”.
Are you aware that this is erroneous? The regulator has tracked environmental damage since 2002.

Your response?”

I received no responses.

Web 11.2.4. Correspondence regarding outstanding information requests

via email to Stakeholder Engagement, Alberta Energy Regulator, 11 March 2017, in regard to outstanding information requests and their 9 March 2017 email

“Dear Stakeholder Engagement:

I am writing in response to your email to me dated 9 March 2017.

In order to assist you in your efforts to respond to my queries in a timely manner, I provide the following additional information.

Your response noted two outstanding queries (additional clarification noted in item 3, below), but failed to refer to two other outstanding queries, as follows:

“(1) Email query directed to [name withheld] on 23 February 2017 regarding recoding of “sensitive areas” as “non-sensitive areas”. The question pertained to discrepancies in the number of crude oil and saline spills in “sensitive areas” in the 2013 and 2017 versions of the FIS database. In the 2017 version, there was a decrease in the total number of sensitive area spills in both the primary crude oil (73 decreased to 53) and primary saline/produced water spill categories (52 decreased to 43). Such a decrease would require that spills earlier classified as occurring in sensitive areas were later recoded as non-sensitive areas. Please explain how that happened.

“(2) Email query directed to [name withheld] on 10 February 2017 to which no response has been received from [name withheld]... [for that email, see above]:
...

“(3) In follow up email correspondence with Ms. Dumanski and Dr. Dubé regarding the high levels of hydrocarbons persisting at the Pace-Spyglass spill, I asked if the high levels of hydrocarbons present at the Amber oil spill were similarly acceptable to the AER. Dr. Dubé replied that a response would be prepared to that query. Please respond to that query.

"In summary, then, there are five outstanding queries for your 'proper subject matter experts' to address in a 'timely manner'. These are:

"(1) Persistent high levels of hydrocarbons at the Pace-Spyglass spill
"(2) Persistent high levels of hydrocarbons at the Amber spill
"(3) Reason for recoding/decrease in number of sensitive area spills
"(4) Reason for discrepancies in number of reported pipeline spills
"(5) Information supplied by [name withheld] to the media (Nikiforuk 2017) in re: my investigation of spills."

Web 11.2.5. Further correspondence regarding the outstanding information requests

On 30 March 2017 I wrote an email to remind Stakeholder Engagement that the information requests remained unanswered. The AER responded on 30 March 2017: "We are currently gathering information from internal sources in an effort to respond to your previous inquiries. We are making best efforts in stewarding towards completion of those requests."

On 26 April 2017, I received a response from Stakeholder Engagement. The regulator responded to four of the five questions. I have put my comments in square brackets.

Question 1. AER wrote:

"The AER has been working with SanLing Energy, the licensee that acquire [*sic*] Spyglass Resource Corporations assets, on a cleanup and remediation plan for contamination discovered at 14-21-108-07W6.

"Since 2015, SanLing has undertaken a number of assessment, remediation, and monitoring activities to ensure the appropriate cleanup of the site. The identified offsite impacts indicated by Parkland Geo in September, 2015, were excavated during February 2016 while frozen ground conditions permitted access to these impacted areas. Open bodies of water were created resulting from the fall 2015/winter 2016 remediation. In the event that any hydrocarbons accumulate in these water bodies preventable measures [?] were implemented [meaning?] to insure [*sic*] containment and to deter any wildlife and/or migratory birds, following spring break up, ongoing site monitoring was conducted which included additional sampling and site assessment. Site maintenance included vegetation control and temporary containment management.

"The fall 2016 remediation consisted of the removal and disposal of impacted material, additional excavation of impacted materials (identified in May, 2016 sampling event) and removal of additional swamp mats. The remaining impacted material in the east containment will be disposed of in January/February 2017. Project management and ongoing site monitoring and assessment will continue throughout 2017."

[The response did not address the hydrocarbon contamination that persisted after remediation. The "containment" structures (float bladders and metal collar) were not working; hydrocarbons continued to escape containment. There were essentially no wildlife deterrents in place. The only "deterrent" that remained was a waist-high plastic snow fence that lay on the ground in places; it was not a wildlife deterrent. The vegetation and soil data demonstrated that the site remained contaminated, impaired, and a threat to wildlife.]

Question 2. I received no response in regard to the persistent contamination at the Amber site.

Question 3. AER wrote:

"Prior to 2009, Sensitive Environment was actually defined by the Sustainable Resource Development (SRD) agency of the Alberta Government. The AER only referenced this in our release reports and used it as an indicator of the impact of the release event and how the AER would respond (response priority).

"In order for our inspectors to determine if the release event occurred within an SRD defined Sensitive Environment, our inspectors would go to a specific page on the SRD website that showed all the areas of the province that SRD considered to have Sensitive Environments. If the release occurred within one of these areas, the AER inspector would check this box off as "Yes".

"Sometime in late 2008, SRD stopped defining these areas and removed the webpage that showed these areas. We have no explanation to offer about why this happened but it did affect how we used this dataset within the AER as of 2009.

“It was decided at that time, since there was no longer an official definition for Sensitive Environment, the AER inspectors would always check off this box as “No”. Under that business process rule, all release records from 2009 to date should have indicated all releases to have no sensitive environment. But unfortunately as time went on this business rule was lost in the many changes to AER staff, leadership and organizational transformations. Inspectors would check off the Sensitive Environment as “Yes” based on their own personal definitions or experience. Where one inspector would consider the environment to be sensitive, another would not.

“The SRD no longer exists and has been rolled into what is now Alberta Environment and Parks (AEP).

“Recently the AER rediscovered this data issue and a decision was made to go back into all the past release records (post-2009) and perform a data correction to switch all releases records that indicated the Sensitive Environment from the incorrect “Yes” to the correct “No”. And as of November 18, 2016, our system was also enhanced to prevent inspectors from ever checking off this data item as “Yes”. It will now always ever show as “No”, eliminating the risk of human error.

“If you look at the same record in your example, Incident 20131107, it now will show the Sensitive Environment as “No”.

“So the short answer to your question is, there is no official definition of Sensitive Environment as the AER does not recognize it a validated and clearly defined dataset.”

[Discrepancies in the number of sensitive areas spills in the 2013 and 2017 versions of the AER data were caused by AER staff recoding the 2009-onwards sensitive area spills as non-sensitive. The regulator’s response doesn’t address why it doesn’t use a sensitive area designation in order to guide spill response priority and management.]

Question 4. AER wrote:

“Discrepancies between numbers between the different AER products is a matter of what data is [*sic*] being included/excluded. Often the notes to the data as with the Product Catalogue or the ‘Notes on the Data’ section in Tableau report for the pipeline performance report are trying to explain. [?] There are two filters being applied to the data that explain why other AER product have a higher incident count and the note section explains such. They are:

“1. The external pipeline performance report includes only pipeline incidents that are hits, leaks, and ruptures and excludes all pressure tests, integrity tests, HDD frac-outs from the data.

“2. The external pipeline performance report does not include pipeline incidents associated with AUC licensees.”

[This response does not explain why pipeline spills resulting from pressure and integrity tests and HDD frac-outs are excluded from AER public reports.]

Question 5. It is unclear to what questions the AER is responding here. AER wrote:

“The AER was provided the opportunity to confidentially review the information provided by you. However, as the release of the information required a confidentiality waiver, which may have limited the AER’s ability to speak about the research once released, the AER was unable to take part. The research was not made publically available to the AER but instead was provided on a confidential basis.”

[Apparently the AER is stating that it chose not to review this study because such a review would have required a confidentiality waiver. You’ll note from my letter to Mr. Protti and Mr. Ellis of the AER (Web 11.2) that I requested that the draft manuscript and AER’s review be kept confidential during the review process. This is standard scientific protocol intended to prevent unauthorized distribution of results prior to publication. After publication of the study, the AER would be free to comment, as would anyone. Whether the AER misunderstood the scientific review process or used a misinterpretation of review confidentiality in order to avoid the review will never be known. The AER did not contact me to discuss the issue.]

“The AER continues to work on an outstanding FOIP request received in September, 2016 that came from the Keepers of the Water Group. You did not make this FOIP request, however, we did find that you were cc’ed on correspondence received from Julie [*sic*, Jule] Asterisk (Keepers of the Water) in that time period. Due to the volume of information being requested and the number of third parties involved the request, the AER has had to extend the timeline to respond to the FOIP request. This work is ongoing as it involves engaging and consulting with third parties to release all of the requested documentation.”

[It's unclear why the AER is addressing the issue of the FOIP.]

"AEP was responsible for tracking this damage prior to 2013. The AER has only tracked this information since receiving a new mandate following the proclamation of REDA."

[The AER has tracked environmental damage in its FIS spill database since 2002. It's unclear why the AER states it has tracked environmental damage since 2013. Regardless of whether AER or Alberta Environmental Protection was responsible for tracking damage, the AER (and its former namesake ERCB) has been tracking the "environment affected" and "habitat/wildlife affected" data in its spill database since 2002.]

Web 11.2.6. Response of AER to questions regarding recovery of condensate and raw production gas

On 1 March 2018, I wrote AER and asked: "How are the volumes released and the volumes recovered determined for accidental releases of condensate? How are the volumes released determined for accidental releases of raw production gas?"

On 19 March 2018, the AER responded:

"When initial release volumes are reported to the AER, the AER requests a description of how the volume(s) were determined and verified including the calculations used (i.e., spill length x width x depth). The AER requires the licensee to complete a release report form, to verify the incident information and the clean-up activities. The release report form is posted on aer.ca.

"There are several different methods to determine accidental release volumes of condensate and raw production gas. The AER requires that the responsible parties use all tools necessary to accurately determine the volume released.

"The type of leak detection used can increase the accuracy of the release volume. Some sites are able to monitor trends to determine when the leak occurred, and review historical production or throughput to help calculate the volume.

"Where there is little evidence of a leak based on production, licensees will use the area affected and the amount of contamination present to determine the amount released.

"To determine the accidental releases of raw production gas, licensees may also use an engineering calculation to determine the volume released, in addition to the methods mentioned above. This would be based off of line diameter, pressure, size of hole in the pipe, and duration.

"The amount of condensate or raw production gas recovered is determined once final clean-up is complete. All the waste material recovered is tracked. Licensees will use truck tickets, tank volumes, and waste manifest to determine the final amount of fluid that is recovered.

"The AER reviews release reports to verify how the responsible party calculated the released volumes, the clean-up/recovery information, which will typically include impacted/contaminated soil removed, and sampling data to identify if contamination of {X} exists. The AER may also conduct field inspections to verify reported information."

Web 12. Background information on Apache spills 11-26 and 15-09

Web 12.1. Apache 11-26 saline spill

Web 12.1.1. Summary of the Apache 11-26 saline spill

The AER FIS database listed the following spill contents: waste, 27 m^3 released, 27 m^3 recovered; contaminated surface water, 6900 m^3 released, 6900 m^3 recovered; raw production gas, 100 m^3 released, 0 m^3 recovered; salt/produced water, 1813.8 m^3 released, 1813 m^3 recovered.

The AER data state there was “no affect” on wildlife/habitat; that the environment was “muskeg/stagnant water” and was not a “sensitive area”; there was release off-site; the area affected exceeded 1000 m^2; and provided 28 February 2015 as the release cleanup date.

There was a delay of 22 days between onset of the spill and its detection. The spill was attributed to crushing of a pipeline end assembly by a bison. Information discrepancies in the various accounts include the date of the spill, the volume of the spill, and the areal extent of the spill. Without access to complete and accurate records, it’s not possible to reconcile the information discrepancies.

Despite the area being cleaned to a standard meeting or exceeding that required by the AER, the soil, water, and vegetation at the site remained impacted.

Apache pled guilty to this spill on 30 September 2016. The company was ordered to pay a fine of $350,000 with most of the funds directed to research on remediating salt-affected soil, an admission that, after decades of saline spills, reclamation on salinized soils still faces serious challenges. Although the AER database stated there was “no affect” on habitat or wildlife, the company pled guilty to causing detrimental effects, an example of how the FIS database doesn’t provide a credible account of environmental effects.

Web 12.1.2. Excerpts from an Agreed Statement of Facts between Her Majesty the Queen and Apache Canada Ltd (from Kallal 2016)

“Apache Canada Ltd (‘Apache’) stands charged that: On or between the 17th day of April 2013 and the 25th day of October 2013, at or near Zama City, in the Province of Alberta, did fail to design, construct, maintain or operate a pipeline in accordance with Clause 13.1.2.14(f) of CSA Standard CSA Z662-11 by failing to protect a reinforced composite pipeline... and did thereby commit an offence contrary to s. 52(2)(a) of the Pipeline Act, evidence of the offence having first come to the attention of the Regulator on October 25th, 2013...

After the 11-26 Site abandonment, the Pipeline was left connected to the 03-10 Battery... pressurized water was present in the Pipeline at the 11-26 Site following removal of the above ground piping system...

A fence or barrier was not erected around the riser where it emerged from the ground...

The area around the 11-26 Site is characterized as peat land dominated with bogs and fens...

On 25 October, 2013,... On arriving at the 11-26 Site, the operator saw water which appeared to be coming out of the ground...

Apache’s investigation concerning the Pipeline failure found that the composite pipeline had been crushed against the steel riser chute that supported it...

Traces of bison hair were found on the End Assembly and bison tracks were evident in the area of the 11-26 Site. A bison scratching itself or otherwise bumping the End Assembly was determined to be consistent with the additional force required to crush the Pipeline as found...

Apache’s investigation concluded that the Pipeline most likely failed sometime on or about October 3, 2013...

The volume of produced water released into the environment was calculated to be 1,813 cubic meters. The produced water collected in the low lying bog and fen like area near the riser...

The chlorides in the produced water were such that the vegetation in the area of the release would have been affected. This involved approximately 2.3 ha of land... [note that Canadian Press (2016) stated that the affected area was 3.8 ha of public land]

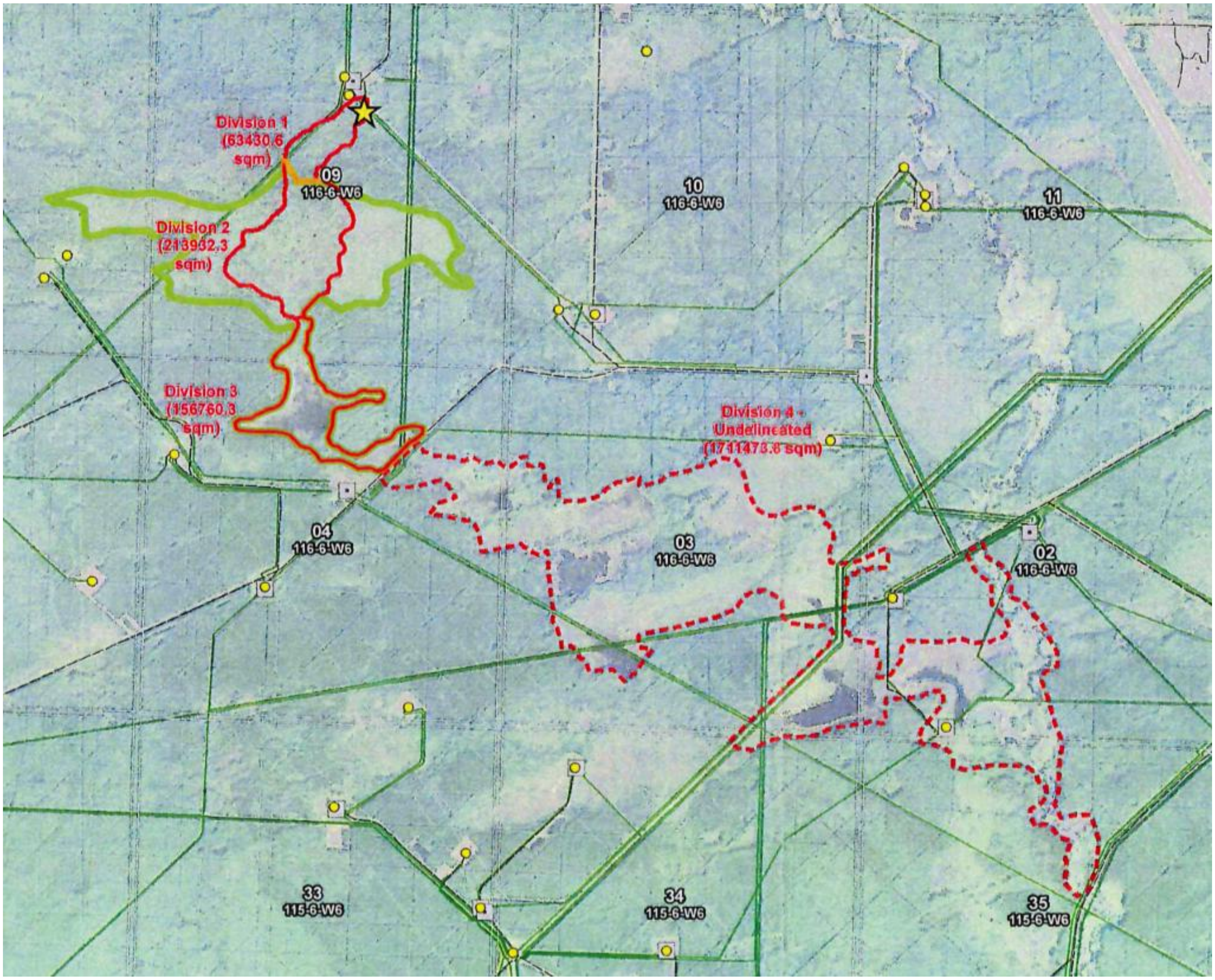
As part of the remedial program approved by the Alberta Energy Regulator, 32 tonnes of affected soil were removed from the 11-26 Site and the area around the Site was turned into a pond for migratory waterfowl and to provide drinking water for wildlife in the area...

No indication was found that people or animals were harmed as a result of the release...

The site was cleaned to a standard meeting or exceeding that required by the Alberta Energy Regulator.”

Web 12.2. Apache 15-09 saline spill map of the affected divisions

This map, produced by Apache, delineates the four divisions affected by the spill. Each section number (9, 10, 11, etc.) lies in the center of a one square mile area. Image captured from a FOIPed page. The yellow star is meant to indicate the origin of the spill.



Web 13. Notes on failures to document environmental effects

Web 13.1. Frequency of environmental and wildlife effects of crude oil and saline primary spills as reported in the AER FIS database.
Current to 6 February 2017. Data tabulated from the "WildlifeLivestockAffected" field.

Crude Oil Spills (n = 24,948)	**Spills (n)**	**Spills (%)**	**Adjusted %** [a]
"No affect"	5767	23.12	98.73
"Habitat affected" [b]	69	0.28	1.18
"Conversion from ENV system"	19106	76.58	---
"Animal(s) injured or killed"	5	0.02	0.09
blank	1	0.004	---
Saline Spills (n = 15,803)	**Spills (n)**	**Spills (%)**	**Adjusted %** [a]
"No affect"	4932	31.21	99.06
"Habitat affected" [b]	46	0.29	0.92
"Conversion from ENV system"	10824	68.49	---
"Animal(s) injured or killed"	1	0.006	0.02

[a] Adjusted % omits "Conversion from ENV system" and blank records as non-data and recalculates the frequency based on the total remaining observations (n = 5841 for crude oil and 4979 for saline water)
[b] In the 2017 version of the FIS database, the "habitat affected" category was renamed "animal(s) affected"

Comment:
These extremely low frequencies of environmental effects recorded in the AER's data are not credible.

Web 13.2. Notes on the AER record keeping for habitat and wildlife effects

Just prior to AER's 2017 decision to prohibit direct communication between AER technical staff and myself, an AER staff person explained to me:
"FIS started being used to capture incident data in 2003 [note: actually in 2002]. Prior to that inspectors captured all incident data (1975 - 2003) in the ERCB's old ENV mainframe system. When FIS was built all that ENV historical data was converted into FIS.

Prior to the conversion, the team that developed FIS saw an opportunity to capture much more detail about each incident. So much more than what was captured in the limited ENV system. So they added all sorts of new data fields in FIS allowing us to capture even more information than what ENV allowed.

When they converted all the mainframe's ENV data over to FIS, these new FIS fields didn't have any data to fill them but due to their mandatory nature, needed to have something in them. To fulfill the mandatory requirements of these new fields, the team decided to use 'Conversion from ENV System'" (W. Gilbart, AER, pers. comm., 10 January 2017).

