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A comparison of the predicted impacts described in permitting documents and spill records from five major operational hardrock mines

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Tanana Chiefs Conference

Norton Bay Inter-Tribal Watershed Council

Brooks Range Council

National Parks Conservation Association EST 1919

Earthworks

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AUTHOR

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Brooks Range Council, Earthworks, National Parks Conservation Association, Norton Bay Intertribal Watershed Council, and Tanana Chiefs Conference.

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Elemental Statistics is based in Seattle, Washington, which is on the traditional lands of the Duwamish and Coast Salish people. I hope to honor these lands and people in the work I do for Alaskan lands and people.

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DISCLAIMER

The retrospective analysis is based on publicly available documents and data and is complete and correct to the best of my ability. The spill data may be updated or corrected after completion of this report. I apologize for any errors or omissions.

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Tanana Chiefs Conference is an Alaska Native non-profit organized as Dena' Nena' Henash or "Our Land Speaks," charged with advancing Tribal self-determination and enhancing regional Native unity. We provide a unified voice in advancing sovereign tribal governments through the promotion of physical and mental wellness, education, socioeconomic development, and culture of the Interior Alaska Native people.

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Norton Bay Intertribal Watershed Council is a non-profit tribal organization focused on protection and sustainable management of water and subsistence resources, climate change adaptation planning, Alaska Native tribal sovereignty and environmental human rights in the Norton Bay Watershed located on the Seward Peninsula, Alaska.

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Brooks Range Council is a local, non-profit association of Alaska stakeholders concerned about the proposed Ambler Road.

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National Parks Conservation Association is a non-profit conservation organization protecting and enhancing America's National Park System for present and future generations.

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Earthworks is dedicated to protecting communities and the environment from the adverse impacts of mineral and energy development while promoting sustainable solutions.

Fort Knox Mine, by Northern Alaska Environmental Center.

Executive Summary

Hardrock mines are large industrial facilities that generate and use large volumes of hazardous and toxic materials which present a significant environmental and public health risk if spilled into the environment. These spills can include processing chemicals (e.g., cyanide solution), ore concentrate (e.g., zinc and lead), fuels (e.g., diesel), mine tailings, blasting agents, water treatment chemicals, and other chemical reagents.

The permitting process is intended to provide decision-makers and the public with accurate information about the potential risks associated with a proposed mine, including any associated pipelines and access roads. Alaska has a long history of mining, and with it, a trove of mine permitting documents and environmental records.

This report reviewed state and federal government records for the five major hardrock mining operations in Alaska (Pogo, Kensington, Greens Creek, Fort Knox/True North, and Red Dog), with the following objectives:

- Assess what spill risks are addressed in the permitting documents
- Use a consistent quantitative model for estimating the number of spills predicted and the probability of at least one trucking accident spill for all hazardous materials
- Compare actual spills to predicted numbers
- Offer model critiques
- Identify data gaps
- Synthesize the findings and make recommendations for the environmental review process for proposed new mines and mine expansions

The Red Dog Mine has repeatedly experienced hazardous materials spills along the 52-mile haul road, and the mine is often featured on the Alaska Department of Environmental Conservation's top ten annual spill list. Photo: USGS.

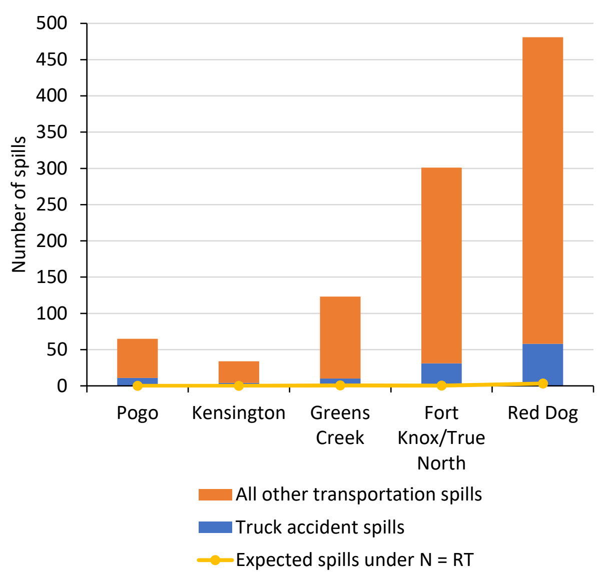
The results of this analysis determined that:

1 **The environmental review process did not regularly include a quantitative spill analysis, and none of the reviews analyzed the cumulative risk of all potential spills for all types of hazardous materials.**