Web 13.3. Notes on AER estimation of spill footprints

Underestimates of spill footprints stem in part from the AER's use of qualitative classes for spill footprints, the largest of which is only 0.1 ha. Here I illustrate five examples of areal underestimates.
(1) For the Apache 15-09 spill, the AER database stated >0.1 ha as the area affected. A FOIPed internal AER document dated 19 May 2015 indicated an impacted area of 15 ha; the court document indicated that 42 ha were affected (see Web 2.4, and Wagener 2015b). Satellite imagery and chemical data indicate that the 42 ha figure is also an underestimate.
(2) For a Plains Midstream 2011 crude oil spill (incident 20110906), the AER database stated >0.1 ha as the area affected whereas ERCB (2013a) indicated that 8.3 ha were affected.
(3) For the 14-21 Pace-Spyglass spill, the AER database stated >0.1 ha as the area affected whereas the area affected exceeded several hectares (see Figure 11.2 in book).
(4) For the 04-25 Barnwell spill, the AER database stated 0.01 ha or less as the area affected; the area affected was ~ 0.06 ha (Web 2.4).
(5) A spill area at a crude oil group battery near the BP Zama spill site (Plot 6) was listed as 0.01 ha or less, but a FOIPed document stated that the affected area was 0.03 ha (incident 20101037).

Web 13.4. Notes on the second largest known saline spill in Alberta history

Acclaim Energy well blowout on 12 December 2004 (incident 20042925).

The following excerpt from EUB (2005) provides background on the blowout.

The large volumes of liquids (primarily salt water, with a small amount of oil) flowing from the well created a large crater around the wellhead. This erosion caused the service rig to topple over, requiring its removal...

The erosion made access to the wellhead a challenge, and fluid control became a priority. Acclaim excavated trenches and pits for fluid diversion and storage in order to improve access to the wellhead. At times, more than 160 tank trucks were used to remove water continuously from the site...

The major problem encountered was disposing of the significant volume of salt water and small quantities of emulsified oil. The number of personnel on location dedicated to well control efforts and the close proximity of the well to Edmonton and other nearby populated areas added to the complexity of well control operations...

The EUB recognized that with respect to handling the massive volumes of salt water and oil emulsion, Acclaim would be unable to meet the EUB requirements for normal operating conditions. The EUB was present on site and was satisfied that the approach that Acclaim was using was acceptable and would result in only short-term impacts that can be remediated...

Acclaim submitted estimates of the volumes of salt water, gas, and oil that were released during the blowout. While the EUB has a conservation mandate to prevent waste, the investigation team believes that the hydrocarbon volumes released and wasted were relatively minor, compared to the volumes produced from 2-26 [the well] over its lifespan.

The EUB (2005) report noted that all evacuees were asked to leave the area immediately because of the blowout, but were given very little information. They were not given specific travel routes to follow to avoid entering the gas plume. They were directed to find their own accommodations without reporting to a reception centre for registration. They were not given instructions as to who would take care of their needs and expenses. They were not informed as to whom they should contact if problems arose, and they did not know who would look after the security of their property, pets, or livestock while they were evacuated. Moreover, the parties conducting the evacuations did not prepare a common message or set of instructions to be delivered to the evacuees.

Neither Acclaim, the EUB, nor Emergency Management Alberta (EMA) initially notified the City of Edmonton, the Capital Health Region Authority, Enoch Cree Nation, and Health Canada. These parties believed that they should have been notified earlier because people in their jurisdictions were calling to express concern or request information about the incident and their safety.

All of the evacuations occurred up-wind from the direction of the gas release; the wind was blowing from southwest to northeast. Edmonton residents who were situated downwind were neither notified nor evacuated, nor was this required. A database was not available to EUB staff to determine whether a well was sweet or sour and, if sour, its hydrogen sulphide concentration.

The findings demonstrate that even after thousands of industry incidents, both industry and responsible agencies struggled to provide effective emergency response and critical and timely information to the public. The same is true today in 2020. Significantly, I found no documentation or study on the environmental effects of the blowout.

Web 14. Cumulative effects

Web 14.1. Estimation of the fossil fuel industry footprint

Wells

As of September 2016, there were 589,634 wells registered in Alberta. Considering that well pads cover roughly 0.6 hectares, means there may be about 3538 km^2 of impacted vegetation and soils on well pads. Well pads are linked in a network with pipelines, seismic lines, roads, batteries, plants, and related facilities. To gain an idea of typical energy infrastructure networks above and below-ground, please see Web 2.4.

Pipelines

Total pipeline length in Alberta was about 415,152 km as of December 2012 (AER 2013a) and operating pipeline length exceeded 360,000 km. However, total pipeline length based on ABMI (2017) data current to 2014 was 591,085 km, roughly 1.5 times the distance between the Earth and the Moon. It's not clear why there is a 175 thousand kilometer discrepancy in total pipeline length. The vegetation and soils of pipeline ROWs differ from natural communities; this makes for an extensive network of damaged soils, vegetation, and stream crossings. Assuming a 10 m right-of-way for pipelines yields a footprint of 5911 km^2.

Seismic Lines

There were 135,529 total wells drilled in Alberta from 1979 to 1995 (AER records), during which time 2.3 million km of seismic lines were approved (Timoney and Lee 2001), but the total distance cut has not been published. Thousands of kilometers of seismic lines are cut each year in Alberta. Given the impacts of seismic lines, it's important to know the total length of seismic lines in Alberta. As with many questions relating to fossil fuel industry impacts, the answer is a surprising one.

Industry and various branches of government have (or had) records of seismic lines in the province. The record includes line location, length, width, dates, companies involved, and so forth. To report the total length of seismic lines in the province, government would simply need to summarize the data on file. It's not clear why the Alberta government does not publish the figures annually. Government publishes the revenues generated by hydrocarbon exploitation but doesn't publish the environmental costs of that exploitation.

If government will not publish seismic line data, the best we can do is estimate their extent from imagery. An indirect measure of the total seismic line length in Alberta was calculated for me by landscape ecologist Peter Lee with ABMI (2017) data. Current to 2014, the total seismic line length in Alberta was 1.98 million km of satellite-detectable lines. That estimate is dependent upon image quality, resolution, vegetation cover, and age of seismic line. Satellite-based digitizing may see less than one-half of actual seismic line extent (Figure 14.2). Therefore, the seismic line total underestimates the true extent of seismic lines (Text Box 14.1). Total seismic line length in Alberta greatly exceeds two million kilometers. Assuming a conservative average 6 m right-of-way for seismic lines yields a minimum footprint of >12,000 km^2.

Text Box 14.1. Estimating Seismic Line Extent
I asked the Alberta Biodiversity Monitoring Institute (ABMI) to comment on the observation that their footprint data underestimated the true seismic line extent. Their reply is excerpted (pers. comm., 27 March 2018): "Readers may not appreciate the limitations presented by using satellite imagery to capture all seismic lines in the region. The geographical extent is enormous and the human resources required to do the work in a timely manner is significant. Next, the scale at which the ABMI captures seismic line information doesn't support the capture of low-impact-seismic [LIS] category. [LIS]... are visible on imagery at scales of approximately 1:5000 (they are approx. 3m wide). Sometimes even at this scale and at the resolution of SPOT imagery, it can be difficult to fully capture the presence and identity of this category."

Roads

The total length of Alberta's road network as of 2014 was estimated at 742,575 km (ABMI footprint data, all uses). If we assume that one-third of the road network is devoted to the fossil fuel industry, and a conservative footprint of a 10 m right-of-way, yields a ballpark road footprint of 2475 km^2.

The extensive network of roads connecting wells, pipelines, and facilities imposes a host of ecological impacts, the most important of which are permanent habitat loss, disruption of hydrologic regimes, declines in water quality, and changes in the movements of materials, plants, and animals. Compacted road materials inhibit the lateral flow of water and disrupt nutrient regimes, productivity, and vegetation patterns. Even well-maintained culverts fail to emulate natural water flows. Wherever roads cross wetlands, the impervious fill inhibits the flow of water and nutrients. Excessive water and nutrients accumulate on the upstream side of roads while the wetlands on the downstream sides of roads dry out. Industrial road crossings cause chronic stream sedimentation and often create hanging or blocked culverts that present barriers to movement, both of which harm habitat and fisheries.

An evaluation of road culverts in the Kakwa River region of western Alberta found that 72 % of culverts posed a significant erosion and sedimentation hazard and 57 % of culverts posed barriers to fish movements (Johns and Ernst 2007).

Given that poorly-constructed and poorly-maintained culverts degrade stream and fish habitat, the researchers concluded that watershed managers should monitor, maintain, and replace culverts more frequently than less hazardous structures such as bridges.

Roads also provide habitat for weedy species (Figure 14.3) and act as a conduit for invasion of exotic species. Much of the network of roads servicing the fossil fuel industry has been salinized to varying degrees and is often dominated by weedy, exotic, salt-tolerant species such as foxtail barley and scentless chamomile. Wildlife/vehicle collisions, increased dust, increased access by recreational hunters, poachers, and off-road vehicle users, and the roadside use of herbicides add to the stresses.

Web 14.1.1. Road salinization and climate change in Alberta

Road salinization is a widespread problem that isn't restricted to fossil fuel industry roads. Increasingly, the effects of salinization and climate change are interacting to produce novel plant communities. I provide one example from the roadside in front of our home in the boreal mixedwood region of central Alberta. Green foxtail (*Setaria viridis*) is a well-known salt tolerant exotic grass of global distribution in temperate regions. It reached North America as early as 1821. As a result of climate change, the species is expanding its geographic range northward. Around 2015 it invaded the rural roadside in front of our home. The cause of the invasion? Our rural road was reclassified as a provincial highway and the road salting rate increased. Since that time, green foxtail has appeared and spread along with other halophytes such as foxtail barley, Nuttall's salt-meadow grass, and rayless aster while reed canary grass has taken over the roadside wetland. Conductivity measurements in the soil and water near the highway and at control sites on our land confirm that the culprit is road salting.

Web 14.2. Contaminated sites, orphan wells, disputed ownership, and remediation: Who pays?

Disputed ownership and abandoned energy sites present growing concerns about cumulative effects. Abandoned industry sites exist in a continuum from well-maintained sites to those that expose wildlife to a variety of hazardous materials. Although the hope would be that abandoned contaminated sites are an exception (Figures 12.8, 12.10), abandoned sites are common wherever hydrocarbons are exploited. Who is responsible for their clean-up? Ownership of industry sites is often in flux and contested responsibility can result in debris and contaminants being left on site indefinitely. What is the impact of these sites on the health of the ecosystems, on groundwater, and on wildlife? No one knows. Who will pay for their remediation? That industry sites can be abandoned without clean-up would seem improbable in a first-world jurisdiction. Yet abandonment without clean-up can happen when there is disputed ownership and therefore responsibility, or when there is no ownership due to bankruptcy. The Orphan Well Association was established to deal with such properties. As of 29 January 2018, the association had registered 1794 wells and 2269 pipeline segments for abandonment, 1103 wells and 1333 pipeline segments for suspension, and 817 sites for reclamation (OWA 2018). The number of abandoned sites that have not been registered with the Orphan Well Association is not known but exceeds 170,000 wells alone (Chapter 8).

The likelihood that contaminated sites will receive no remediation increased in 2016 when Alberta's Court of Queen's Bench ruled that a company's creditors held precedence over environmental regulations and found that the trustee for Redwater Energy, a company placed in receivership, was not financially responsible for clean-up of the company's 127 properties (Bakx and Seskus 2018). That decision was upheld by the Alberta Court of Appeals. Since that time, 1800 AER-licensed sites have been abandoned with estimated liabilities of more than $110 million and the inventory of the Orphan Well Association has tripled. The court decision reduced environmental and safety obligations to unsecured monetary claims that could reach $8.6 billion dollars (an underestimate, see below). Encouragingly, in January 2019, the Supreme Court of Canada overturned the lower court decisions and ruled that energy companies cannot abandon their clean-up obligations when declaring insolvency (Johnson 2019). Although this decision is helpful, the unsettling truth is that 99.4 % of the environmental liability of the fossil fuel industry in Alberta remains unsecured.

The Supreme Court decision, while properly concluding that companies are responsible for their environmental clean-up, has had an unintended consequence (W. Donahue, pers. comm., January 2020). Because the old approach of shielding companies from their environmental financial liabilities is gone, some companies that were financially viable under the old system are no longer viable. In reality, many companies were economically viable only as long as society paid for their liabilities or simply accepted the harm. The new reality has caused a rash of bankruptcies and a surge in the number of unfunded abandoned industry leases. The short-term effect is that society is inheriting greater environmental and financial liabilities, but we would have inherited the debt anyway because the companies never intended to pay for the harm they caused. The long-term effect is positive in that the future damage caused by unviable companies will be avoided because they'll declare bankruptcy sooner than later. But for governments in Alberta and elsewhere that have based their solvency on unfettered growth of the hydrocarbon industry, the unpleasant part of a Faustian bargain awaits payment.

The financial liabilities continue to grow. In November 2019, Houston Oil and Gas entered receivership, abandoning 1264 wells, 41 facilities, and 251 pipelines in Alberta (Bakx 2019). Although the AER has estimated the company's liability at $81.5 million, its liability estimates are suspect (see below). If all of Houston's wells are added to the

Orphan Well Association, its inventory of wells will rise by about 37 %, and that's just from one insolvent company. Alberta MLA Dr. David Swann has witnessed this process firsthand. He observes that conventional fossil fuel companies have been losing money since 2009 and have taken to transferring unproductive wells to junior companies with an increasing number of companies taking what they can get and walking away from clean-up obligations (Swann 2019). He notes that governments continue to turn a blind eye to industry clean-up liabilities because both government and its "so-called 'arms-length' regulators ... have been captured by the industry and the Orphan Well Association... is now lost in a sea of insolvencies, begging for public money."

The situation could get much worse, and quickly, as energy prices slump and large companies such as Shell transfer wells, facilities, and pipelines to small companies such as Pieridae Energy with insufficient assets to deal with large environmental liabilities. A resident of the Shell gas field in the foothills of southern Alberta summarized the problem: "Our children and our grandchildren are going to end up with an environmental cleanup that is way beyond their capability to deal with" (Weber 2019). The Pieridae sale was seen by observers as a test of the AER's responsibility to prevent transfer of company liabilities to taxpayers. In a surprise decision in May 2020, the AER refused to allow the transfer of licenses from Shell to Pieridae for the 284 wells, 66 facilities, and 82 pipelines (predominantly involving sour gas) because the application split the clean-up liabilities into past (Shell) and future (Pieridae) (Weber 2020). According to the AER, this maneuver would reduce clean-up incentives and nullify some enforcement measures.

The process by which insolvent companies game the system at the public's expense has been dubbed the "Manitok Maneuver" (Appel 2020). It works like this: Manitok Energy declared bankruptcy in February 2018 and transferred 181 wells, 31 facilities, and 282 pipelines to the Orphan Well Association (OWA). The financial liability for the wells alone was estimated at $72 million dollars. In late February 2018, Persist Oil and Gas was established and headed by the former CEO of Manitok Energy; the new company even retained the old Manitok phone number. By November 2018, Persist had acquired all 942 of the non-OWA wells, facilities, and pipelines. The "Manitok Maneuver" allowed the company to avoid paying its environmental liabilities by transferring those liabilities to the now taxpayer-funded OWA. Doing so is illegal according to the recent Supreme Court of Canada decision, but the enforcer of the regulation is the AER, which has become the paragon of regulatory capture and corruption.

As of November 2019, the number of registered orphan wells had grown from 1794 to 3400, which is a lot of orphan wells, but it represents only 2 % of the 170,000 abandoned wells in Alberta, a colossal ticking time bomb of future public liabilities. The financial and environmental liabilities posed by the fossil fuel industry in Alberta are enormous. A recent internal AER report revealed that the estimated liability of shutting down and cleaning up all fossil fuel industry sites in Alberta was $260 billion dollars, $200 billion more than the liability figure released publicly by the regulator (Jarvis et al. 2018). The AER responded to the uproar caused by release of that report by apologizing for the "concern and confusion that this information has caused" and added that "using these estimates was an error in judgment and one we deeply regret".

When the regulator was asked if it disputed the $260 billion dollar liability it stated that the estimate had "not been validated". It's unlikely that the calculations and findings were not confirmed by the regulator before they were released. The report presented by AER's vice-president of its closure and liability branch in a private meeting with industry revealed that the high financial liability resulted from flawed oversight. The regulator's report noted that the public liability estimate of $58 billion dollars was derived from industry-reported data whereas the $260 billion dollar estimate was derived from calculations by the regulator's experts. The report, disowned later by the regulator, cautioned that provincial officials need to act quickly to ensure that taxpayers are not left responsible for the financial liability.

Although industry and government have for decades assumed that abandoned seismic lines regenerate to their former vegetation cover, that assumption has been based more on hope than on evidence. The assumption of wholesale natural regeneration has now been disproven by numerous studies. More than two million kilometers of seismic lines exist in Alberta, cumulative seismic line length is growing each year, and the cost of seismic line reclamation has been estimated at $3066 to $4466 per km, not including access and monitoring costs (van Rensen et al. 2015). The eventual cost of seismic line reclamation may exceed $10 billion. One would have to be preternaturally optimistic to believe that such reclamation will occur on the scale necessary to restore whole landscapes.

The industry's unfunded clean-up costs have been kept off the balance sheets through creative bookkeeping practices (Boychuk 2018). The costs are hidden in five ways: by using absurdly low cost estimates for clean-up; by delaying payments of clean-up costs far into the future; and by discounting costs over long time periods to arrive at a net present value that estimates the costs at less than one penny for every dollar of real costs; by using reclamation standards that are so low they are easy to achieve; and by its failure to monitor and ensure that reclamation has met standards. The accounting allows insolvent companies to continue operating at profit until the companies' executives exit via the bankruptcy escape hatch. As of 2018, the AER's internal report calculated the clean-up liabilities at $130 billion for bitumen mining, $100 billion for oil and gas and *in situ* production, and $30 billion for pipelines. In comparison, $1.6 billion dollars have been collected in securities to cover this $260 billion dollar liability, leaving 99.4 % of liabilities unsecured. Currently in Alberta, companies avoid the costs of abandonment and reclamation by instead paying annual compensation fees and thereby defer the day of reckoning into the distant future (Hartshorn et al. 2015). The financial solvency and environmental health of Alberta have been endangered by the industry and its complicit partners. When the ravens come home to roost, the industry and regulatory executives along with their politician allies will be long gone.

Where does this leave us? It's unrealistic to hope that the industry will meet its financial obligations. The almost certain future is that the public will be left with crushing liabilities, that government will not be successful in convincing taxpayers to pay for the mess, and that the majority of sites will be left unremediated. Moreover, given that all scientific evidence demonstrates that, even after remediation, fossil fuel industry sites are impaired ecologically, the environmental liabilities will be as crushing as the financial liabilities.

Private profits and public liabilities are not restricted to Alberta. Royal Oak Mines, near Yellowknife, Northwest Territories, operated the Giant gold mine from 1948 to 1999 then declared bankruptcy. Remediation of the mine then became the federal government's responsibility and the Canadian taxpayer's liability. The project, contracted to a U.S. company, is expected to take ten years to complete and cost $900 million (CBC 2018), and that value does not include the costs of remediating the contamination that extends beyond the mine site. On a smaller scale than the Giant Mine, yet more damaging in their impact, are the thousands of abandoned contaminated sites spread across Canada, often in people's backyards. Underground fuel storage tanks at gas stations are perhaps the most prevalent contaminated sites. Depending on the jurisdiction, laws may exist to manage contaminated sites, but enforcement tends to be lax.

The burden to manage contaminated sites often falls on local governments without the resources to hold the responsible parties to account. In Edmonton, these contaminated sites are known as "dead zones", abandoned lots that pockmark communities like scabs. Even in Vancouver and Los Angeles, with their high land values, the cost of remediation can exceed the value of the lots. Contaminated sites can persist for decades while the landowners sell the lots to unsuspecting parties, pay yearly taxes to delay clean-up, pay lawyers to contest responsibility in court, or if ordered to clean up a site, complain to appeal boards, which often side with the polluters. The result is an underground community scourge. The contamination is another impact of our dependence on fossil fuels.