For those that did analyze the potential for spills, transportation-related spills were the only type of spills considered, and some modeled only the risk of a spill for a single hazardous substance (e.g., truck accidents spills of diesel at Kensington and Pogo and ore concentrate at Red Dog, or tailings slurry pipeline spills at Kensington). *None of the reviews analyzed the cumulative risk of on-site and transportation-related spills for all hazardous materials.*

2 **Applying the model to single substances underestimates the risk of spills.**

Most of the quantitative spill estimates in mine Environmental Impact Statements (EISs) are for truck accidents, using the model $N = RT$, where N is the number of predicted spills, T is the total miles traveled by hazardous materials, and R is the spill rate per truck mile. Pogo and Kensington's EISs showed a 1% and a <0.4% of a diesel spill from a truck, respectively. This analysis included applying the $N = RT$ model to all five mines in this report for all hazardous materials transported by truck that were listed in the EISs (or less intensive environmental assessments (EAs)) to compare the model predictions of truck accident spills with the actual spill records kept by the Alaska Department of Environmental Conservation (ADEC) from July 1995-December 2020. Considering the predicted number of miles traveled for all five mines through 2020, the $N = RT$ model would have predicted 4.3 truck accidents with spills of hazardous materials and a 98.6% chance of at least one truck accident spill (Figure ES.1 and Table ES.1).



Number of transportation spills by mine—predicted vs. actual spills

Figure ES.1. Predicted and actual spills from truck accidents and all other transportation spills for the five mines through 2020. The dotted yellow line is the predicted spills. The actual spills are shown in blue and orange. See Table ES.1.

3 Spills were severely underestimated.

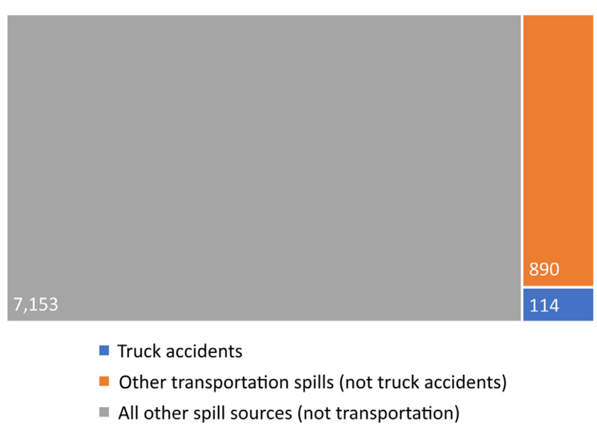
The spills analysis conducted during the permitting process for all five mines grossly underestimated the number of actual spills. None of the mines' EIS/EAs had quantitative spill predictions for anything other than transportation-related spills, and even these were severely underestimated (Table ES.1).

- **Truck accident spills:** Based on the records from ADEC (2021), there were 114 *collision/allision* and *rollover/capsize* accidents associated with these five mines, which is 26.5 times as many as would have been predicted with the $N = RT$ model. These 114 accidents spilled nearly 6,000 gallons and 1,660,000 pounds of hazardous materials.

- **All transportation-related spills:** While truck accident and pipeline spills are the only spills with quantitative representation in any of the EIS/EAs examined, they are only a small portion of all the transportation-related spills identified in the ADEC database (e.g., unsecured cargo, overfilled tanks, leaks). There were 1,004 total transportation-related spills at all five mines, resulting in aggregate totals of 33,404 gallons and 1,771,077 pounds of hazardous materials spilled. As a result, when all transportation-related spills from the ADEC database were included, there were more than 230 times more actual transportation-related spills of hazardous materials than the model would have predicted for truck accident spills alone. (Figure ES.2)

There were 230 times more actual transportation-related spills than the model would have predicted for truck accident spills alone.

- **Total spills (transportation-related spills and other on-site spills (e.g., spills of hazardous materials from the processing facilities):** There is no model for predicting total spills. The environmental review process for the five hard rock mines did not consider any non-transportation related spills, yet the ADEC database for the five hardrock mines documented more than 8,150 total spill incidents, releasing >2,360,000 gallons and >1,930,000 pounds of hazardous materials since 1995 (Table ES.1 and Figure ES.3). This is eight times more spills than transportation-related releases (on-site and to and from the mines) account for. While 92% of the spills with quantities given by volume were of <100 gallons, the remaining 8% of spills accounted for 97% of the hazardous materials released by the mines (Figure ES.4).