Web 14.3 Reclamation concerns

During reclamation, introduction of exotic or inappropriate species is widespread. This creates ecological uncertainty about the future of the sites, but the uncertainty runs deeper. Most often it's not known what plant species were used at reclamation sites (Text Box 14.3). Energy companies don't conduct the reclamation. Instead, they hire reclamation companies, which in turn, may subcontract other reclamation companies. Reclamation companies procure their seed from seed suppliers who sometimes mislabel the species or use common or trade names that are equivocal. Although there are recommended species for planting, the recommendations aren't mandatory and native species aren't required. Government doesn't oversee or verify the taxa, genetics, or places of seed origin. Nor do the energy companies have the expertise to verify the plant species used by the reclamation companies. The tendency is to use whatever plant species are readily available, inexpensive, fast growing, and tolerant of disturbance and impaired soil conditions.

Few people know what species are being introduced, intentionally or unintentionally, to the landscape. The reclamation certification process similarly rests on the shaky ground of regulatory capture. Two reclamation biologists related their concerns to me after an Alberta Energy Regulator 2014 training course on Detailed Site Assessments (DSAs) of former well sites and roads. They were astonished to learn that companies hired for site reclamation were also hired to assess and certify their own reclamation work. Reflecting on the training course, the biologists were "concerned

Text Box 14.3. Major Unknowns-- Plant Species Introduced at Reclamation Sites

Ecologists visiting industrially reclaimed sites should be prepared for surprises. In summer 2016 at the 11-26 Apache spill site, an employee informed me they were planting black spruce, larch, lodgepole pine, and willow. Reclamation staff on site were unable to tell me the species of willows being planted, the provenance of any of the species, nor why lodgepole pine, a species that doesn't grow in the area, was being planted. Many of the planted tress and shrubs will probably die due to residual soil salts. In all likelihood, the 11-26 reclamation will result in an impaired soil and plant community along with an excavated pond that poses risks to wildlife as observed at the 15-09 Apache saline spill site (see the book Addendum).

I asked a botanist who has studied fossil fuel industry sites to summarize some of the uncertainties posed by introducing reclamation species: "Exercise caution in taking anything as fact what an energy company says it seeded. They might cite what they recommended, what a botanist/environmental consultant recommended, or what regulations recommend (as in the case of some public lands). However, the people that you talk to may be one to three steps removed from the person who bought the seed, who may have made an executive decision to change it to save money or align with seed availability, or they may have been deceived, or they may have made an honest mistake in thinking one species of a genus can be exchanged for another (as in the case of sheep fescue being substituted for plains rough fescue). Your difficulty in getting this information is not uncommon. I studied 53 well sites and pipelines at Rumsey for my M.Sc. and few if any of the seed mixes identified was what actually went into the ground. Almost all sites did not have a mix on record ... with clear deviations from the recommendations showing up in an assessment 10 to 20 years later" (M. Elsinger, Rangeland Biologist, pers. comm., 12 September 2016).

See Web 10.3 for more on introduced species.

that in a class of 15-20 people, there was only one other person able to identify the plant species in tame and native grasslands and woodlands... None of the other people would have been qualified to conduct a DSA in natural vegetation. Whether they confined their assessments to cultivated land, we don't know, but we suspect that they did not" (names withheld, pers. comm., April 2019).

Although allowing a reclamation company to certify its own work constitutes a conflict of interest, analogous to allowing a political party to be in charge of polling stations, it's consistent with the behavior of a captured regulator. All functions have been brought under one roof at the AER. The regulator promotes and approves hydrocarbon development, allows self-reporting and self-certification, and facilitates private profits while externalizing financial and environmental liabilities onto the public. Its corrupt certification process contributes to reclamation failure, the introduction of non-native vegetation, and impaired soils.

Web 14.4. Impacts upon the Dene Tha First Nation and other First Nations

The lives of First Nations peoples, often the first and most affected by industrial activities, have been forever changed by the cumulative effects of the fossil fuel industry. Many struggle with what is going on around them and strive to continue to see their past, present, and future in a landscape that is irrevocably transformed (Parlee et al. 2012). All who are connected to and dependent upon the land have been deeply affected by violation of treaties and the Natural Resources Transfer Agreement (Parlee et al. 2012). The cumulative effects have been sufficiently profound that the United Nations has adopted a formal declaration of indigenous rights in hope that governing parties will act to prevent the worst of abuses (Web 14.2).

The impacts of the fossil fuel industry upon the Dene Tha First Nation have been significant (Stevenson, n.d.). Industry has undermined biodiversity and the ability of the Dene Tha to conduct traditional activities. Seismic lines, roads, and other linear disturbances attract weekend hunters and reduce or displace moose, bear, caribou, and furbearers. Spills reduce water quality and damage the health of animals. Herbicides are used to control vegetation at industry sites (Figure 14.5). Flare stacks and compressor stations are a constant source of noise and air pollution. Industrial activities increase airborne dust and suspended matter in water. Well sites leak harmful chemicals, and by attracting animals, expose wildlife to human conflicts and contaminants. Energy activities have reduced moose, caribou, songbirds, and waterfowl.

These impacts have changed how the Dene Tha exercise their treaty rights. One hunter observed “my family has been impacted by all the oil and gas and forestry... We cannot go into areas that [we] once did and want to go. We cannot make a living as we once did from hunting, fishing, and trapping. There are less animals in the areas around the communities where we live as they have been covered by roads, pipelines, and cut blocks. …The animals are shifting and moving to places further away from us”. The Dene Tha no longer drink water from the land and believe that it smells, tastes, and looks different. They now take bottled water into the bush. Many Dene Tha have stopped hunting moose and other animals near energy facilities, or where they can smell gas, for fear of contamination. Concerns over contaminants have displaced Dene Tha hunters five to thirty kilometers from suspected contaminant sources, depending on perceived risks, which has estranged many Dene Tha from their traditional lands. Cumulative impacts force Dene Tha hunters to travel farther in search of animals.

In addition to damage to their lands, the Dene Tha have had to cope with misinformation and failures to inform from both the AER and the National Energy Board (NEB). In response to a major gas pipeline explosion and a failure by the NEB to release the incident report to the community, Baptiste Metchooyeah stated: “They should let the public know about these deficiencies... We have to start saying something about these incidents because the regulator is not there for us” (Hildebrandt 2014).

The impacts upon the Dene Tha are felt by other First Nations. In the wake of a 200 m^3 pipeline spill of crude oil in January 2017 spill on the Ocean Man First Nation in Saskatchewan, emotions in the community ranged from anger to sadness (Dao 2017). Clint Big Eagle had been detecting a “greasy smell” in the air for at least ten days when he decided to search for and later discovered the spill. Mr. Big Eagle was “sick and angry”. He observed “It’s not just a little leak when it fails, it gets real terrible real fast.” As is often the case, it was a First Nations person who discovered the spill. Government stated that local air quality and wildlife had not been affected.

In July 2016, a Husky Energy pipeline spilled about 225 m^3 of crude oil along the banks of the North Saskatchewan River near Maidstone, Saskatchewan (Canadian Press 2018). An estimated 90 m^3 entered the river and endangered the water supply of tens of thousands of people. Three cities were forced to shut down their water intakes for almost two months. The James Smith First Nation, after observing that crude oil remained in the water, soil, vegetation, and debris on its land, filed a lawsuit against the Saskatchewan government for failing to act on pipeline safety recommendations made by the province’s auditor general. The auditor general’s report concluded that some regulations were being ignored and that the government did not have the resources to ensure its regulations were being followed. Husky was later charged by the Saskatchewan government for unlawfully permitting the discharge of a substance that caused an adverse environmental effect and was also charged by the federal government under the Fisheries Act and the Migratory Birds Convention Act (Canadian Press 2018). Prince Albert’s Mayor Greg Dionne observed that “Now that I know there are more pipelines than I ever assumed there were, and crossing under waterways that concerns me even more because that tells me it could happen again.” In June 2019, Husky pled guilty and was fined a total of $3.8 million dollars. Investigation found that the pipeline leak detection system did not provide location information; 900 km of shoreline had to be searched before the leak was found. As with too many spills, it was reported not by the company but by a civilian and later by a third party operator (CBC 2019).

After two train derailments near Gogoma, Ontario in February and March 2015, the Mattagami First Nation filed a lawsuit against CN Railway (Olthuis et al. 2018). The lawsuit alleged that the spills released millions of liters of crude oil that damaged traditional land and water and compromised the ability of the Mattagami to exercise their aboriginal and treaty rights. Chief Chad Boissoneau observed “This is our homeland. Harvesting, hunting and fishing here have always been central to our livelihood and central to who we are. Because of the oil spills, many of our people don’t go out on the land anymore. We can’t gather the food we need... It’s devastating... It’s not right that CN Railway should be allowed to ignore safety measures and dump oil into our homeland. We’re the ones who have to live with the damage” (Mattagami First

Nation 2017). The derailments were caused by failure to properly inspect, maintain and repair railway tracks and by deficiencies in the company's training and safety systems.

The Lubicon Cree of north-central Alberta have faced industry impacts for decades. One of the largest spills in Alberta's history, a release of 4500 m^3 of crude oil from a Plains Midstream pipeline in April-May 2011, illustrates their difficulties (Figure 14.6). The Lubicon experienced nausea, burning eyes, and headaches; the community closed its school and ordered children to stay at home (CBC 2011). Oil-covered beavers and waterfowl at the spill were euthanized. The principal of Little Buffalo School observed that children and staff "were disorientated, getting headaches and feeling sick to their stomachs. We tried to send the children outside to get fresh air as it seemed worse in the school, but when we sent them out they were getting sick as well." The Lubicon Chief Steve Nosky stated that "The ERCB [former name of the AER] is not being accountable to our community; they did not even show up to our community meeting to inform us... The company is failing to provide sufficient information to us so we can ensure that the health and safety of our community is protected."

A spokesperson for the regulator said he did not believe that the Lubicon people were getting sick from the spill and surmised that the illnesses may be related to a nearby oil and gas installation, to an asphalt operation, or to feed lots. The AER record for this spill states that the public was not affected. The spill prompted then New Democratic Party leader, Rachel Notley, to call for an investigation into how the province inspects pipelines. Notley said the public needs to know that government has sufficient staff to properly inspect pipelines. She alleged political interference may have been involved in delaying public notification of the spill until after a federal election. When the regulator first reported the incident, just before the election, it suggested the leak would total hundreds of barrels of crude oil. The revised estimate, released after the election, was 28,000 barrels. Notley observed "Either there's an incredible inability on the part of this government to know what's going on on the ground, environmentally ... or we have evidence of political interference..." Ms. Notley was later elected Alberta's premier and became an ardent supporter of the regulator, the fossil fuel industry, and the status quo.

During August 2013 anthropologist Tristan Jones paddled down the Athabasca River from Fort McMurray to Fort Chipewyan with a group of ten people to bear witness to the toll of hydrocarbon development. People along the river offered consistent advice: "don't drink the water; don't eat the river's fish; it's best if you don't even clean your pots with the river water. It wasn't always like this." Jones met John Bonnetrouge [pseudonym], a Dene living along the lower Athabasca River, and asked him what he thought of the recent oil spill. John observed "Oil was floating down the river here not long ago, a month ago… These people told my band... it was natural. That's not natural… My ...[friend] was driving [his boat] down the river and all of a sudden he notices that he's in the frigging river full of frigging oil. The whole thing was covered with oil... [from bank to bank]".

In Fort Chipewyan, Jones asked about the changes people had seen. A resident recalled: "We used to fish all over the area of the delta, up on Lake Athabasca, up the lake for about 20 miles... I remember as a kid... you check your net – all the fish that come out, they're this clean and healthy looking. The water and everything is just clean. You could just take them... home and eat them... The fish now, they're having red spots, they're covered in red and they're deformed. So something's happening in the water.

"This spring we had also a die-off of fish in three or four different locations throughout the delta. So what's causing these fish to die? Is it the water? In my opinion, it has to be the water... We also had a die off of seagulls – young seagulls about a month ago [around the same time as the spill Bonnetrouge described]... I counted three hundred seagulls in about maybe half a kilometer... all dead along the shore. It's sad to see that. Never seen that before in the forty years I been in this delta. I talked to the elders, they'd never seen that too. So something's in the water that's killing the birds and the fish...Once you damage the environment, how long does it take to bring it back? ... [People] keep telling stories and nobody's listening,.. it looks like nobody cares."

Denials of environmental and public health impacts, underestimates of spill volumes, failure to listen to or notify affected parties, failure to provide information, and disproportionate impacts on First Nations people continue unabated.

Web 14.4.1. United Nations Declaration on the Rights of Indigenous Peoples

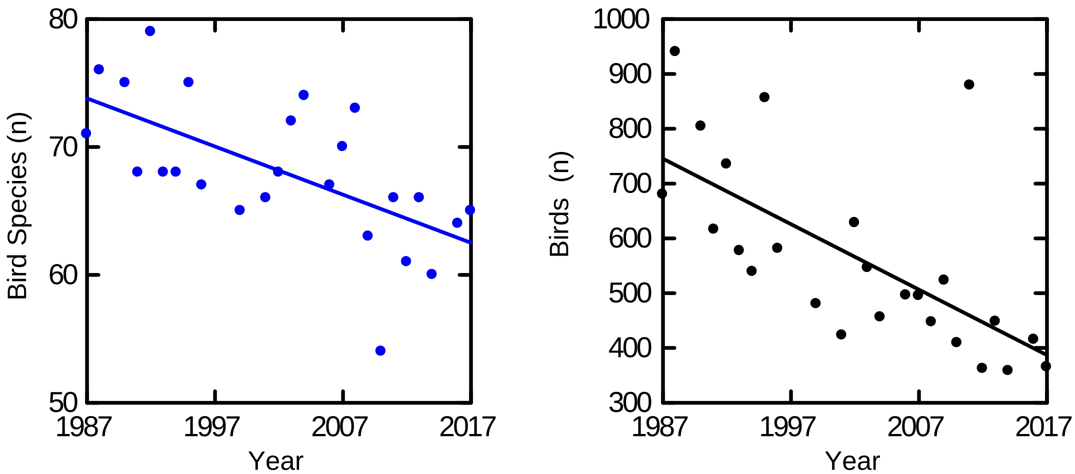
The General Assembly of the United Nations (UN 2008) has adopted a declaration on the rights of indigenous peoples. Many articles of the declaration bear directly upon the situation faced by Indigenous peoples, including the Dene Tha First Nation, attempting to cope with the cumulative impacts of the fossil fuel industry. The declaration states:

"Indigenous peoples have the right to their traditional medicines and to maintain their health practices, including the conservation of their vital medicinal plants, animals and minerals...
Have the right to maintain and strengthen their distinctive spiritual relationship with their traditionally owned or otherwise occupied and used lands, territories, waters and coastal seas and other resources and to uphold their responsibilities to future generations in this regard...

Have the right to the lands, territories and resources which they have traditionally owned, occupied or otherwise used or acquired...
Have the right to own, use, develop and control the lands, territories and resources that they possess by reason of traditional ownership or other traditional occupation or use, as well as those which they have otherwise acquired...
Have the right to the conservation and protection of the environment and the productive capacity of their lands or territories and resources. States shall establish and implement assistance programmes for indigenous peoples for such conservation and protection, without discrimination...
Have the right to determine and develop priorities and strategies for the development or use of their lands or territories and other resources...
[And that] States shall give legal recognition and protection to these lands, territories and resources. Such recognition shall be conducted with due respect to the customs, traditions and land tenure systems of the indigenous peoples concerned...
Shall take effective measures to ensure that no storage or disposal of hazardous materials shall take place in the lands or territories of indigenous peoples without their free, prior and informed consent...
Shall consult and cooperate in good faith with the indigenous peoples concerned through their own representative institutions in order to obtain their free and informed consent prior to the approval of any project affecting their lands or territories and other resources, particularly in connection with the development, utilization or exploitation of mineral, water or other resources...
[And] shall provide effective mechanisms for just and fair redress for any such activities, and appropriate measures shall be taken to mitigate adverse environmental, economic, social, cultural or spiritual impact."

In a recent report on the rights of Indigenous peoples in Canada, the United Nations Special Rapporteur (Anaya 2014) concluded:
"Indigenous peoples' concerns merit higher priority at all levels and within all branches of government, and across all departments. Concerted measures, based on mutual understanding and real partnership with aboriginal peoples, through their own representative institutions, are vital to establishing long-term solutions. To that end, it is necessary for Canada to arrive at a common understanding with indigenous peoples of objectives and goals that are based on full respect for their constitutional, treaty and internationally recognized rights."

Web 14.5. Trends in breeding birds in the Swan River area of northern Alberta over the period 1987-2017.



Comments:
The data show clear downward trends in the number of breeding bird species and in the abundance of breeding birds. Over the thirty-year period 1987-2017, the number of bird species declined 14 % while the overall abundance of breeding birds declined 47 %.

Linear regression of total bird species (y) by year (x) and total number of individuals (y) by year (x):
Pearson r = -0.626 (bird species) and r = -0.661 (bird individuals), both n = 25, both $p < 0.001$.

Data downloaded from: https://www.canada.ca/en/environment-climate-change/services/bird-surveys/landbird/north-american-breeding/overview.html. The Swan River breeding bird survey route is 04-251.

Web 14.6. Breeding bird species that have decreased or increased in abundance in the boreal taiga plains region of Alberta over the period circa 1970-2015.

Common Name	Annual Trend (%)	Change (%)
Decreasers		
Black-billed Magpie	-1.42	-47.5
Yellow Warbler	-1.55	-50.4
American Kestrel	-1.59	-51.3
European Starling	-1.69	-53.6
Clay-colored Sparrow	-1.88	-57.5
American Wigeon	-2.2	-63.2
Song Sparrow	-2.21	-63.4
Spotted Sandpiper	-2.25	-64.1
Mourning Warbler	-2.37	-66
Red-winged Blackbird	-2.49	-67.9
Savannah Sparrow	-2.5	-68
Mallard	-2.67	-70.4
Alder Flycatcher	-2.78	-71.9
Traill's Flycatcher (Alder/Willow)	-2.89	-73.3
Common Yellowthroat	-2.93	-73.7
Least Flycatcher	-3.11	-75.9
Olive-sided Flycatcher	-3.15	-76.3
Northern Harrier	-3.16	-76.4
Varied Thrush	-3.2	-75.3
Eastern Kingbird	-3.48	-79.7
Le Conte's Sparrow	-3.74	-82
Black Tern	-3.99	-84
Barn Swallow	-4	-84.1
Yellow-headed Blackbird	-4.4	-86.8
Northern Pintail	-4.43	-87
Baltimore Oriole	-4.8	-89.1
Northern Oriole (Bullock's/Baltimore)	-4.8	-89
Lesser Yellowlegs	-5.22	-91
Western Wood-Pewee	-5.27	-91.2
Common Nighthawk	-5.52	-92.2
Killdeer	-5.6	-92.5
American Bittern	-5.96	-93.7
Lesser Scaup	-6.02	-93.9
Brewer's Blackbird	-6.2	-94.4
House Sparrow	-6.34	-94.7
Increasers		
Ovenbird	1.48	93.7
Rose-breasted Grosbeak	1.83	126
Pileated Woodpecker	2.2	167
Solitary Vireo (Blue-headed/Cassin's)	2.48	201
Blue-headed Vireo	2.89	260

Orange-crowned Warbler	2.95	269
Ring-necked Duck	3.15	304
Bufflehead	3.16	306
Sandhill Crane	3.55	381

Comments:
Significant population trends are filtered to those species with at least a 95 % probability of decrease or increase, 95 % confidence intervals that are < 0 for decreasers and > 0 for increasers, and medium to high data reliability.

Thirty-five breeding bird species decreased and nine species increased in abundance in the Alberta portion of the Breeding Bird Survey boreal taiga plains region over the period 1970-2015.

Overall, 38 % of the species (35 out of 93 species with medium to high data reliability) decreased while 10 % of the species (9 out of 93) increased.

The news is not all bad. Two species that decreased in abundance, house sparrow and European starling, have a negative effect on some native bird populations.

Species are sorted by magnitude of the annual population trend.

Data downloaded from: https://www.canada.ca/en/environment-climate-change/services/bird-surveys/landbird/north-american-breeding/overview.html. Breeding bird survey region is the Alberta portion of BCR-6.

Web 15. Components and representatives of the hydrocarbon meta-organization in Canada

Legitimators (Media)	Enablers (Educational and Research Institutions)	Enablers (Industry-sponsored Monitoring)	Enablers (Enforcement, Surveillance, Security)
Calgary Herald	Grant McEwan University	Alberta Biodiversity Monitoring Institute	Canadian Security Intelligence Service
Edmonton Journal	Northern Alberta Institute of Technology (NAIT)	Cumulative Environmental Management Association	Private Security Companies
National Post	Royal Society of Canada	Fort Air Partnership	RCMP
Rebel Media	University of Alberta	Regional Aquatics Monitoring Program	
Wall St. Journal	University of Calgary	Wood Buffalo Environmental Association	Political Parties (Policy, Legislation)
			Conservative Party of Canada (federal)
Legitimators (Think Tanks, Promoters)	Regulators	Governments (Policy, Legislation)	Saskatchewan Party (Saskatchewan)
Business Council of Canada	Alberta Energy Regulator	Federal	United Conservative Party (Alberta)
Canada West Foundation	National Energy Board	Provincial	
CD Howe Institute	North Dakota Ministry of Health	State	Enablers (Lobby Groups, Industry Organizations)
Energy Council of Canada	Saskatchewan Ministry of Energy and Resources	(Municipal)	Canada Action
Fraser Institute			Canadian Association of Oilwell Drilling Contractors
Macdonald-Laurier Institute	Producers (examples among thousands)	Partners (Production-related Companies)	Canadian Association of Petroleum Landmen
Media and Public Relations Consultants	Baytex	Drilling	Canadian Association of Petroleum Producers
Resource Works	British Petroleum (BP)	Engineering	Canadian Energy Centre ("War Room")
	Canadian Natural Resources Ltd (CNRL)	Environmental Consulting	Canadian Energy Pipeline Association
Enablers (Service-related Companies)	Chevron	Exploration	Canadian Oil Sands Innovation Alliance
Accounting Firms	Enbridge	Laboratories	Energy4Me
Hydrocarbon Marketers	Imperial Oil	Pipeline Construction, Maintenance	Energy Policy Institute of Canada
Law Firms	Husky	Reclamation	Explorers and Producers Association of Canada
Suppliers (goods, services)	Nexen	Shippers (pipelines, railways, trucking, ships)	Inside Education
	Obsidian	Spill Cleanup	Orphan Well Association
	Repsol	Waste Disposal	Petroleum Services Association of Canada
	Shell	Well, Oilfield Service	Petroleum Technology Alliance of Canada

Banks, Asset Managers, Insurance Companies
Financial Foundation of Network

Comments:
The table provides a small sample of the representatives within the vast meta-organization. My purpose here is to illustrate how the tendrils of the meta-organization penetrate diverse sectors within and outside of government.

Although municipal governments lie within the core of the organization as examples of democratic institutions influenced by the industry, they aren't privy to incident and environmental data and therefore lie outside the information firewall.

The Corporate Mapping Project (https://www.corporatemapping.ca/) provides background on many of these groups. As of 2017, it had documented the participation of 1656 organizations and 4433 people and tracked 53,225 relationships within the hydrocarbon meta-organization. Data from the Corporate Mapping Project can be accessed at: https://littlesis.org. Addendum 2 provides an example of the meta-organization as it relates to one company.

Web 15.1. AER responses to ten questions about FIS spills data

Here I illustrate how the regulator responded to ten questions pertaining to spills. I posed the first nine questions in June 2013; these are followed by the regulator's responses (AER 2013b) set in quotes. I posed the tenth question to the regulator in September 2016.

(1) What does it mean when the amount released is zero and the amount recovered is some non-zero number?
"This refers to contaminated soil, snow, fresh water, or surface water recovered in spill and cleanup operations. No soil, snow, fresh water, or surface water was released, but there is a volume that was recovered."

This is misleading. Recovered volumes can exceed spilled volumes for substances such as crude oil, saline/produced water, not just soil, snow, etc.

(2) For a large number of incidents, the volume recovered is equal to the volume released. Does ERCB verify both the volume released and the volume recovered for each spill?
"The AER reviews licensee release reports to confirm incident information and cleanup activities. If the report indicates that the spill was completely cleaned up, it is reasonable that the recovered volume matches the released volume.
In addition to reviewing release reports, AER inspectors will: conduct field inspections on larger release incidents, and conduct field inspections on approximately 10-15% of all other release incidents to verify reported information and cleanup operations."

Little of substance is provided here. AER states that it reviews release reports. What does that mean? Does it simply check the math? AER indicates that if the released volume matches the recovered volume, the recovery is 100 %. What does AER mean when it writes that it field verifies reported information in 10-15 % of incidents? No proof has been provided by AER that spilled and recovered volumes have been verified. The regulator supplied no evidence to support its assertion that it inspects 10-15 % of release incidents. In light of the inaccuracy and unreliability of AER's incident data, skepticism about that assertion is justified.

(3) How would a company achieve 100% recovery of a spill? [and] (4) Especially when the spill is into water?

"If the licensee release report indicates that the spill was completely cleaned up, it is reasonable that the recovered volume matches the released volume; achieving 100% recovery. The recovery of spills into water depends on whether the water is flowing water or stagnant. For stagnant water areas (e.g. muskeg) where removal of the impacted waters occurred, and sampling confirms that there is no longer contamination, it is reasonable that the recovered volume matches the released volume."

This is pure obfuscation and tautology. AER is stating that it accepts the energy company's version of events at face value with no verification: if the "release report indicates the spill was completely cleaned up,... the recovered volume matches the released volume; [sic] achieving 100 % recovery." The scientific literature demonstrates that perfect recovery of spill liquids is not possible.

(5) How does the ERCB determine that there is no effect on wildlife? [and]

(6) Does it conduct a study or get the information from the company?
"The licensee is required to determine the effect of the incident on wildlife and livestock. If the release is a larger incident, environmental contractors and/or provincial wildlife biologists are typically involved to help determine the effects."

Post-spill studies of environmental and ecological impacts are rarely conducted. They are sometimes conducted when: (a) the spill is not under AER jurisdiction; (b) the spills are large; and (c) are reported in the media (e.g., oil spill into Wabamun Lake). In other cases, although a post-spill study may have been conducted, it may have been superficial, flawed, or not made available from the regulator.
Given the paucity of available post-spill studies, statements to the effect that no environmental impacts were observed are not credible. The regulator's dependence on the energy companies to provide scientifically robust data on environmental impacts is neither defensible nor credible. On the rare occasions when a field inspection by AER is conducted, such as at the Apache 15-09 saline spill and Pace-Spyglass oil spill, their observations indicate greater impacts than those reported by industry. Another illustration of industrial underestimation of impacts and the need for mandatory field inspections is provided by an 18 July 2014 release of 80-90 m^3 of saline "flow-back" fluid high in chlorides and boron by Trilogy Resources Ltd (Miller 2016). Trilogy reported to the regulator that the spill had remained on site and had not impacted water. However, a 30 July 2014 AER inspection revealed that the spill had flowed off the lease and had damaged black

spruce wetlands and other wetlands and killed vegetation. AER concluded that Trilogy did not take reasonable steps to assess and contain the spill nor did it recover the spill in a timely and effective manner.
Because the regulator doesn't conduct a standard impact assessment to define an effect, nor establish a threshold for remediation, the regulator is unable to provide a credible assessment of effects on wildlife and habitat.

(7) Why are there no records prior to 1975?
"There are no electronic records of releases/incidents prior to 1975 because information was captured on paper files. The cut off for manually entering paper file records onto the mainframe was 1975."

This is a major deficiency in the regulator's records. The public can't ascertain the nature, location, and volume of spills prior to 1975. Some spills prior to the 1975 cutoff were large and continue to be detectable today as in the Turner Valley area, which Jaremko (2013) described in its heyday as "a dense, wasteful, and hazardous jam of unregulated derricks, offices, and homes." The statement that prior to 1975, "spill information was captured on paper files" is not verified. Jaremko (2013) disclosed that the prior to the mid-1970s, the regulator had no system for recording spill information.

(8) Are there spills that are missing from the database?
"Spills entered in the database have three criteria:
The spill is an unrefined product from upstream installation (such as a gas plants, oil batteries, drilling operations, pipelines, or wellheads)... the licensee has notified the AER, and ...the incident meets reporting criteria. Any unrefined product release is reportable if the spill is: More than 2 cubic metres on-lease...Off-lease... From a pipeline... A sweet gas release greater than 30,000 cubic metres... Any oil, water or unrefined product that may cause, is causing, or has caused an adverse effect as defined in the Environmental Protection and Enhancement Act. In addition to the above reportable releases, there are other incidents reportable to the AER where no spill volume released [sic] such as pipeline hits and fires."

AER didn't answer the question. The question was simple: are there spills missing from the database? The simple answer would be yes or no. AER instead provided criteria for spills to be entered into the database but didn't acknowledge the fact that spills are missing from the database.

(9) What causes ERCB to specify "unknown" as the operator responsible for a release?
"There are occasions when spills of unknown origin are reported to the AER (e.g. if a spill is noticed by passing motorists). The AER will attempt to identify a responsible party for these spills. If a responsible party cannot be identified, the incident will be reported as an unknown spill..."

How does that explain unknown spills at pipelines, batteries, and well pads? How can the responsible party not be known to the regulator?

On 7 September 2016, after analyzing the 2013 version of the AER spill and recovery data as part of this study, I wrote the Alberta Energy Regulator:

(10) The median recovery after oil spills in Alberta is 100.0% in both the Muskeg/Stagnant Water (n = 100 spills) and Air/Land (n = 21,475) categories and 66.6 % in Flowing water (n = 901). Overall, the median oil recovery in Alberta is 100.0% (n = 23,009 spills). Would you please explain how Alberta achieves such high oil recovery rates after spills?
AER (2016b) responded (12 September):
"For every release that is entered into the AER's system, we will send the licensee a Release Report to verify the incident information and the clean-up activities. When the release report is submitted back to the AER, the information is reviewed. When reviewing the Release Report information, and the recovered volumes from a release, if the Release Report indicates that the spill was completely cleaned up (all impacted/contaminated soil removed), then the AER may decide that it is reasonable to enter the recovered volume of the substance released very close to or matching the released volume being that the spill was completely cleaned up. The term "recovered" in the system does not necessarily mean that all of the oil cleaned-up was recycled or reprocessed, as some may have went [sic] to a waste management facility (where there can be some oil removal from the waste prior to disposal), but more so may reflect that the released material was removed/recovered from the environment."

In short, on the basis of an office evaluation, the regulator accepts the spill and recovery volumes as reported by industry.

Web 15.1.1. Correspondence regarding the regulator's prohibition of direct communications between the public and technical experts

Regarding the issue of controlling the public's access to information, I posed three questions to AER Stakeholder Engagement in March 2018. I wrote:

"With regard to the directive that 'all future engagement from yourself or the organizations you are representing, be submitted to the stakeholder engagement branch...', does that directive apply only to me or to all citizens, corporations, companies, organizations, and other entities? Secondly, who is responsible for that directive? Thirdly, was a memorandum distributed to AER staff that prohibited communication with me?"

I waited over two months, and, after sending reminder emails, I received a partial reply to one of the three questions in May 2018:

"Thank you for your patience. Due to an email error, your correspondence of Friday, March 09, 2018 10:15 AM was not actioned in a timely way. We apologize for the delayed response. We have determined that due to the highly technical nature of your requests, input and review from several AER subject matter experts is required in preparing a response. The Alberta Energy Regulator's request that you direct your correspondence to the stakeholder.engagement@aer.ca mailbox was initiated to create a more effective process for preparing accurate, timely and consistent responses in a coordinated manner. We trust this provides clarity to your inquiry."

The regulator's response is double-speak. In place of direct, timely communication with knowledgeable staff, the regulator instituted a policy of slow and uninformative communication with public relations staff. Secondly, the regulator didn't answer the question: did this prohibition of direct contact with scientific and technical staff apply only to me or to everyone? The response implies that the prohibition applies only to me. It's unclear whether such a directive is lawful. Significantly, the regulator didn't answer the questions of who was responsible for the directive and whether a memorandum was distributed to AER staff that prohibited communication with me.

To avoid disclosing damaging information, the regulator chose the time-tested policy of silence. Unknown to the regulator, I knew the answer to the third question because a former AER staff member had informed me that a memo had been circulated prohibiting staff from direct communication with me. I asked the regulator about that memo to ascertain whether it would tell the truth. On 18 May 2018, I wrote: "Did the prohibition of direct communication with scientific and technical staff apply only to me or to everyone? The response implies that the prohibition applies only to me. Is that true? You did not answer the questions of who was responsible for the directive and whether a memorandum was distributed to AER staff that prohibited communication with me. To facilitate your response, you may wish to consult AER communication records that refer to me during the period late 2016 to March 2017. Please answer those questions." The regulator didn't reply.

Web 15.2. Example of an AER online record listing the attributes provided.

Attribute	Example Value
Reference No.	20180118
IncidentDate	2018-01-10
Company	NAL Resources Limited
Location	25 km E Red Deer
Operation Type	Pipeline
Product	Emulsion
Status	No emergency phase
Notification Date	2018-01-10
Volume	30 m^3
Summary	Release occurred due to an issue with a well. Clean up is underway. No reported impacts to waterbodies or wildlife.

Comments:

Online reporting provides limited spill information in comparison to a FIS record (compare this information to that of a FIS Record in Web 2.8).

The AER's online reporting criteria are ambiguous, confused, and applied inconsistently. According to the regulator, spills reported online meet three criteria: they involve hydrogen sulphide, "affect a water body, whether on or off lease"; and involve "hydrocarbon or produced water that migrates off lease or on pipeline right-of-ways". As written, a spill would not be reportable unless it met all three criteria. Inspection of the online data indicates this is not the case.

Of the 1557 spills reported online (data from 16 January 2018), only 29 involved release of hydrogen sulphide. Secondly, spills that do not flow off lease are not reportable (unless a water body is affected), despite the fact that leases are components of ecosystems. Whether a spill occurs on or off a lease is ecologically irrelevant. Thirdly, the criteria for online reporting are more restrictive than for FIS reporting (see glossary).

Even so, FIS reporting criteria allow many spills $\leq 2\ m^3$ to go unreported. The same is true for releases of production gas. Non-pipeline gas releases of $\leq 30{,}000\ m^3$ may go unreported unless there is release off site or if the company believes there is an adverse effect. It isn't stated, but it's relevant, that the company responsible for the spill decides if the spill has affected a water body. Finally, variations in spill volume reporting thresholds over the years (Chapter 6 and Web 6.21) and missing spills (Chapter 8) deepen the uncertainty in the AER's reported spill rates.

The AER has added the following disclaimer to its online Compliance Dashboard:

"The Compliance Dashboard summarizes data collected at different points in time and does not necessarily represent the most current information available. This summary should not be relied upon by any person intending to deal with the company or any property, assets, or interests of the company. This information is provided without warranty of any kind, and the AER disclaims any liability for losses or damages resulting from the use of or reliance on this information."

Web 15.3. Comparison of frequency of crude oil primary spills in Alberta in 2012 by source of spill for the 2013 and 2017 versions of the data.

Source of Spill	Spills in 2012	
Source / Dataset version	**2013**	**2017**
oil well	121	116
multiphase pipeline	109	93
crude oil group battery	67	68
oil bitumen satellite	21	17
suspended well	13	16
crude oil pipeline	11	12
blank (no source provided)	10	9
crude oil single battery	7	7
service well	5	4
crude bitumen group battery	4	2
drilling well	4	4
gas plant acid gas flr/inj	4	5
gas well	4	4
gas proration effluent battery	3	2
custom treating facility	3	2
other pipeline	3	3
water pipeline	3	4
natural gas pipeline	2	1
other injection/disposal	2	2
compressor station	1	1
crude bitumen single battery	0	1
total	397	373

Comments:
Reasons for discrepancies in the number of 2012 spills in the two versions of the regulator’s data were not divulged by the regulator.
Spills from crude oil pipelines represent a small proportion of crude oil spills from all pipelines and only about 4 % of total crude oil spills. The FIS data permit an estimate of the spill rate for crude oil from all pipelines in Alberta. If we examine the FIS data for 2012 (table above), we see there were 397 reported crude oil primary spills, of which 120 spills took place at pipelines; multiphase pipelines accounted for 109 of these spills while crude oil pipelines accounted for only 11 spills. The rate of crude oil spills from multiphase pipelines was about ten times higher than the spill rate from crude oil pipelines.

Web 15.4. Comparison of pipeline incident rates as reported online by AER (2017a) and pipeline incident rates as reported in the AER FIS database.

	Year			
Statistic	**2016**	**2015**	**2014**	**2013**
A. Online Pipeline Releases [a]	460	473	656	540
B. FIS Pipeline Releases [b]				
Crude Oil Pipelines	56	72	63	16
Multiphase Pipelines	168	206	273	235
Natural Gas Pipelines	251	295	297	224
Other Pipelines	115	104	98	46
Sour Gas Pipelines	31	33	36	20
Water Pipeline Releases [c]	105	116	137	122
Total FIS Pipeline Releases [d]	726	826	904	663
Unreported Pipeline Releases [e]	266	353	248	123
Unreported [f] %	36.6	42.7	27.4	18.6

[a] As reported in AER (2017a); values for 2014 and 2013 are from the excel file that accompanied AER (2017a): pipelineperformance.xlsx

[b] Data on pipeline releases from FIS data current to 6 February 2017

[c] Water pipelines carry and spill a variety of toxic substances including saline/produced water, crude oil, waste, and condensate

[d] The total number of pipeline releases from FIS; values are minima because totals do not include source = “unknown” and source = “blank”

[e] Unreported pipeline releases = Total FIS releases – total online releases

[f] Unreported = (Unreported pipeline releases / total FIS pipeline releases) x 100

Web 15.5. Conformity to Benford distribution in total annual emissions of volatile organic compounds as reported for various jurisdictions.

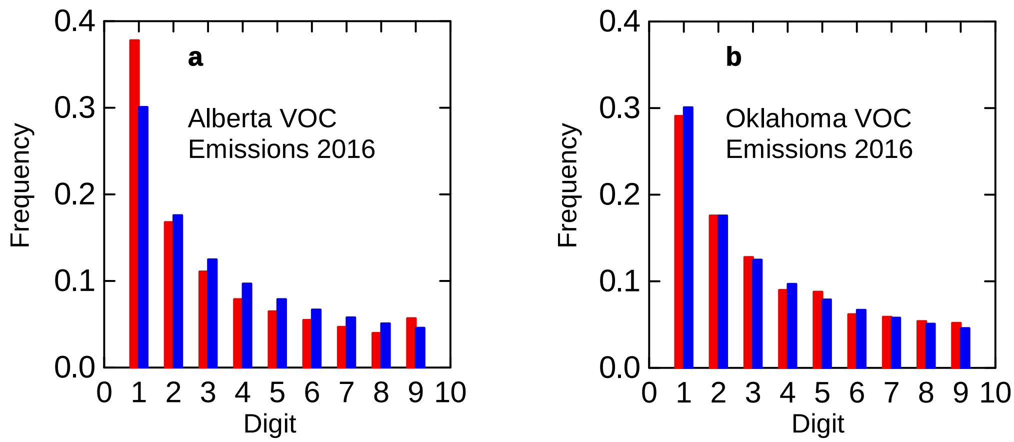
Data are sorted from highest to lowest deviation from the expected Benford distribution.