Total spills for all five mines (8,157)

Figure ES.2. The number of truck accidents (blue rectangle) were only a small proportion of the total number of transportation related spills (combined blue and orange areas), which in turn were only a small fraction of the total number of spills from all causes at the mines (combined blue, orange, and grey areas). Note that 114 truck accidents + 890 other transportation spills = 1,004 total transportation spills and 114 + 890 + 7,153 = 8,157 total spills.

4 A flawed model.

The math for implementing the $N = RT$ model is straightforward, but it requires accurate and detailed information about what hazardous materials will be transported, how much of each, and in what size loads to calculate the number of trips and miles traveled. In the EIS/EAs examined in this report, most of those data were incomplete and/or had to be based on inference. One key flaw is the use of the widely cited value for R of 1.87×10^{-7} spills per truck miles for two-lane rural roads (Harwood and Russell 1990), which is based on data from rural two-lane roads in California, Illinois, and Michigan that are at least 30 years old. The $N = RT$ model is overly simplistic in that it treats all miles of road as the same, not accounting for varying road conditions on industrial access roads to remote Alaska mines. *Furthermore, this model only predicts truck accident spills, and does not consider other transportation releases or spill incidents at the mine site.*

Predicted vs. actual spills

Table ES.1. Comparison of the truck accident spill risk predictions using $N = RT$ for the five mines and the actual spill record for truck accident spills, all transportation-associated spills, and total spills (transportation and on-site), by number, cumulative volume, and cumulative weight.[1]

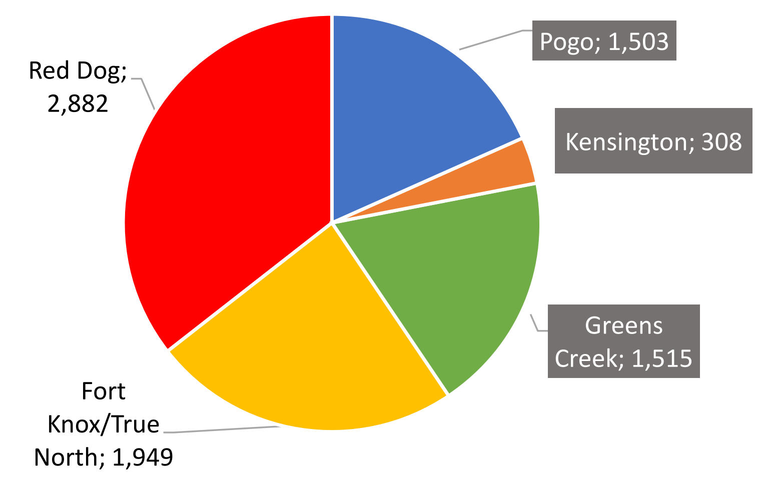
	Pogo	Kensington	Greens Creek	Fort Knox/ True North	Red Dog	Total
Predicted truck accident spills using $N = RT$ with Harwood and Russell (1990) estimate of R through 2020						
	0.10	0.035	0.76	0.21	3.2	**4.3**

Actual spills						
Actual truck accident spills through 2020 (collision/allision + rollover/capsize)						
Number	11	4	10	31	58	**114**
Cumulative volume (gal)	952	332.5	89	1,177	3,373	5,924
Cumulative weight (lbs)	0	0	0	0	1,658,481	1,658,481
Actual transportation-related spills through 2020 (truck accidents + all other transportation spills)						
Number	65	34	123	301	481	**1,004**
Cumulative volume (gal)	1,603	495	2,396	11,631	17,279	33,404
Cumulative weight (lbs)	0.5	2	0	10	1,771,064	1,771,077
Actual total spills through 2020 (all transportation + on-site spills)						
Number	1,503	308	1,515	1,949	2,882	**8,157**
Cumulative volume (gal)	267,710	6,272	111,333	527,533	1,450,397	2,363,245
Cumulative weight (lbs)	29.5	4	13,899	5,024	1,919,563	1,938,520

The predicted number of spills severely underestimated the actual number of spills:

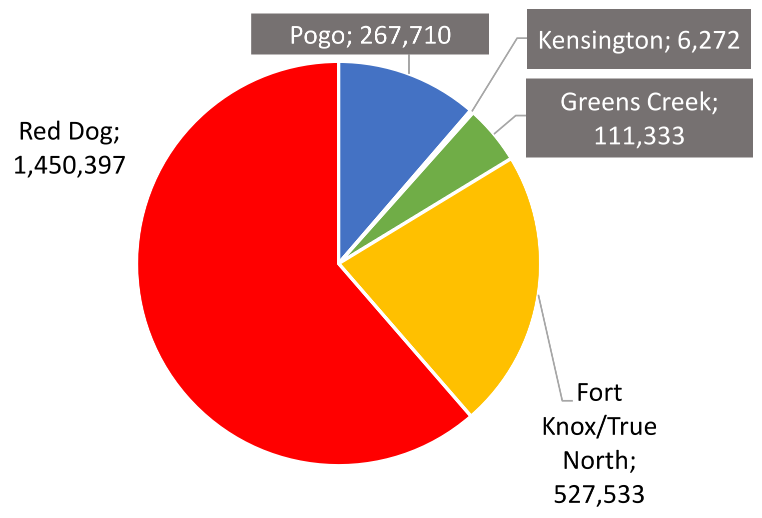
- **Most mines only predicted truck accident spills for diesel or ore concentrate transport.** When the model ($N = RT$) was applied to ore concentrate, chemical reagents, explosives, tailings, and diesel transportation by truck at all five mines, it predicted 4.3 truck accident spills, whereas the actual number of truck accident spills totaled 114 spills.
- **In terms of percentages:** Truck spills were 11.4% of the actual number of actual total transportation-related spills (1,004), and transportation-related spills were 12.3% of the actual number of total mine spills (8,157), which included on-site spills.

Total number of spills by mine — through 2020



a.

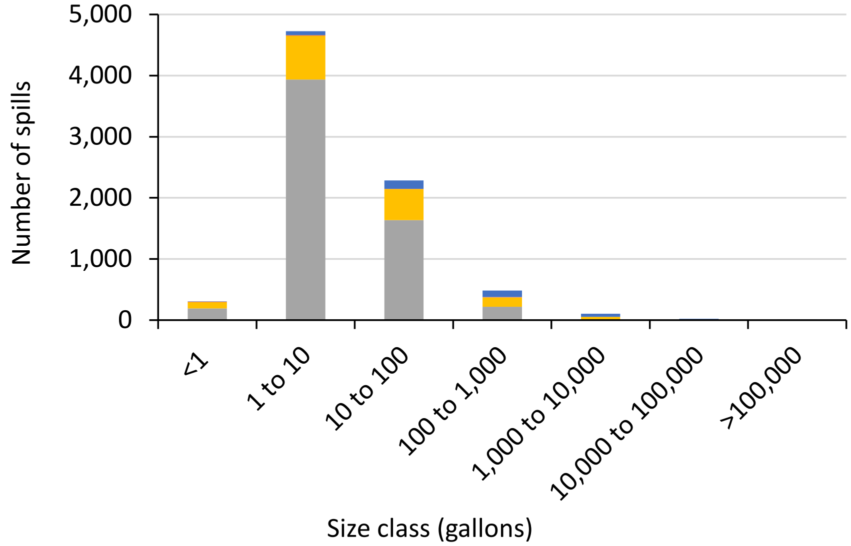
Spill volume by mine (gallons) — through 2020



b.

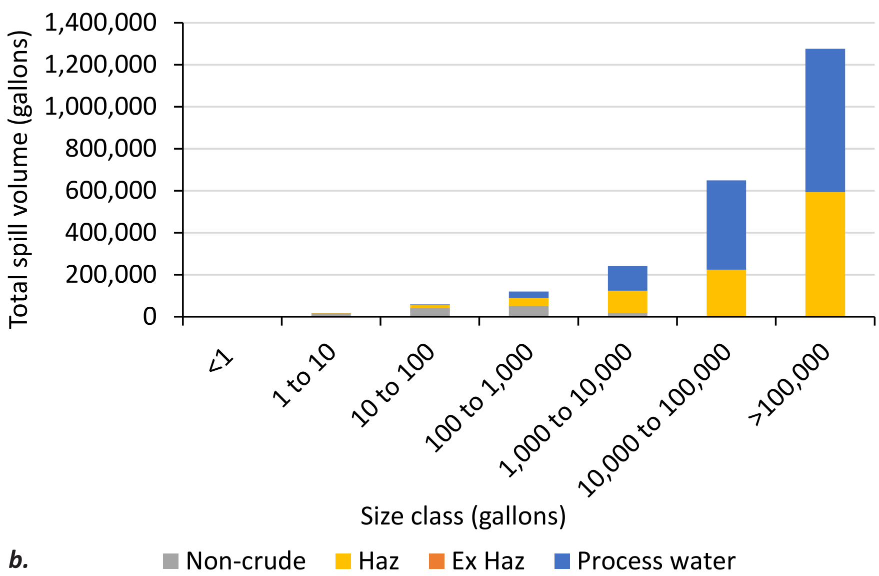
Figure ES.3. Relative proportions of total spills (a) and cumulative volume for the five mines (b). Mine names in dark boxes indicate underground mines rather than open pit mines.