Dataset, Total Annual VOC Emissions	Dmax	Significance (p)	Comments [b]
Alberta, 2002-2016	0.103	~0 [a]	n = 11490
British Columbia, 2002-2016	0.083	~0 [a]	n = 5038
Alberta, 2016	0.077	$1.5*10^{-4}$	n = 802
Quebec, 2002-2016	0.068	~0 [a]	n = 6614
Saskatchewan, 2002-2016	0.061	$1.7*10^{-7}$	n = 2205
Ontario, 2002-2016	0.039	~0 [a]	n = 13206
North Dakota, 2015	0.033	0.190	n = 1083, conforms to Benford
Texas, 2015	0.032	0.042	n = 1910, nearly conforms to Benford
Manitoba, 2002-2016	0.027	0.465	n = 983, conforms to Benford
Ohio, 2016	0.016	0.053	n = 7075, conforms to Benford
Oklahoma, 2016	0.014	0.327	n = 4616, conforms to Benford

[a] ~ 0 means p value < 3×10^{-8}, the smallest p-value listed in Smirnov (1948); significance was determined with the Kolmogorov-Smirnov statistic for the goodness of fit to the Benford distribution; Dmax is the maximum observed deviation between the observed and the expected cumulative frequencies in the significant digits 1-9 ; n provides the number of records with a value > 0

[b] the most recent datasets available were used in all cases; values reported as tons/year from facilities; Canada provincial data from National Pollutant Release Inventory, https://open.canada.ca/data/en/dataset/40e01423-7728-429c-ac9d-2954385ccdfb, file: NPRI-SubsRele-Normalized-Since1994.xlsx; North Dakota data from www.ndhealth.gov/aq/reporting.aspx, Annual Emission Inventory Reports, 2015, file: ND 2015 Emissions.xls Oklahoma data from http://www.deq.state.ok.us/aqdnew/emissions/inventory_data.htm, file : ODEQ_2016AnnualPointSourceEmissions.xlsx; Texas data from https://www.tceq.texas.gov/airquality/point-source-ei/psei.html, file: 2015statesum.xlsx; Ohio data from http://epa.ohio.gov/dapc/aqmp/eiu/eis.aspx#126013925-download-eis-data-and-reports, file: eis2016.xlsx.

I illustrate deviations between observed and expected frequencies of first significant digits for Alberta and Oklahoma reported VOCS for 2016 in Web 15.6.



Web 15.6. Comparison of observed (red bars) vs. expected (blue bars) frequencies of first significant digits in industry-reported volatile organic compound emissions for 2016.
(a) Alberta; (b) Oklahoma. The Alberta data do not conform to the Benford distribution; the Oklahoma data do conform.

Web 15.7. Estimating condensate releases in raw production gas releases and overall condensate recovery

A study of the 1982 Amoco Lodgepole sour gas blowout estimated a release of 77-97 million m^3 of sour raw production gas and 19-60 thousand m^3 of condensate rained down on 445 hectares (Monenco Consultants 1983; Baker 1990). In comparison, FIS reported a wildly inaccurate release of 9999.9 m^3 raw production gas and 18 thousand m^3 of condensate.

Analysis of the FIS condensate and raw production gas releases suggests that raw production gas release volumes may be underestimates and condensate recovery volumes may be overestimates.

To estimate the total condensate in raw production gas releases over the 2002-2011 period used in the Environment Canada – Health Canada (2016) study, I examined FIS spills that reported both raw production gas and condensate volumes. If the 1982 Lodgepole blowout is deleted because the FIS data are inaccurate, there were 378 such incidents. Total condensate released relative to raw production gas released was 0.000288 m^3 condensate per m^3 raw production gas, which is consistent with reported gas condensate ratios. Therefore, an estimated 90,576 m^3 of condensate may have been released in the 2002-2011 raw production gas release of 314.5 million m^3. This value does not include the condensate released in other spill types such as crude oil and marketable gas releases.

In the FIS data, the median ratio for condensate released:gas released was 0.001 m^3 per m^3, which is a much higher condensate:gas ratio than is typical and suggests that FIS data underestimate raw production gas release volumes. Moreover, the correlation between condensate volume and raw production gas volume was weak (Spearman r = 0.16). There is no ostensible reason for condensate releases to be so weakly correlated with production gas releases. Inaccuracies and human subjectivity in estimating production gas and condensate release volumes may be the explanation.

Reported recovery of spilled condensate was suspiciously high. Of 1698 condensate spills with spill and recovery volumes, 794 spills reported perfect recovery. Median condensate recovery was 90 %, which is remarkably high given the environmental mobility and low boiling point of many condensates. Because the condensate recovery data are suspect, I asked the AER’s Stakeholder Engagement to explain how condensate and production gas volumes are determined. The AER’s response is provided in Web 11.2.6.

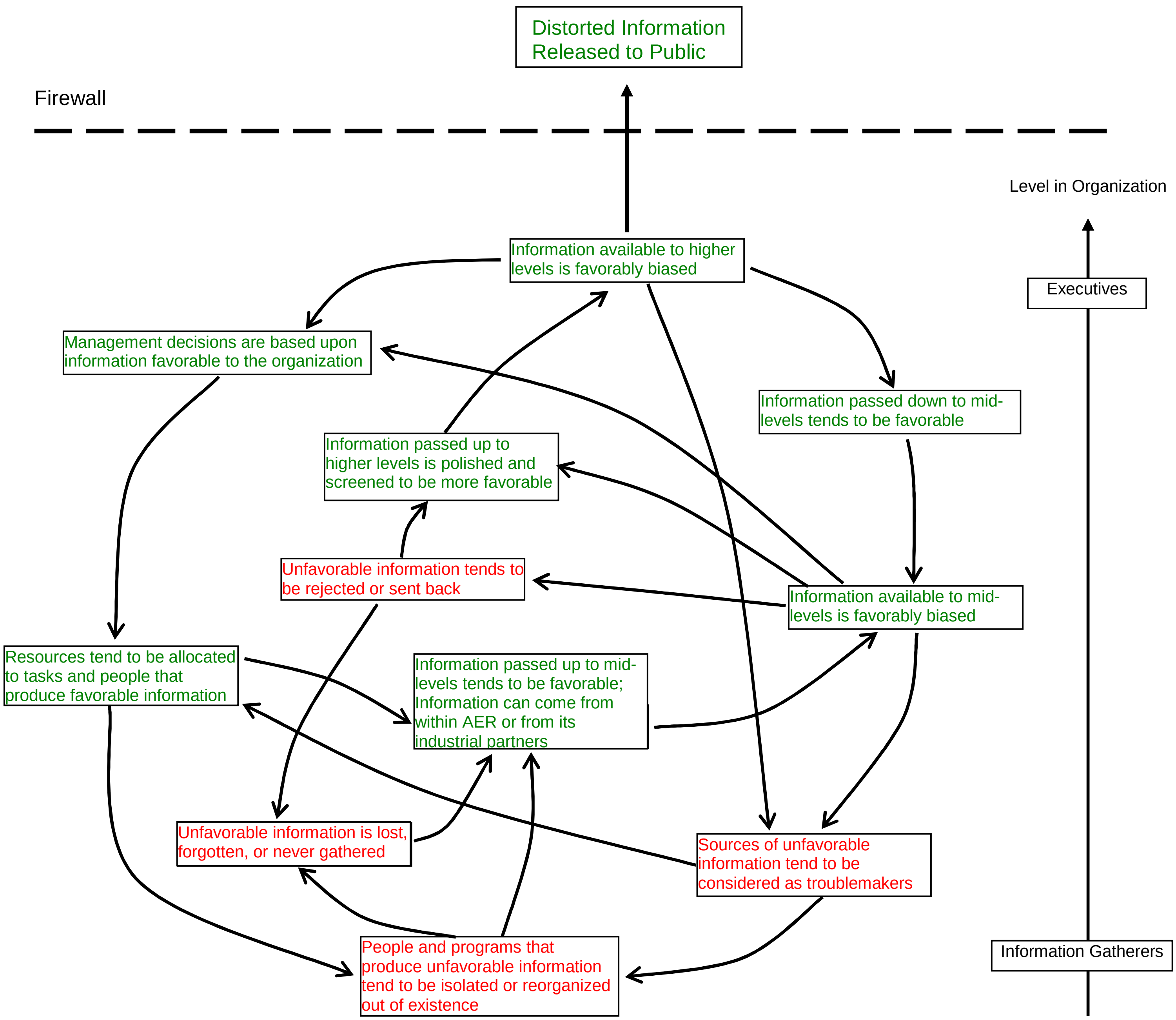
Web 15.8. Comparison of spills of crude oil in provincial and interprovincial pipelines in Alberta based on FIS and National Energy Board data (comparison period: 5 June 2008 to 4 Feb 2017).[a]

Crude Oil Spills	FIS Crude Oil Spills (Provincial)		NEB Crude Oil Spills (Interprovincial)	
Pipeline Type	**N**	**Volume (m^3)**	**N**	**Volume (m^3)**
Crude oil	113	1123.7	13	273.2
Multiphase	1416	3931.5		
Natural gas	53	45.4		
Other	23	5352.8		
Sour gas	15	51.1		
Water	44	47		
Total	1664	10551.5	13	273.2
Yearly average	191.9	1217.0	1.5	31.4
How many times the Alberta crude oil pipeline spill rate (FIS) exceeds the NEB pipeline spill rate (for number of spills)	128			
How many times the Alberta pipeline spill rate (FIS) exceeds the NEB crude oil pipeline spill rate (for total volume of spills)	38.6			

[a] data files overlap from 5 June 2008 to 4 Feb 2017, 8.67 years, NEB crude oil spills include those of sweet, sour, and synthetic crude

Comments:
Data comparison uses only spills in Alberta.
The NEB data were downloaded from https://www.cer-rec.gc.ca/sftnvrnmnt/sft/dshbrd/mp/dt-eng.html. A check of this address in September 2020 revealed a broken link. The functioning link as of 21 September 2020 was: https://www.cer-rec.gc.ca/sftnvrnmnt/ndstrprfrmnc/dshbrd/mp/dt-eng.html.
See Web 3.2 for spill frequency and volume by source of spills for both crude oil and saline water.
NEB electronic data are not available for years before 2008.
On 28 August 2019, with passage of the Canadian Energy Regulator Act, the NEB was renamed the Canada Energy Regulator.

Web 16. How information distortion arises and examples of reporting by industry after two recent spills



Web 16.1. How an organization distorts information (modified from Bella 1987).
"Favorable" (green) in this context means supporting the ambitions and survival needs of the organization. Unfavorable information (red) is filtered, rejected, or forgotten, and sources of unfavorable information are deemed troublemakers that are isolated, deprived of resources, and removed from positions of influence. In a meta-organization, information distorted in one organization is passed to the next organization and the process continues within a self-reinforcing system. The public, lying outside the meta-organization information firewall, receives distorted information.

Web 16.2. Reporting example: Penn West pipeline spill, June 2013

In 2013, Peter Lee and I examined company, regulator, and media communications in response to two spills. Web 16.2 and 16.3 summarize the findings (Timoney and Lee 2013).

On 19 June 2013, a spill of produced water from a Penn West pipeline was identified by company personnel near Red Earth, Alberta. Like the Plains Midstream spill near Little Buffalo, this spill was also reported on Lubicon Cree land. Although the volume of the spill was initially stated to be 5 m^3 ... a news release (Newswire 2013) by the company later estimated the spill to be 400-600 m^3 ... The news release stated: "The pipeline was immediately shut-in and isolated, and required regulatory authorities and First Nation Communities were notified. Penn West responders were immediately dispatched to the site, the spill was contained and remediation efforts are underway. There were no injuries as a result of this incident and the spill does not pose a hazard to any waterways in the area... While the cause of the release has not been confirmed, Penn West is committed to protecting the environment and continues to work with the regulatory authorities to resolve this incident.

The Alberta Energy Regulator (AER 2013c) stated: "The failure has resulted in the release of produced water into nearby wetlands... The spill has been fully contained, aquatic barriers are in place, and water sampling and cleanup is underway... PennWest has estimated that volumes released are between 400 and 600 m^3. The AER has not confirmed these volumes.

The company news release did not state when the spill took place, the chemical composition of the spill, that the spill had taken place in a wetland, nor provide an accurate location so that the hazard to waterways could be evaluated.

It isn't explained how "aquatic barriers" can be expected to stop the dispersion of produced water.

A 24 June update by Penn West (2013) provided some clarification: "Penn West operations detected a small amount of oil at surface in our Slave Field near Red Earth, Alberta on Wednesday, June 19. The pipeline located at 13-05-083-14W5 is a 3" pipeline which carries 97% produced water and 3% crude oil... The oil released was localized in muskeg and contained immediately. No waterways have been affected. Spill response personnel have been on site since June 19... By Thursday, June 20, First Nations were notified - Sawridge, Swan River, Drift Pile, Sucker Creek, Kapawe'no. On Saturday, June 22, AER requested Penn West to conduct further notification of both Lubicon leadership groups. Initial notification stated 5m^3 of oil was released based on visual inspection at the site. Upon further testing of the area, it was determined that the volume of produced water was 400m^3 – 600m^3. The spill footprint is approximately 18,000m^2 or 1.8 hectares/~4 acres. Water testing has been ongoing at the site. Results to date confirm no Petroleum Hydrocarbon's [sic] are present in the water. Impacts of produced water are greatest at the breakpoint and diminish over distance. Salinity of the water at the breakpoint is 35,000 ppm and 120 ppm at the last sample point approximately 1 km away." The update added: "June 23, 2013: Continue transfer of impacted fluids to storage tanks. 93m^3 of fluid transferred to storage tanks... Pending Operations... Begin break point exposure and disposal of impacted soils.

The update from Penn West is significant for the following reasons:

(1) Although the initial spill volume of 5 m^3 was later estimated by the company as 400-600 m^3, the regulator provided a different description of the spill volumes: salt/produced water, 1950 m^3 spilled, 40.5 m^3 recovered; contaminated surface water, 0 m^3 spilled, 48,814.4 m^3 recovered; waste, 0 m^3 spilled, 27,733 m^3 recovered; crude oil, 5 m^3 spilled, 0 m^3 recovered. The estimate of the saline spill volume rose from an initial estimate of 5 m^3 to 1950 m^3, a factor of 390 times.

(2) The water quality results are questionable: If the spill footprint is 1.8 ha (according to Penn West), the finding of water of 120 ppm salinity one km from the spill site suggests that the spill footprint may be affecting hundreds of hectares;

AER indicated that the affected area was < 0.1 ha. This is interesting given that the company indicated that the affected area was 18 times larger. Such data underscore the significant uncertainties in the regulator's spill reporting.

(3) If the spill was of 400-600 m^3 of 3 % crude oil, then 12-18 m^3 ... of crude oil were spilled; if water testing has failed to find any petroleum hydrocarbons in the wetland, the reliability of the water quality tests must be questioned. The approximate nature of the volumes spilled and recovered data call into question the water quality results.

(4) Salinity of 35,000 ppm... is essentially equivalent to sea water and would result in impacts to the vegetation, especially upon sensitive taxa such as black spruce and bryophytes which, as a group, have low salt tolerances.

(5) The location of the spill provided by Penn West was 13-05-083-14W5. Upon plotting the spill, the authors contacted Penn West with our concern that the location provided may be incorrect given the pipeline distribution in the area. The corrected location was later provided as 03-15-083-14W5...

Later still, the location of the spill according to the AER February 2017 data was given as 03-10-083-14W5. It is unclear which location is correct. Why is it so difficult to report a correct location?

The preceding comments are not meant to fault Penn West for its communications following the pipeline spill. Indeed, its communications effort was above average. Its daily updates and its provision of a list of actions to date and pending actions were an improvement over standard disclosure practices. The comments are meant to highlight the need for widely-disseminated, accurate, and timely information; to demonstrate that the "bar" needs to be raised when responding to spills and reporting to the public, and that these are the regulator's responsibilities; and to demonstrate that independent monitoring of the effects of this, and all other spills, is required to ensure best practices and transparency.

Web 16.3. Reporting example: Enbridge pipeline spill, June 2013

Reported on 22 June 2013: A spill of synthetic crude oil from an Enbridge pipeline of an estimated 750 barrels... took place in a wetland and a lake about 70 km southeast of Fort McMurray.

From the company's press release (Marketwire 2013): "We are still investigating the cause, however we believe that unusually heavy rains in the area may have resulted in ground movement on the right-of way that may have impacted the pipeline... There have been no reports of harm to wildlife... Line 37 was constructed in 2006 and is a 12-inch diameter pipeline that is 17-kilometers long and connects facilities in the Long Lake area to Cheecham and is part of Enbridge's Athabasca system."

The company statement uses the standard press release script that no harm to wildlife has been reported, which is not equivalent to stating that no harm to wildlife has occurred. The date or duration of the spill were not provided. Nor did the press release disclose the fact that this oil spill flowed into a wetland and a lake. It's significant that the company states that a rainfall event could result in failure of a pipeline that is seven years old.

A news release by the regulator (AER 2013d) stated: "As of June 23, 2013, the pipeline remains shut in and isolated and the company continues to receive the equipment and personnel required to clean and mitigate the synthetic crude oil release. In addition to installing booms to contain the spill, the company has installed wildlife deterrents and contracted environmental consultants to conduct water sampling and a wildlife survey. There were no injuries as a result of the incident and no impacts to wildlife have been observed. Enbridge continues to estimate the volume released at between 80 m^3 and 120 m^3. The AER has not confirmed these volumes."

The news release indicates that (a) equipment and personnel to mitigate the spill continue to arrive; (b) booms have been installed, indicating spillage into water; (c) environmental consultants had been contacted to conduct a wildlife survey.

A 25 June update by Enbridge (2013a) stated: "Recovery of oil and contaminated water continued today, June 25, 2013, in response to a release June 22 of approximately 750 barrels of Light Synthetic Crude oil from Line 37 near Enbridge's Cheecham, Alberta, terminal.

Approximately 100 personnel are expected on site today. The release occurred in a remote area accessible by helicopter and all-terrain vehicles. Enbridge is using rig mats to allow access to the site by vacuum trucks and skimmers, which will be used to remove product from the area.

As of 8 a.m. MDT today installation of rig mats to access the site was approximately 50 percent complete. As of this morning 1,700 feet of containment boom had been deployed along with absorbent mats. Approximately 17 cubic meters of a mixture of water and oil has been recovered and treated. Wildlife deterrents have been deployed and the area is being fenced to prevent wildlife incursion. The southern portion of Enbridge's Athabasca pipeline (Line 19) was safely restarted June 23 and operations between Cheecham and Hardisty have been restored. The line segment north of Cheecham remains shut down until Enbridge can ensure its safe restart... Enbridge is in contact with our customers and keeping them advised of the status of our system."

The news release is significant for the following reasons:

(1) Enbridge implies that the release began on 22 June, but the company hasn't provided proof to that effect.

(2) The company appears to try to excuse itself for the slow response to the spill by noting the spill is in a remote area. A minimum of three days post-spill, and the installation of rig mats to allow truck access was 50 % complete, which indicates that no trucks had yet reached the site.

(3) Given the estimated spill volume of 119 m^3, the removal of 17 m^3 of "water and oil" represented an inadequate response.

(4) Fencing of the area can do nothing to minimize the impact to the biota that are resident in the wetland and lake. Nor does the standard orange plastic snow fence keep out wildlife of any kind.

(5) The emphasis on returning the surrounding pipelines to production and communicating with customers signals the priorities of the company.

An update (Enbridge 2013b) update on 26 June added: “The release on Line 37, which connects the Long Lake Oil sands project to Enbridge’s Cheecham Terminal, is believed to have resulted from ground movement on the right-of-way as a result of unprecedented precipitation levels which exceeded a 1 in 100 year event... A geothechnical [sic] analysis of the pipelines in the vicinity of Line 37 will need to completed [sic] and excavation and inspections undertaken, [sic] before these lines can safely be restarted. Heavy equipment and crews have been mobilized to the site to augment resources, but extremely wet working conditions continue to pose challenges to response efforts... The cost of containing and cleaning up the light oil released from the Long Lake lateral failure has not yet been estimated. Enbridge carries liability insureance [sic] for sudden and accidental pollution events and expects to be reimbursed for its covered costs, which is [sic] subject to a $10 million deductible.”

Because there were unknowns and unsupported statements in the Enbridge media updates, Peter Lee and I corresponded via email with Enbridge.

We first asked (25 June 2013): “could you tell me the legal location of the Line 37 release?” On 26 June 2013 we received this response from Graham White of Enbridge: ‘This is just our very preliminary assessment of what occurred. In the first few days our first priority is containment, safety and clean-up. If you are familiar with our previous incidents or that of other companies, you will know that there are exhaustive investigations on incidents conducted by regulators and industry. The results are public and posted on the websites of the regulator. I would encourage you to stay tuned to those evaluations as to definitive parameters for cause. Location is approximately 70 kms south of Fort Mac. I don’t have a ‘legal location...’.

On 27 June 2013 we responded: “Dear Graham, your response did not answer my questions: Legal location – Are you saying that Enbridge does not have a legal location (Legal Subdivision, Section, Range, Township, and Meridian) of the Line 37 release by stating: ‘I don’t have a ‘legal location.’? Enbridge’s published statement is as follows: ‘… believed to have resulted from ground movement on the right-of-way as a result of recent unprecedented precipitation levels which exceeded a 1 in 100 year event.’ What is the basis for this statement? What precipitation parameter was used to derive this result of a 1 in 100 year event? Can you provide answers to these questions or direct me to someone in Enbridge who can?”

To these queries we received ‘out-of-office’ responses from Enbridge. We then wrote the media relations group (27 June 2013): “Dear Enbridge, I am receiving out-of-office responses from Graham White and Chris Meyer. Could you provide answers to my questions? Thank you.” On 2 July 2013, we received the following email from Graham White: “There is a legal location for that area but due to the high level of activity taking place there and related safety concerns we are not providing it publicly. The specific details you are looking for in the precipitation numbers will be based on metrological [sic] reports and will come out with the incident investigation analysis and report.”

To summarize: Enbridge declined to provide the location of the spill, declined to provide the scientific basis for their statement about the 1 in 100 year event and declined to state the kind of event to which they referred (e.g., an hourly, daily, 3-day, 7-day, 30-day event).

Enbridge’s 1 in 100 year precipitation statement is not defensible for the following reasons. (1) Statistical calculation of 1 in 100 year events assumes a stationary mean. Because climate change is well documented in the region, estimates of the probability of rare events with long return intervals are fraught with error. (2) Assuming for a moment that climate change is not occurring, the statistical uncertainty as to the magnitude of a 1 in 100 year event is large. Most climatologists would not resort to their use in the current situation. (3) Calculation of a 1 in 100 year event requires data, yet the only significant set of data comes from Fort McMurray, roughly 70 km away, and its record starts in 1960, which is scarcely long-term. There are insufficient local data to make long-term calculations. (4) The erosive capability of a rainfall event is a complex phenomenon that depends not only upon the precipitation, but also upon the antecedent precipitation, the degree of soil saturation before the event, the soil type, texture, slope, and upon the landform and landscape position. Explaining this or any pipeline failure based solely on a precipitation event oversimplifies the causality of the failure. (5) Assuming for a moment that the Fort McMurray record is relevant, the 30-day total precipitation recorded at Fort McMurray for 27 May to 25 June 2013 was 146.4 mm, which was exceeded by both 1991 and 1995 accumulated precipitation amounts of 162.7 mm and 147.6 mm. The bottom line: it was not a 1:100 year precipitation event.

If, for the sake of discussion, we accept that Enbridge’s view is plausible– that a large volume of precipitation resulted in erosion which caused the pipeline failure—it’s relevant to ask why a six-year old pipeline would fail. Does the company not engineer its pipelines for precipitation events? Furthermore, inspection of the precipitation timing raises a serious question... The peak rainfall period, during which 116 mm fell at Christina Lake near Winefred (station 07CE906), the weather station nearest to the spill, extended from 8-13 June, or 9-14 days prior to the announced date of the spill (22 June). During the next eight days only 9 mm of rain fell. Therefore, if heavy rain caused the pipeline failure, then the pipeline more likely failed approximately 9-14 days prior to 22 June, not as Enbridge intimates on 22 June. It’s possible, given the precipitation data, that the Enbridge pipeline was spilling oil for some time prior to 22 June.

Taken together, the news releases demonstrate a slow response to the spill, excuses made by the company for the slow response, inadequate information from the company as to the spill occurring in a wetland and adjacent lake; a statement from the company that no wildlife harm had been reported despite no wildlife observations having been conducted at that point; and uncertainty as to the volume of the spill, when the spill occurred, how long it persisted, the cause of the spill, and the location of the spill. The company's news releases sought to reassure investors and customers in relation to restarting the flow of oil and minimizing financial liabilities.

Enbridge appears to have failed to learn lessons from its disastrous Talmadge Creek and Kalamazoo River, Michigan spill of 25 July 2010. In that event, the U.S. National Transportation Safety Board concluded that the company ignored safety procedures, suffered "pervasive organizational failures", and was aware of cracks in the pipeline before the spill, yet failed to fix them. Reportedly, Enbridge failed to inform the US EPA that the spilled material was diluted bitumen (which floats briefly then sinks) not typical crude oil. As a result, response to the spill was slow and the damage from the spill was greater than it need have been. The evidence revealed that Enbridge staff, after the rupture yet unaware of it, twice pumped more diluted bitumen, about 81 % of the spill, and that it took Enbridge nearly 17 hours to shut down their Line 6B after the rupture was reported.

The US EPA (2013) recently stated that Enbridge initially reported a release of 819,000 gallons which was later revised to 843,000 gallons. As of May 2013, Enbridge estimated it had removed 1.15 million gallons of oil from the Kalamazoo River. The US EPA estimates that about 180,000 gallons of Line 6B remain in the sediment of the Kalamazoo River and have ordered Enbridge to remove the recoverable portion of the oil, about 12,000 to 18,000 gallons, by dredging. The residual 162,000 to 168,000 gallons of oil left in the river's sediment may remain in the river for an extended period. The additional costs of dredging are expected to push the cost of the cleanup to one billion dollars, which exceeds the company's insurance coverage (Cryderman 2013).

Although the June 2013 Enbridge oil spill near its Cheecham terminal was smaller than the Michigan spill of 2010, the company's slow response, its insistence that it was acting effectively, and its failure to provide accurate, timely information are consistent in the two events.

It's difficult to imagine what advantage Enbridge thought it might gain by not providing its spill location to the public. For a company wishing to acquire a social license for approval of pipeline projects, failing to provide pipeline spill information to the public is a dubious strategy. Failure to provide timely, relevant information, such as when Enbridge failed to inform the US EPA that their Kalamazoo, Michigan spill consisted of diluted bitumen, not typical crude oil, can prove costly to society, to companies, shareholders, governments, and ecosystems.

Web 18. The path forward

An astute civil servant once told me: “After all is said and done, all we’ve done is said”. How do we apply what we’ve learned and move from talk to action? We need people of many backgrounds to work together: policy experts, politicians, engineers, universities, and most of all we need an informed, concerned public. We need new federal legislation modelled after the U.S. Superfund Act (see glossary) that will tax industries to fund an agency empowered to document and remediate hazardous sites. That agency should prepare a national priorities list for clean-up of the most dangerous sites. The new legislation must include retroactive liability to prevent the companies responsible for contamination and ecological damage from avoiding liability by declaring bankruptcy or selling affected sites to unwitting buyers. As it stands, a polluter can avoid responsibility by simply selling the site. There is a way out this mess but it faces a Catch-22 (Kaiser 2009).

The Catch-22 works like this: We need to change legislation, but the politicians have been captured by the industry and will not enact the needed changes. We need to change policies, but the regulator has been captured and has put those policies in place in league with industry. To change the regulator, we need to change legislation, but see above. We need to elect different politicians, but the industry controls campaign financing and therefore the political parties. We need to change the electoral system and get dark money out of politics, but the electorate has been misled by years of disinformation. We need to staunch the flow of disinformation to and from universities and media outlets, but they are financially compromised. If they refuse to serve their funders, they lose income.

We need a political movement with the power to redirect captured government and regulators toward protecting the public interest (MacLean 2016). As a counterbalance to industry, citizens and consumer groups need to be empowered and organized to influence regulatory agencies and politicians. Judges need to receive better training to recognize and thwart regulatory capture. Universities should form partnerships with government to assist in forming policies that protect the public interest. This would provide policy makers the resources to stand up to industry “experts”. Academics should form partnerships with journalists and citizens and use social media to directly inform policy makers, regulators, and voters in order to make politicians more responsive to the public interest (MacLean 2016).

These initiatives could be funded by taxing a small fraction of the profits of hydrocarbon companies. The same approach could be used to fund scientific research and policy changes to transition from a carbon economy to a green economy. Given the eroding social license of the fossil fuel industry, research into innovative technologies could prove a boon to hydrocarbon companies transforming into green energy companies.

Repair of the industry’s social license requires that it communicates the true costs of its activities to the public and that it takes tangible steps to minimize those costs such that they are acceptable to society. Fines for spills and other contraventions should be commensurate with the offenses, large enough to serve as a deterrent rather than so small that they encourage business-as-usual. All monitoring, environmental protection, and enforcement mandates should be taken over by government and therefore placed under the control of voters.

In our schools, we need to reclaim the primacy of free discussion rather than indoctrination, we need to teach biology, not ideology. In order to produce young adults with the capacity to rise to the threats facing them, we need curricula that teach critical thinking as an inoculant against disinformation. Our children’s curricula must teach the impossibility of sustaining both ecosystems and fossil fuel production, how to envision life after oil, and how to act collectively to meet the challenges they will face in life. Most of us adults are too stuck in our ways to rise to the challenges before us. Children represent our best hope for transformation of our global society. We need to free their minds.

At some point society will have to recognize that captured regulators are corrupt enterprises whose goal is to defraud the public of its financial and environmental security. Let’s suppose that society succeeds in striking at the roots of evil and decides to replace the Alberta Energy Regulator and industry regulators in other provinces and states. This is where science can play a role. Three kinds of studies are needed to help establish new regulators: studies of the environment, the regulators, and industry. Now is the time to conduct these studies.

Web 18.1. Study and monitoring of the environment

The era of covert spills and secrecy must end. All crude oil and saline spills cause detectable effects. Beyond the question of detectable effects lies a deeper question. What level of ecological effects is socially acceptable? Society needs to answer that question and government needs to act accordingly. Cumulative effects must be addressed. Monthly high-resolution satellite imagery should be gathered for all regions where hydrocarbon exploitation takes place. Automated change detection can be used to efficiently detect, map, and monitor spills and the industrial footprint. Documentation of post-spill ecosystem response could be improved by use of sequential imagery coupled with ground data to determine how sites change over time and whether the sites have met thresholds for socially-acceptable recovery. All imagery should be available free for public download. Province- and state-wide data on soils, vegetation, biological composition, and water quality should be collated and incorporated into geographic information systems in order to characterize normal background conditions and ranges of variation and to inform daily operations of the regulators.

A task force composed of scientists should be formed to assist in the detection, study, prevention, and response to spills. The Oil Spill Academic Task Force of the southeastern United States might serve as a template. Spill prevention should receive concerted attention and the findings should be made available to all companies. An independent panel of scientists should establish a standard methodology for the assessment and monitoring of the impacts of spills, including standard methods for measuring volumes released and recovered, ecological impacts, and change over time. Thereafter, all studies of spills should be conducted by government, not by industry. The cost of the studies should be covered by a trust fund to which all energy companies are required to contribute. All data and reports on the spills should be available to the public.

Web 18.2. Studies and actions related to the regulator and its data

Although the Alberta Auditor General investigated the AER in 2019, its investigation focussed on financial wrongdoing (Russell and Rusnell 2019). The Auditor General should conduct a broader audit. It has the mandate and legal standing to require the regulator to provide all relevant information, to determine the causes for deficiencies, and to recommend ways to correct those deficiencies in order to prevent similar failures of whatever agency replaces the regulator. The process will require the participation of auditors with a diverse set of skills including scientists, statisticians, engineers, policy experts, and First Nations.

Policies and procedures relating to spills, reclamation, certification, liability, project approvals, oversight, data, protection of whistleblowers, and conflict of interest need to be overhauled based on a system-wide audit. An audit of the financial records of senior executives should be conducted annually. A five-year ban on switching employment between the regulator and the industry should be enacted and supported by significant legal penalties. We need to padlock the revolving door. If we don't, the corruption will continue.

This is the era of open data and open government. It is time to regulate accordingly. The freedom of information process is an abject failure. Much of the dysfunction can be removed by simply making environmental information publicly-available online. In Alberta, the AER possesses thousands of environmental reports and impact assessments and reams of data. For undisclosed reasons, the AER does not release these reports when requested by the public. That secrecy is undemocratic and unacceptable. Reports produced by the regulator should be audited for accuracy, data quality, transparency, and consistency by an independent third party. An audit of the scientific competence of regulatory staff is required. Discrepancies between required competence and observed competence should be corrected.

Government should locate and publish all records for missing spills, including those for the period before 1975. All spill-related environmental information held by regulators should be audited for accuracy and completeness. Similarly, the full extent of the clean-up costs and environmental liabilities imposed by industry sites must be communicated to the public. Government must obtain security deposits from industry as a prerequisite for continuing operations. Failure to provide those deposits should result in revocation of company licenses and leases.

In late 2019, the AER improved its online reporting. Although the online record at the "Compliance Dashboard" presents a subset of the spills and a subset of the attributes, the full FIS record can now be found online. This is an improvement over the recent past. Unfortunately, the spill and environmental data remain unreliable, and, because spill locations are based on township and range (legals), locations remain approximate. Reporting could be improved by requiring companies to report the geographic coordinates of spills accurate to ± 5 m and require that spill locations refer to the actual spill site, not to the nearest facility.

Web 18.3. Studies and actions related to the industry and its data

Industrial reports on spills must be made available online to the public. Meanwhile, third party audits should be done of all environmental reports and data submitted to the regulator with the audits made available online. The scientific competence of industrial staff that deal with environmental issues should be audited and deficiencies corrected. Operating licenses should be revoked for companies lacking the required expertise. Companies involved in hydraulic fracturing should be required to disclose the chemical composition of their fracking fluids and to fund scientific study of groundwater effects and wastewater disposal. Industry must report spills to the public within 24 hours of detecting a release. Meaningful penalties should be imposed for failing to report accurate information in a timely manner.

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Acknowledgments

I thank Keepers of the Water Council for their support and encouragement; Baptiste Metchooyeah (deceased), Warren Danais, Gabriel Didzena, Matt Munson, Joe Chonkolay, and Norm Chonkolay of the Dene Tha First Nation for their traditional knowledge, support during the fieldwork, and provision of reports and data; Dorothy Fabijan (University of Alberta Herbarium); Brett Feland and Allan Harms (University of Alberta Natural Resources Analytical Laboratory) for chemical analyses of soil and water; Maxxam Analytics for hydrocarbon analyses of soil; Dr. Pete Kershaw, Dr. Brett Purdy, and Mae Elsinger for vegetation and soils data; Alberta Environment and Parks for ecologically sensitive area information; Anne Robinson for her work on bryophytes and lichens and for field, office, and editorial assistance; Ed Zwolinski for local knowledge on chemical dumping in the New Jersey Pine Barrens; investigative journalist Leslie Young (Global News) for the 1975-2013 FIS spills database, and the Alberta Wilderness Association for the 1975-2017 FIS database.

Funding in support of publication of *Hidden Scourge* was provided through the generosity of The Gavia Group Inc., Laura Jackson and Patrick Lamb, Robert A. Cameron, Cecile Fausak and Bruce Jackson, Evelyn and Harvey Scott, Keepers of the Water, and the Federation for the Humanities and Social Sciences.

I thank all those, named and anonymous, who provided eye-witness observations and testimony in personal communications.

I am indebted to Alan Dunn P.Eng., Dr. William Donahue, Mae Elsinger, Dr. Geoff Holroyd, Dr. John Honsaker, Dr. Tristan Lee-Jones, Dr. Pete Kershaw, Geoff Kershaw, Peter Lee, Joseph Maslen, Anne Robinson, Cliff Wallis, and several anonymous reviewers for their critical reviews.

Most of all, I thank my wife Anne who supported me on a years-long journey down a dark rabbit hole. Without her unflagging help, this book would have never seen the light of day.

Addendum 1. Continued Degradation, Corruption, and Growing Liabilities

Recent revelations and events demonstrate that the fossil fuel industry's and the AER's corruption and malfeasance may in fact be worsening. With your forbearance, I report two recent spills, an example of fraudulent reclamation, and update the growing public liabilities forced on the public by a corrupt regulator. First the spills.

Daily spills and the negligence of the AER and industry continue with sickening regularity. But now with the excuse of Covid-19 and the virtual cessation of monitoring of spills and their effects, the hidden scourge has become more hidden from the public. Given that the book and these web materials document the occurrence and effects of over 100 thousand spills, the evidence of ubiquitous ecological degradation is incontrovertible. I would, however, like to bring two recent large spills to your attention because they illustrate that the conduct of the AER and industry remain reprehensible.

1.1 Husky Energy Spill

On 28 October 2020, a spill of 900 m^3 of saline water was reported at a Husky Energy pipeline in the Dene Tha territory southwest of Rainbow Lake, Alberta (Phil Heidenreich, Global News, "Husky Energy pipeline shut in after 900,000 litres of produced water leaks in northern Alberta", 28 Oct 2020, https://globalnews.ca/news/7426637/alberta-energy-regulator-pipeline-produced-water-husky/). According to Husky Energy, "Some of the water entered nearby muskeg... Cleanup efforts are underway, including the use of pumps and vacuum trucks... [there have been] no observed impacts to wildlife and fencing is in place to keep wildlife from the area." The spill was first reported to the AER with a volume of 500 m^3, but later that volume was nearly doubled. The AER assured the public that "If we determine that Husky is not in compliance with our requirements, we have a number of compliance and enforcement tools to bring them back into compliance."

1.2 ARC Resources Spill

On 29 December 2020, a spill of 400 m^3 of saline water was reported at an ARC Resources Ltd pipeline near Drayton Valley, Alberta (Dan Healing, The Canadian Press: "400,000 litres of produced water spills from pipeline near Drayton Valley: AER". Global News, 29 Dec 2020, https://globalnews.ca/news/7545846/alberta-energy-regulator-pipeline-water-spill-drayton-valley/). The spill, detected and reported on Christmas Day by a landowner, not by the company, flowed into a creek and then into the North Saskatchewan River. The unnamed creek supposedly did not support fish, but fish were later found in the creek. The company did not detect contaminants and impacts to the North Saskatchewan River: "All of our testing to date shows there's no impact to the North Saskatchewan at all... We sampled it as soon as we got there and there's no sign of any impact and no impact to wildlife at this time." This view was accepted by the AER without data. There was no information provided about impacts to the creek and no credible independent evaluation of the spill.

The two spills illustrate that the *status quo* of a corrupt regulator persists. We see:
lack of independent evaluation of the spills and their effects;
detection and reporting of a spill by the public, not by the company;
the regulator's acceptance of unfounded industrial good news stories of no impacts without credible assessment;
misinformation about a creek not bearing fish;
lack of information about the effects on the creek that received the ARC Resources spill;
the acceptance of useless wildlife fencing that no credible regulator would accept;
an under-reporting of spill volume; and,
an empty assurance that the AER may take steps to bring Husky Energy into compliance.

1.3 Fraudulent Reclamation

On 14 January 2021, The Globe and Mail published a story titled: Energy firms misled Alberta regulators on cleanup of well sites (by Emma Graney, https://www.theglobeandmail.com/business/article-energy-firms-misled-alberta-regulators-on-cleanup-of-well-sites/). The story describes repeated cases of fraudulent well site reclamation abetted by an incompetent and corrupt regulator.

Aeraden Energy Corporation owns 59 natural gas well sites near Jenner, Alberta that require reclamation. Aeraden hired CEPro Energy & Environmental Services to shut down the wells, clean up the sites, and reclaim the land. After CEPro certified that the sites had been reclaimed, it applied to the AER for reclamation certificates affirming that the well sites had been "returned to natural prairie." Without verification, the AER issued the reclamation certificates. But landowners objected when they received reclamation certificate packages that fraudulently indicated the landowners had signed off on clean-up work when they had not. Subsequently, the AER launched a two-year investigation that cancelled the certificates.

The investigation found equipment left in place, open excavations, and dead vegetation; in short, evidence of fraud. Groundwater monitoring wells and fences and berms remained and the company had failed to reclaim slumping soil and dead vegetation. In one case, CEPro had filed for a reclamation certificate for a site that was still active. An audit of all reclamation applications submitted by CEPro since 2016 found that the company had submitted site photos that were not of the wells being reclaimed and had certified reclamation was complete at sites with remnant excavations and infrastructure.

Despite the repeated contraventions of the Environmental Protection and Enhancement Act (EPEA), neither company was fined. The two-year time limit for EPEA investigations and the regulatory incompetence of the AER resulted in inspections of only a fraction of the 59 sites. Two years and a fraction of the sites inspected? That level of incompetence can only be intentional. Two competent ecologists could have inspected the 59 sites within a week.

Instead of penalties, each company received a warning letter from AER that stated the matter was "very serious." The letter added: "With additional time and investigation, it is likely that a more significant enforcement action would have been taken." AER ordered Aeraden to complete remediation of the sites.

Matthew Oliver, chief regulatory officer of the Association of Professional Engineers and Geoscientists of Alberta (APEGA), observed that this a "serious case of falsification of documents... One count of falsifying a document is immensely serious. [The AER] felt there were grounds there to cancel 59 reclamation certificates... We know times are tough in the industry right now, but that moves me to say we need to be focused even more on people not cutting corners and not falsifying things, because the protection of the public is even more critical."

Shockingly, the AER stated it had no evidence of a deliberate attempt by either company to mislead regulators. AER went on to defend its OneStop system for reclamation applications which does not require that inspectors visit sites before issuing certificates that state the land has been returned to its pre-disturbance condition. Instead, OneStop trusts that the energy companies provide true and correct information. Across the ravaged landscapes of the oil patch, we see where this misplaced trust leads.

Lian Zhao, president of CEPro, declined to answer questions posed by The Globe and Mail reporter. CEPro's office manager similarly did not return phone calls and emails asking for comment, nor did CEPro's owner, Saliance Global Holdings Co. Ltd. Saliance owns Aldesta Hotels Group, which operates luxury hotels and resorts in British Columbia and Australia and is an affiliate of Shanghai SanDun Auto Parts Co. Ltd and G&Q Real Estate, an Australian property development and management company.

Welltraxx, a company that assists landowners to manage oil and gas leases, has examined the Aeraden record. Welltraxx found that Aeraden had failed to pay local farmers and ranchers the money they're owed for the leases on their land and observed that most well sites were not close to being ready for reclamation certification.

As bad as the egregious abuses by the AER, Aeraden, and CEPro are, the bait-and-switch scam of "certified" reclamation is even worse. When land has been reclaimed by industry, it has not been returned to its pre-disturbance state. As I have documented under sections pertaining to soils, vegetation, contamination, wildlife effects, the disturbance signature, domains of attraction, and cumulative effects, land "certified" as reclaimed has been permanently damaged. For the evidence that industrial land reclamation is an ecological fraud, see Chapters and Web 5, 10-12, and 14.

Sadly, for those who believe that surely by now the AER will have learned from its mistakes and leave its corrupt ways behind, there is nothing in the data that supports such a belief. Indeed, the data point towards the opposite conclusion: the AER is working exactly as it is designed, that is, to maximize private profits while externalizing the resultant financial and environmental liabilities onto the public. The AER's abject failure to enforce its reclamation regulations sends a clear message to industry: abuse has no consequences.

1.4 Growing Liabilities

On 17 March 2021, the AER suspended the operations of Mojek Resources Inc at 32 wells, 35 pipelines, and one facility for repeated failures to remediate multiple spills and for failure to comply with provincial regulations. The new order required that the Orphan Well Association and Mojek's "working interest participants" provide care and custody of the sites and that they address historical non-compliance (translation: unremediated spills and other liabilities). Mojek reportedly owes $1.76 million in security deposits to the AER for end of operation obligations in addition to other unspecified debts to the Orphan Well Association and the AER. Energy Minister Sonya Savage stated that the Alberta government plans to implement a new liability management framework that should result in "tougher enforcement". The proposed framework will supposedly allow the AER to work with financially distressed companies to meet their obligations.

The Mojek Resources suspension adds to the growing list of flagrant regulatory failures that are slowly coming to light. In 2019, Trident Resources declared bankruptcy and left behind over 4,000 unreclaimed wells. As you read in the book's Postscript, in March 2021, the AER suspended SanLing's operating license for its 2,266 wells, 227 facilities, and 2,170 pipelines—this is the company that inherited responsibility for the Pace-Spyglass spill (Chapter 11)—for repeated failures to remediate its sites. SanLing owed the AER $67 million in unpaid security deposits. As expected, in April 2021, SanLing informed the AER that it would cease operations as of 30 April 2021. A receiver will be responsible for sale of SanLing's inventory to responsible parties while remaining assets (if any) will be assigned to the Orphan Well Association.

A June 2021 report by the Alberta Liabilities Disclosure Project concluded there were roughly 300,000 unreclaimed wells in Alberta that will cost $40 billion to $70 billion to clean up. Additional liabilities exist for pipelines, batteries, and other infrastructure. Due to government grants to fund reclamation, and unpaid taxes and royalties, the Alberta Liabilities Disclosure Project estimates that the public subsidizes energy cleanup at the rate of $4.3 million/day.

The specter of liabilities being transferred to the public by insolvent hydrocarbon companies exists wherever regulatory capture has undermined the regulatory regime. There are more than 75,000 abandoned and inactive wells in

Saskatchewan where liabilities continue to grow under the regime overseen by the Saskatchewan Ministry of Energy and Resources. In June 2021, one Alberta company dumped the single largest number of orphaned wells into the lap of Saskatchewan's Orphan Well Fund when Bow River Energy Ltd. orphaned 671 sites. The company is under bankruptcy protection with unpaid cleanup and decommissioning costs, taxes, royalties, and debts in excess of $100 million owed to farmers, ranchers, rural municipalities, First Nations, businesses, and governments in Saskatchewan and Alberta. In June 2021, Saskatchewan Energy Minister Bronwyn Eyre assured the public that "We can manage the risk... We have a strong program, we have a strong regulatory structure. I'm very proud of the regulatory structure and taxpayers should be as well." Is it a surprise that people's faith in government is in freefall?

Reclamation and remediation of industrial sites present growing public liabilities because industry knows that the regulator works for them. In Alberta, when companies comply with the AER's ecologically uninformed guidelines, they still leave the land permanently damaged. When companies fail to comply, they know that years will pass before any actions are taken. At that point, these companies walk away from their liabilities and declare insolvency, after which they may reconstitute as a new corporate entity and resume operations. Captured regulators have no one to blame but themselves. The system is broken and they have broken it. We the public inherit the ecological and financial liabilities. The Alberta Liabilities Disclosure Project has suggested a novel solution: Establish a reclamation trust that takes over wells from failing companies and use the revenue generated from hydrocarbon production to clean up industrial sites and create as many as 10,000 reclamation jobs across Alberta. CAPP and Energy Minister Savage rejected the solution.

In the same vein of growing liabilities, the hydrocarbon industry in Alberta is increasingly defaulting on the property taxes it owes to rural municipalities. In 2019, the industry failed to pay $81 million in property taxes; in 2020, that debt grew to $173 million; and in February 2021, its unpaid taxes for the year had grown to $245 million. These unpaid taxes amount to 10-20 % of municipal budgets, sufficient to undermine government planning and the delivery of services to rural communities such as repairs to roads and bridges. Paul McLauchlin, President of the Rural Municipalities of Alberta, views these unpaid taxes as akin to the environmental liabilities the industry is dumping onto the public.

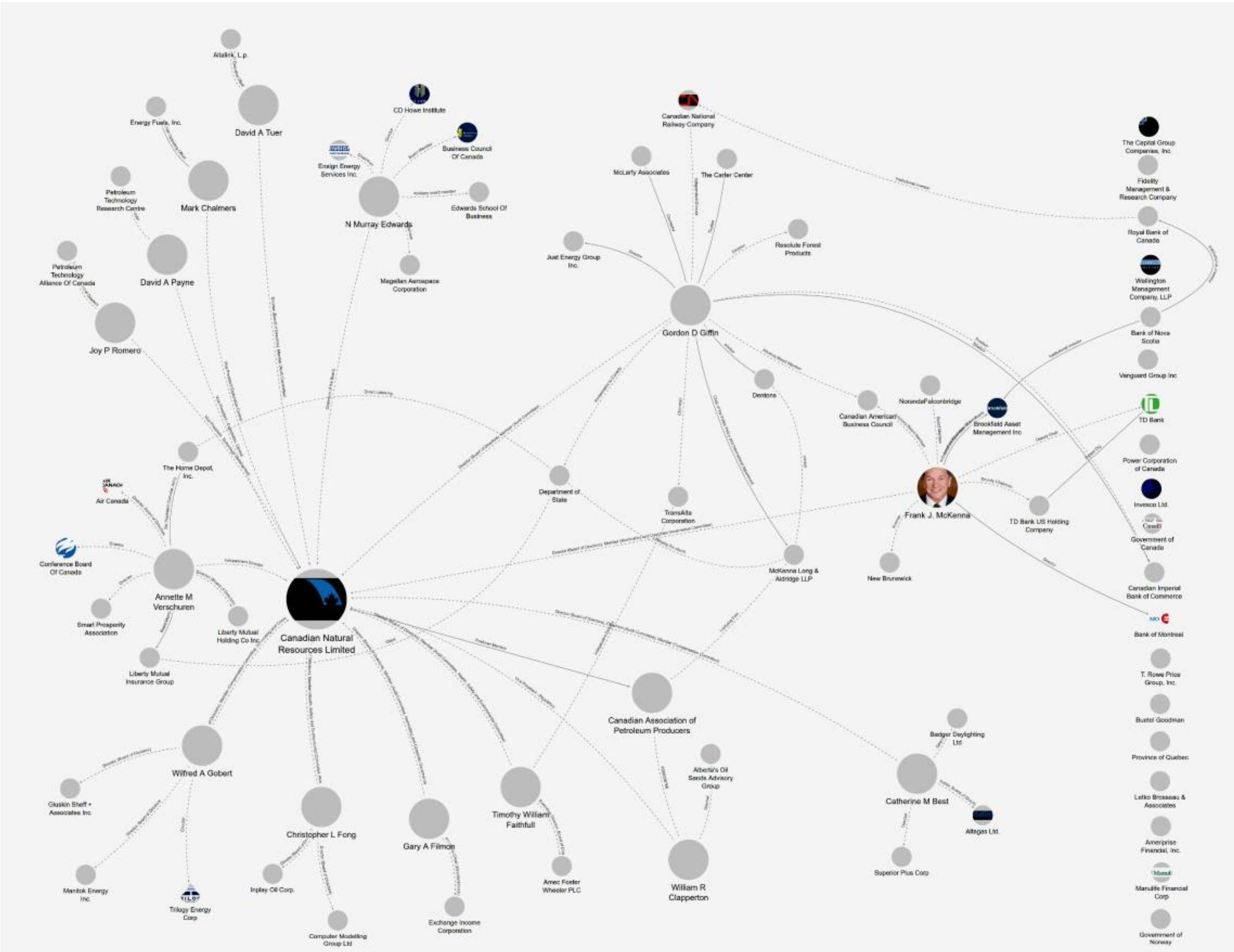
The AER is aware of these tax defaults but has failed to take substantive action. In the meantime, the industry has received billions of dollars in taxpayer-funded financial support under the guise of Covid-19 relief. In July 2021 it was learned that the $1.7 billion in taxpayers' money ($1 billion of which went to Alberta) provided by the federal government to speed reclamation instead served as a subsidy to the industry. The Parkland Institute found that the federal funds, administered in Alberta by the Kenney government, replaced monies that would have been spent by either the provincial government or the industry. The federal funds amounted to a bail-out of defaulting companies and the Alberta government. Much industry-funded reclamation ceased with the announcement of the federal program. The profitable Canadian Natural Resources Ltd received more than $100 million of this taxpayer-funded subsidy (see Addendum 2). The betrayal of the public trust by the industry, the Alberta government, and the AER deepens with each passing day.

In late May 2021, the AER announced that it would soon take action to require companies to spend a specified amount of money each year on environmental clean-up. That announcement came nearly a year after Energy Minister Sonya Savage announced that Alberta would make sweeping changes to management of the industry's liabilities (translation: our liabilities). After a year of waiting, what do we have in place? Statements by the AER that they are working on the problem and that it anticipates it will require companies to spend 4-5 % of the total value of their liabilities each year on clean-up. That sounds like progress but what does it mean? Because each company has control over its bookkeeping and accounting practices, the dollar value of environmental liabilities can be manipulated with ease; 4-5 % of nothing is nothing. Nor does this promise of future action address the continued abuse of municipalities by companies defaulting on their taxes. See Chapters 16 and 17 for a discussion of liabilities.

On the same day, the AER also announced that it is considering an overhaul of their website to make information more readily available. Laurie Pushor, the current AER CEO, told the Globe and Mail that the AER has "started to really work hard on being as transparent as we can in the work we do, so that Albertans know what we're doing and how the industry is performing, and they can evaluate whether we're doing our jobs." Considering an overhaul… starting to really work hard at being transparent… seriously? Does the AER think the public is that credulous? Would anyone in possession of the facts believe any statement coming from the AER? For a recent example of the AER's transparency, see Addendum 3.2. Against the backdrop of the continued disinformation, the only logical response to the AER's statements is incredulity.

Whether it's the propagandists in Mr. Kenney's "War Room", the anti-science conspiracy theorists in Mr. Kenney's "Public Inquiry into Funding of Anti-Alberta Energy Campaigns", the industrial tools that run the AER, crony government ministers and senior bureaucrats posing as civil servants, or the right-wing extremists that fund them, their objectives are the same— to undermine the public interest, prevent decarbonization of our economy, and protect the profits and privilege of the fossil fuel meta-organization while it shifts liabilities onto the public.

Addendum 2. An Example of the Meta-Organization Network: Canadian Natural Resources Limited



Because the fossil fuel meta-organization permeates almost all sectors of government and society, bringing about the energy transition from fossil fuels to renewables faces strong and often invisible resistance. Here I illustrate relationships that pertain to Canadian Natural Resources Ltd as identified by the Corporate Mapping Project and available from: https://littlesis.org/oligrapher/3618-canadian-natural-resources-limited. Financial support is provided by the entities in the right column. To examine the linkages, it's best to view at magnification; try 300%.

Noteworthy linkages within the CNRL network include the Government of Canada, various major banks, Home Depot, Air Canada, Canadian National Railway, Petroleum Technology Alliance of Canada, CAPP, Frank McKenna (Premier of New Brunswick), CD Howe Institute, Business Council of Canada, Edwards School of Business, Manitok Energy, and the Conference Board of Canada.

One of the most frustrating aspects of the meta-organization's long tendrils is that it is nearly impossible for citizens to withdraw financial support. If you shop at Home Depot, do your banking at CIBC, TD, RBC, or BMO, or fly on Air Canda, to name a few, you inadvertently support the fossil fuel meta-organization and, in this example, CNRL.

Addendum 3. Step Up and Tell the Truth

Misinformation, disinformation, and suppression of information are essential to maintain the influence of the fossil fuel meta-organization. The proximate goals of information control are to reinforce the beliefs of the meta-organization and maintain cohesion within the fossil fuel industry's social network. Without this continual maintenance of a distorted reality, truth seeps in and erodes the foundations of the meta-organization. The ultimate goals of information control are broader and aimed at everyone. Through the use of deception, distraction, and suppression, distorted information sows confusion, undermines public discourse, and delays the green energy transition. The fossil fuel meta-organization works tirelessly to maintain the *status quo*.

Although a scientist friend once recommended that I learn to ignore the "hare-brained statements that come from the industry", allowing pseudo-science to go unchallenged contributes to the industry's ability to maintain its social license through fraud. Yes, there is the possibility that discussing bogus information can inadvertently lend it credibility by pointing to it in a scientific forum. Conversely, it's important to realize that stories published by the Canadian Association of Petroleum Producers (CAPP), the AER, the Canadian Energy Centre, and similar outlets are simply that: they are stories. The stories inform us not about the natural world but about how misinformation and disinformation are used to maintain power and influence.

At the risk of feeding oxygen to a dump fire, it might be instructive to illustrate that information abuse continues to undermine the transition to a sustainable economy. I provide two examples. The first (downloaded 13 February 2021) comes from an article by CAPP entitled "How much boreal forest has been disturbed by oil sands mines?" (https://context.capp.ca/infographics/2019/infographic_boreal-forest-and-land-rec). The second documents the experience of a biologist who asked the AER questions pertaining to coal exploration and development in southwestern Alberta.

3.1 CAPP Misinformation and Disinformation

The CAPP article tells us, without evidence, that only "0.2 % of Alberta's boreal forests have been disturbed by oil sands mining over the past 40 years" and reassures us that "What's more, once operations are complete, all disturbed lands are reclaimed by law... This includes contouring the land with soil to control erosion, and replanting a native plant community to form natural, self-sustaining habitat for wildlife." This is, of course, demonstrably false. Is it a surprise that oil majors such as Total have withdrawn from CAPP?

As the evidence has shown (Chapters and Web 4, 5, and 14), industrial disturbance creates permanently-damaged ecosystems recognizable by their disturbance signature. Reclamation as practiced is a bait-and-switch in which healthy, natural ecosystems are replaced by dysfunctional ecosystems with residual contaminants that are dominated by non-native plant communities and that pose a threat to the biota. Reclamation does not create "natural, self-sustaining habitat for wildlife".

Why the article refers to the disturbance created "over the past 40 years" is not stated. Bitumen operations have been disturbing northeastern Alberta since the late-1960s, roughly 53 years as of this writing.

Now let's examine the claims about the extent of the footprint.

If we do the math on the CAPP footprint, 0.2 % of 142,000 km^2 equals 284 km^2. For essentially the same "Oil Sands Region" (140,213 km^2), the Alberta Biodiversity Monitoring Institute, using data current to 2016, estimated a fossil fuel industry footprint of 3211 km^2, 11.3 times larger than the CAPP footprint (https://abmi.ca/home/reports/2018/human-footprint/details.html?id=19). That's a large difference. CAPP minimized the footprint by limiting it to mining, as if the effects of the entire hydrocarbon industry footprint in the region is not relevant. But even the narrowly-defined CAPP footprint is incorrect. As of 2016, Alberta Environment and Parks reported the bitumen mining footprint to be 953 km^2 (http://osip.alberta.ca/library/Dataset/Details/27#), 3.3 times the CAPP figure. Moreover, the footprint continues to grow each year.

Ecological footprints are an easily misunderstood metric. Without ecological understanding, footprints can be misinterpreted to reach absurd conclusions. By medical analogy, it would be logical (and wildly incorrect) to conclude that a stab wound does less damage than a skin abrasion. Footprint estimates by their nature are conservative because they underestimate the extent of linear disturbances such as seismic lines and don't include edge and fragmentation effects, changes to the movements and flows of plants, animals, water, energy, and materials, and the footprint of damaged air, soil, and water quality and noise and light pollution (Chapter 14). For Alberta as a whole, the strictly-defined fossil fuel industry areal footprint exceeds 30,000 km^2. If a 100 m wide buffer is added to all fossil fuel industry disturbances to account for these underestimates, the footprint increases by more than a factor of 10 to cover more than one-half of Alberta. See the accompanying file "Spills Maps" for more on the footprints of spills and wells.

3.2 The AER Continues to Undermine the Public Interest

In the second example of the continued abuse of the public trust, Lorne Fitch, biologist and former adjunct professor at the University of Calgary, recounts his experience in the wake of submitting an information request to the AER on 4 February 2021. He writes:

What does one hope for in a government agency—transparency, accountability, honesty, trust, working in the public interest? Most of us naively believe these agencies work for Albertans. When it came to questions about coal exploration in the Eastern Slopes, I approached the Alberta Energy Regulator (AER) with a sense answers would be forthcoming.

My questions related to the decision-making process and procedures the AER follows with respect to the environmental impacts of coal exploration, in particular approvals provided to a number of coal companies with leases in the headwaters of the Oldman River in southwestern Alberta.

I wanted to know what requirements are provided to coal companies that obligate them to undertake environmental impact assessments of their proposed activities since the scope and scale of these features is extensive.

There are linear disturbance density thresholds set out in the Livingstone-Porcupine Hills Land Footprint Management Plan (2018) and so I asked if the AER was adhering to these as well as what were the thresholds for new linear features (roads and trails).

Given that multiple companies operate in the same watersheds, I asked if the AER had undertaken a cumulative effects assessment to determine the overall impact of all current and proposed coal exploration programs to ensure critical ecological thresholds (like linear density) will not or have not been exceeded.

I wondered what water quality monitoring has been asked of coal companies to ensure the impact of new and re-opened roads and drill sites will not or has not affected receiving streams containing native trout species. In a similar vein I asked about water quantity, how much was asked for to facilitate drilling programs and if this was assessed in terms of the needs of any trout species at risk, like Westslope cutthroat trout and bull trout.

I was concerned about the timing, specifications, and efficacy for reclamation/restoration of the coal exploration footprint and whether performance bonds have been secured.

Several allowances to operate outside of critical wildlife timing windows had been provided to companies. I asked the AER if they could provide me with the rationale for this and what wildlife studies were undertaken to ensure wildlife species were not put at risk by such decisions.

A less than fulsome answer was delivered to me 39 days later when the AER provided the policy and legislation it purportedly follows related to coal exploration. Some of the hard questions on cumulative effects assessments and linear density thresholds were punted to Alberta Environment and Parks as these were not in the AER mandate (despite being the designated regulator). The AER plays both ends against the middle. They say they are the "one window", the sole regulator, yet defer hard questions to AEP or simply don't answer the questions. The only direct answer to any of my questions was that "the AER does not collect any bonds or security for CEPs [coal exploration programs]". None of my other questions were answered. An introductory sentence and a concluding one were meant to put my mind at rest:

"The AER ensures that energy development is safe, environmentally responsible, and meets all requirements"; and, "As the single regulator for energy development in the province, we are committed to ensuring that development is carried out in a manner that protects public safety and the environment".

Statements from the AER roll off corporate tongues so glibly, if you don't parse the words, you might be inclined to trust and believe them.

In response, I wrote again to thank the AER for reminding me of the legislation and policies they administer, but that what I was really after were answers to my questions (which I reiterated). The AER response to that was swift, telling me they had provided all the answers I was going to receive, or words to that effect. It was a "PFO" letter.

Bureaucracy can be an impenetrable fortress protected by mazes, labyrinths, dead-ends, codes, and draw bridges to keep the great unwashed (that's us) from ever divining the truth. Captured bureaucracies are staffed by functionaries who have perfected the non-answer, couched in terms of obscure references to legislation, policy, and plans.

The icing on the cake of non-answers is the solemn assurance they are working on our behalf, are deeply committed to some nebulous goal but would prefer never to hear from us again. We are, of course, with our incessant requests for information, standing in the way of them getting on with the real work, the extent of which can't be revealed to us.

I pondered the non-response of the AER and considered it in philosophical terms. A syllogism is a form of reasoning in which a conclusion is drawn (whether validly or not) from two assumed propositions. Each proposition shares a term with the conclusion, and shares a common or middle term not present in the conclusion. An example: all cats have four legs; my dog has four legs; therefore my dog is a cat.

The AER follows a political syllogism: The AER's mandate includes a legislation that protects the environment. Therefore, the AER protects the environment. Confused? So is my dog and you have every right to be as well.

When the AER refuses to answer our questions, we can attempt to find information on the AER website. It's indeed a web, a labyrinth to be navigated to find an answer without being ensnarled in dead ends. Even tech-savvy people find it challenging. It is as if a door exists, but has no handle and may not even have hinges. As a final indignity, when you penetrate this sealed vessel, you find you are expected to pay for information that should be publicly available.

No thanks to the AER, I received help accessing the applications coal companies have made for coal exploration programs. The process of deciphering the AER's "public" portal is described here: https://ab4coalfreerockies.ca/blog/life-of-a-mine-consultation?fbclid=IwAR0DnnhccZIEDXnL2mRSBMIjf5B98fkXrrhe_U0AbGjR4ftXBOo82iMfKI. Although the AER has streamlined its procedures to facilitate industrial exploitation, when it comes to the public, the AER loves its red tape, the better to tie the public in knots.

In reading the coal applications, I thought that something as extensive as a coal exploration program, with a considerable and lingering footprint would require that a company submit a detailed impact assessment before the AER issued a permit. With bighorn sheep, mountain goats, bull trout, and cutthroat trout within the footprint of activity, I expected there would be information on recent fish and wildlife inventories, plus botanical summaries, especially of scarce, rare or imperiled species like whitebark and limber pine. I thought these applications might recognize and define the critical habitats for avoidance by industrial disturbance.

Because coal exploration occurs in key headwaters, water quality monitoring to create a benchmark before activity occurred would be necessary. Drilling to ascertain coal resources requires water and so amounts, where the water would be sourced, any issues with existing trout populations, and perhaps instream flow requirements might have been necessary. New and reopened roads can cause serious erosion and sediment transport issues to receiving streams so risk assessments and reclamation plans are essential. Lastly, since there are multiple companies engaged in this exploration work a cumulative assessment would tell the regulator if key thresholds were going to be exceeded. None of these issues were addressed in the applications provided to the AER.

Applications from coal companies relied on "desk-top" analyses which are perfunctory searches of databases and maps on fish, wildlife, and plants. As a starting point there is nothing wrong with this approach. The problem is, this seems to be the endpoint of acquiring information that would allow the company and the regulator to assess risk and make informed decisions about the exploration activity.

Referral maps and the species data bases from Alberta Environment and Parks are generalizations and summaries derived from a variety of sources at irregular intervals. They are often depauperate in information on scarce, rare, threatened, and endangered species, ones most likely to be impacted negatively by a land use activity like road-building, drill site preparation, stream crossings, and any subsequent reclamation attempts.

Information on many groups of plant and wildlife species is unavailable because departmental priorities do not allow inventories to be completed. Amphibians and rare plants are common examples of overlooked or under-reported species. There is a high likelihood of data gaps and the existing information may be incomplete and out of date. In light of consistent, crippling budget cuts and lack of resources available to government staff to update inventories and research, availability of critical information is severely limited.

Habitat features define the presence, absence, abundance, and distribution of fish and wildlife species, yet these critical features can be poorly understood, mapped imperfectly, or missing from maps. Similarly, travel corridors, important for ungulates like sheep, elk, and goats as well as large carnivores do not appear on referral maps. Population dynamics are not tracked, yet an understanding of this is key to appreciating (and responding to) the vulnerability of a population to a land use activity.

Timing windows, within which a land use activity can proceed, are at best guidelines and require competent biologists to assess the situation on the ground. Assessing the efficacy of setbacks and buffers isn't something that can be done from an office—this too requires on the ground inspections. Cumulative effects and future land use activities which contribute to a footprint are not assessed. Cumulative effects always exceed the superficial and uninformed assessments of captured regulators.

Coal exploration creates multiple roads in sensitive terrain on fragile soils which makes reclamation virtually impossible. It leads to disruption of a natural drainage network, allowing water capture, increased erosion and transport of sediment to receiving waters, many of which contain species at risk trout. Reclamation plans are perfunctory, merely stating slopes will be recontoured (a dubious proposition) and replanted with native vegetation (but never stating what native vegetation was there before and what reclamation success rates might be).

A coal exploration permit allows companies to search and quantify coal reserves for two years. Then, they have three years to undertake reclamation. That's a lot of time for erosion and sediment transport to occur, even before a total reclamation failure occurs.

As such, desk-top assessments are not robust enough to use exclusively for decision-making. It is a starting point, a set of guidelines to understand what additional information has to be collected, the timing of the collection, the appropriate methodology, and how detailed the assessment should be to better understand impacts and avoid or mitigate the negative effects of a proposed land use activity. Unfortunately, the AER's system is geared to rapid assessment of applications and speedy approval. The predictable outcome of coal exploration and development are degraded fish and wildlife populations, damaged biodiversity, water quality, and water quantity and unacceptable cumulative effects.

Here I summarize my interactions with the AER over questions related to coal exploration:

When you ask the AER what they know that you don't know, they know what they know but don't want you to know what they know and keep you from knowing what you'd like to know. If you knew then you would also know what they don't know and then everyone would know they don't know everything and they don't want you to know they don't know everything and that they are unwilling to know more than what they already know because to know more complicates a known answer. The AER says AEP is supposed to know and if they know, the AER then assumes both know, but AEP may not know and if they don't know AER doesn't ask what they know, and AEP doesn't ask AER what they need to know which means they both don't know what they should know so they can both know when they are in the know and when they are not in the know, crucial to knowing what they need to know to provide answers to your questions.

Steven Magee, author and astronomer, believes that, in the case of captured regulators, it becomes our responsibility to regulate the government and corporations. Magee concluded that "The biggest mistake that you will make in life is believing that governments act in the public interest."

The AER can't or won't answer fundamental questions about how they regulate coal exploration. Is the AER protecting the public interest? I am forced to conclude that they act, not as the public guardian, but rather as an industry enabler. Albertans deserve better.

3.3 Final Thoughts

The experience recounted by Lorne Fitch is unfortunately the norm whenever a citizen attempts to access information from the Alberta Energy Regulator or indeed from anywhere within the fossil fuel meta-organization. What makes his experience different is that he has the knowledge to navigate the labyrinth of misinformation, the social conscience to know that other people may benefit from his experience, and the courage to tell the story.

As Martin Luther King observed, in time of crisis, it's not the glaring noisiness of the bad people that is so tragic, but the appalling silence of the good people. Many of us know smart and experienced people with important knowledge to share. But when it comes to speaking out or taking a stand, they remain silent. Why? There may be several reasons. Some people are timorous; they can't bring themselves to advocate or to oppose authority. Some people may feel that their contribution is unimportant. I encourage both these groups of people to step forward. Their voice is important and they are not alone. But these are not the people who are holding us back.

Far more serious among those failing to step forward are the privileged who place their power, wealth, and position above their social responsibilities. Some find the benefits of their academic or consultancy sinecures too seductive to threaten. They are content to work as cogs within machines, content to serve as functionaries, and never question how their work may be used to support a meta-organization that abuses citizens and our planet. I know many such people. Over the years, I have been dismayed by those who refuse to go on the record, who commiserate in private yet maintain silence in public. For some the money is just too good. Others believe that scientists should remain detached from their social ecosystems, sealed off from the real world of pain and suffering and injustice. They think their objectivity would be compromised by taking a stand. They are wrong.

If we want to learn about wetlands, we have to get wet and muddy. Similarly, if we want our knowledge to do some good, we have to engage in the real world. If we have knowledge that can make the world better, it's our responsibility to make that knowledge known to the greater community. A mentor professor once taught me, "Your work isn't done until you communicate your findings to the world." I've learned that "the world" has flexible boundaries. In some cases, communicating our findings simply means submitting reports to the responsible agency. In other cases, the world means to anyone who will listen.

For all those consultants and academics who have seen the horrors inflicted in pursuit of fossil fuels and still remain silent, this is your time. What good is your knowledge if you don't share it? To remain silent is to become a tool of injustice. Tell the truth and explain why the objective facts are subjectively important. Why did you choose your field of science, whether that was wildlife ecology, toxicology, soils, vegetation, reclamation, or aquatic ecology? Surely it was because you loved it. Now it's time to return that love. Step forward and tell the world what you have seen.

One such group that has stepped up and told the world the truth is the United Nations-sponsored Intergovernmental Panel on Climate Change (IPCC). In its August 2021 sixth assessment report (Climate Change 2021 The Physical Science Basis, available from: https://www.ipcc.ch/report/ar6/wg1/), the panel synthesized the current state of knowledge of the Earth's past, present, and future climate and its social and ecological effects.

Before I summarize the panel's findings, it's appropriate to provide some background. IPCC reports are massive undertakings that require the contributions of a large scientific community. They take years to prepare and are subject to the approval of member countries. In the case of the 2021 report, 195 countries had to approve the report before it could be released to the public. Preparation by committees and the necessity of government approvals has meant that IPCC reports tend to be conservative in their predictions. Far from being prepared by a secretive cabal of radicals as portrayed by the extreme right-wing, IPCC reports are the product of a large academic community with transparent governance.

The IPCC has been cognizant that a single incorrect prediction could be used to undermine the public's perception of the global assessment process. Therefore, IPCC reports have erred on the side of caution in their predictions and in their attribution of culpability. Indeed, comparison of the predictions made in the IPCC reports with later scientific studies indicates that IPCC reports tend to underestimate the effects of climate change (examples: sea level rise, loss of sea ice).

Furthermore, rates of climate change have accelerated over recent decades, which means that earlier predictions tended to underestimate the rate and magnitude of changes.

Given the global importance of the IPCC reports, the incredible complexity of the Earth-climate system, and the abundance of misinformation and disinformation available, it's risky to depend upon the media or the internet to provide a meaningful summary of the sixth IPCC report. Although the full report (3949 pages) is unlikely to be read in its entirety by anyone but the report's authors or proofreaders, it is useful to download as a reference tool. The Summary for Policymakers (at only 41 pages) provides an excellent overview for concerned citizens. I summarize those findings below verbatim with edits for brevity. I have inserted explanatory text in blue font.

A. The Current State of the Climate

It is unequivocal that human influence has warmed the atmosphere, ocean and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere, and biosphere have occurred.

The scale of recent changes across the climate system as a whole and the present state of many aspects of the climate system are unprecedented over many centuries to many thousands of years.

Human-induced climate change is already affecting many weather and climate extremes in every region across the globe. Evidence of observed changes in extremes such as heatwaves, heavy precipitation, droughts, and tropical cyclones, and, in particular, their attribution to human influence, has strengthened since AR5. [the 5th assessment]

Improved knowledge of climate processes, paleoclimate evidence and the response of the climate system to increasing radiative forcing gives a best estimate of equilibrium climate sensitivity of 3°C with a narrower range compared to AR5...

Human-caused radiative forcing of 2.72 [1.96 to 3.48] W m–2 in 2019 relative to 1750 has warmed the climate system. This warming is mainly due to increased GHG concentrations, partly reduced by cooling due to increased aerosol concentrations.

B. Possible Climate Futures

Future emissions cause future additional warming, with total warming dominated by past and future CO_2 emissions.

With every increment of global warming, changes get larger in regional mean temperature, precipitation, and soil moisture.

Projected changes in extremes are larger in frequency and intensity with every additional increment of global warming.

Continued global warming is projected to further intensify the global water cycle, including its variability, global monsoon precipitation, and the severity of wet and dry events.

Under scenarios with increasing CO2 emissions, the ocean and land carbon sinks are projected to be less effective at slowing the accumulation of CO2 in the atmosphere.

Many changes due to past and future greenhouse gas emissions are irreversible for centuries to millennia, especially changes in the ocean, ice sheets, and global sea level.

Human activities a ect all the major climate system components, with some responding over decades and others over centuries.

C. Climate Information for Risk Assessment and Regional Adaptation

Natural drivers and internal variability will modulate human-caused changes, especially at regional scales and in the near term, with little effect on centennial global warming.

These modulations are important to consider in planning for the full range of possible changes.

With further global warming, every region is projected to increasingly experience concurrent and multiple changes in climatic impact-drivers. ["Climatic impact-drivers" include mean surface temperature, extreme heat, heavy precipitation, ocean acidification, and many others] Changes in several climatic impact-drivers would be more widespread at 2°C compared to 1.5°C global warming and even more widespread and/or pronounced for higher warming levels.

Multiple climatic impact-drivers are projected to change in all regions of the world.

Low-likelihood outcomes, such as ice sheet collapse, abrupt ocean circulation changes, some compound extreme events, and warming substantially larger than the assessed *very likely* range of future warming cannot be ruled out and are part of risk assessment.

D. Limiting Future Climate Change

[In this section, the authors predict future climates based on differing scenarios of greenhouse gas production]

... Limiting human-induced global warming to a specific level requires limiting cumulative CO2 emissions, reaching at least net zero CO2 emissions, along with strong reductions in other greenhouse gas emissions. Strong, rapid and sustained reductions in CH4 emissions would also limit the warming effect resulting from declining aerosol pollution and would improve air quality.

Every tonne of CO2 emissions adds to global warming.

Scenarios with very low or low GHG emissions... lead within years to discernible effects on greenhouse gas and aerosol concentrations, and air quality, relative to high and very high GHG emissions scenarios...

Under these contrasting scenarios, discernible differences in trends of global surface temperature would begin to emerge from natural variability within around 20 years, and over longer time periods for many other climatic impact-drivers...

For North and Central America, the 6th assessment concluded that the following changes will be common to the region [see: IPCC_AR6_WGI_Regional_Fact_Sheet_North_and_Central_America.pdf]:

North and Central America (and the Caribbean) are projected to experience climate changes across all regions, with some common changes and others showing distinctive regional patterns that lead to unique combinations of adaptation and risk-management challenges. These shifts in North and Central American climate become more prominent with increasing greenhouse gas emissions and higher global warming levels.

Temperate change (mean and extremes) in observations in most regions is larger than the global mean and is attributed to human influence. Under all future scenarios and global warming levels, temperatures and extreme high temperatures are expected to continue to increase (*virtually certain*) with larger warming in northern subregions.

Relative sea level rise is projected to increase along most coasts (*high confidence*), and are associated with increased coastal flooding and erosion (also in observations). Exceptions include regions with strong coastal land uplift [isostatic rebound] along the south coast of Alaska and Hudson Bay.

Ocean acidification (along coasts) and marine heatwaves (intensity and duration) are projected to increase (*virtually certain* and *high confidence*, respectively).

Strong declines in glaciers, permafrost, snow cover are observed and will continue in a warming world (*high confidence*), with the exception of snow in northern Arctic...

Tropical cyclones (with higher precipitation), severe storms, and dust storms are expected to become more extreme (Caribbean, US Gulf Coast, East Coast, Northern and Southern Central America) (*medium confidence*).

[end of IPCC Summary]

As I review these findings in August 2023, the fossil fuel meta-organization's degradation of ecosystems continues unabated. Its undermining of the green energy transition and our democratic institutions, its damage to the global climate, and its willful endangerment of life on Earth constitute crimes against the planet and crimes against humanity. The perpetrators may hope that future generations will forgive them but that's doubtful. Sociopaths and psychopaths feel little or no empathy and have no need for forgiveness.

As for the rest of us, we can hope that future generations will forgive our complicity and complacency. Whether advanced civilization will survive the meta-organization's crippling of government institutions and the erosion of our Earth's life support systems is an open question.

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Errata and Clarifications

1. On page 18 of Hidden Scourge, the text states: “The press release of former Alberta premier Alison Redford in reference to a 2012 Plains Midstream pipeline oil spill into the Red Deer River (missing from the AER’s spill database)...” Referring to the same spill, on page 112 of Hidden Scourge, the text states: “Even recent well-publicized spills, such as the Plains Midstream crude oil spill into the Red Deer River in August 2012, are missing.” The spill, incident number 20121187, was not missing from the AER FIS database. I am unable to explain how I made the error. When initially informed of the spill, I understood that the spill had occurred in August 2012. I searched the FIS database and could not find the spill. However, the spill had actually occurred in June 2012. Perhaps being given the incorrect date for the spill caused me to limit my search too narrowly. I should have nevertheless caught the error.
It is interesting to note discrepancies in the reporting of this spill. In the AER’s 2013 version, sensitive area = “yes”, WildlifeLivestockAffected = “habitat affected”. In the AER’s 2019 version, sensitive area = “no”, WildlifeLivestockAffected = “animal(s) affected”.
2. In an earlier version of the web materials, the final paragraph of Web 6.1.1 referred to book Figures 12.11-13 in reference to the Apache 15-09 spill. Those figure numbers changed late in the editing. The correct images are book Figures 12.10-11, Plate 12.3b, Plate PS1a-f, and Web 2.5, Figure d.
3. On page 49 of Hidden Scourge, the text states that the 1 June 1975 Federated Pipe Lines Ltd spill of 445 m^3 of crude oil adjacent to the Moosehorn River was located 57 km south of Great Slave Lake. The Moosehorn River flows into Lesser Slave Lake, not Great Slave Lake.
4. On page 89 of Hidden Scourge (and Figure 6.13 and Web 6.20.3), I show that in Alberta, there is a negative correlation between annual crude oil production volume and the annual number of saline water spills, and no significant correlation between annual crude oil production volume and the annual saline spill volume. With regard to the lack of correlation between conventional crude oil production volume and annual saline spill volume, underreporting of spill volumes or inaccurate spill volume reporting could be the explanation as I noted in the book. As for the negative correlation between conventional crude oil production volume and annual number of saline spills, there might be two reasons for the negative correlation: (1) In the earlier years (1975 to about the mid-1990s), there may have been gross underreporting of the number of saline spills. (2) Aging infrastructure used to handle corrosive saline produced water (pipelines, wellheads, welds, valves, etc.) could result in rising spill rates over time. It is less expensive to respond to a spill than it is to conduct wholesale preventive maintenance. In other words, it is less expensive to repair a component after it fails. Unfortunately, that economic model results in more spills.
5. On page 191 of Hidden Scourge, I stated: “For a Plains Midstream spill of April 2011, the AER database states “Habitat affected,” not that animals were injured or killed.” That statement was correct when I wrote the paragraph about that spill (incident number 20110906). However, at a later date, the FIS database was updated to “Animal(s) affected”. I did not detect the FIS database change until after Hidden Scourge was published.