Number of spills by size and substance class for five Alaskan hardrock mines



a.

Cumulative volume by spill and substance class for five Alaskan hardrock mines



b.

Figure ES.4. Number of spill incidents (a) and cumulative gallons spilled (b) for non-crude oil, hazardous substances, extremely hazardous substances, and process water in different spill size classes for five Alaska hardrock mines from July 1995-December 2020 based on ADEC (2021).

Recommendations

This analysis demonstrates that improvements are necessary to predict the risk of spills from mining operations more adequately. Recommendations include:

1. **A comprehensive spill risk analysis is an essential part of the permitting process to provide accurate information to decision-makers and the public about the potential social and environmental impacts of a proposed mining operation and associated infrastructure. The EIS process must include a quantitative spill risk assessment that includes the potential for all on-site and transportation-related spills and considers the full range of hazardous materials.**

2. **To inform the spill risk analysis, any forthcoming mining EISs should:**
   - Include an explicit, complete, and quantitative hazardous materials list for substances transported to or from the mine or used on-site.
   - Include complete descriptions of the transportation methods, load sizes, and frequency for the hazardous materials, as well as tailings and other hazardous wastes.
   - Include quantitative transportation spill risk estimates for the aggregated total of trips for the whole mine operation's cumulative hazardous materials spill risk.
   - Use a more detailed transportation spill risk model based on those from the peer-reviewed literature, with up-to-date risk rates and location-specific descriptions of the transportation corridor instead of $N = RT$ with the estimate of R from Harwood and Russell (1990). (See Table 11.5 as a starting point.)
   - Explicitly state that the transportation corridor to model is not just defined by the length of the any newly built roads associated with the mine, but instead extends to the origin(s) and destination(s) of the hazardous materials.
   - Be explicit about the numbers of predicted potential spills from truck accidents.
   - Acknowledge that accident modeling only describes one potential way hazardous materials are released from vehicles, and that transportation-related releases can have a multitude of causes, many of which are not modeled in current EISs. Future EISs should include quantitative estimates of all transportation-related spills, even if there is great uncertainty in the estimates.
   - Similarly, acknowledge that transportation-related spills are themselves only a small fraction of the total spills associated with hardrock mining, and future EISs should include quantitative estimates of all potential spills, including other on-site spills, even if there is great uncertainty in the estimates.

Predicting the risk of spills requires a new approach.

3 **The ADEC database and the EIS process should include enough detail to fully characterize the environmental consequences of the spills.** The EIS process under NEPA is intended to explicitly consider potential environmental impacts associated with proposed projects and inform the public. Neither of those has been accomplished for spill risks related to these five mines. This analysis shows that spills can and do occur at the mine site and along the transportation corridor. Impact analyses should be based on the quantitative estimates of spills that may occur in all locations associated with mining activities.

4 **Underestimation of mining spill risks is likely systematic, and the lessons learned here should be extended to mine environmental review processes nationally.** Development of a comprehensive and publicly accessible spill database with clear and consistent definitions, including which spills are reported, is necessary for quantitative spill risk estimates in future environmental reviews. This analysis used five Alaskan mines as case studies, partly because ADEC's spill database, unlike many other state spill records, is robust, up-to-date, and easily accessible. Based on the experience from these five mines, we cannot expect that spills are low probability events or that their total frequency can be accurately predicted based on overly simplistic models that only address two potential spill causes/sources (trucks and pipelines). Unfortunately, both National Response Center (NRC) and Pipeline and Hazardous Materials Safety Administration (PHMSA) failed to capture spill records at the same level of completeness that ADEC did.

5 **Environmental impact analyses and predictions should draw on recent, applicable peer-reviewed science to the greatest extent possible.** Spill risks were only one aspect considered in the EIS/EAs of the five case study mines in this report, but they serve to illustrate the failure to use the latest, best available science in the EIS process.

The two goals of the EIS production process are to clearly state potential consequences of projects and to inform stakeholders and decision makers of those impacts. The current treatment of spill risks in mining EISs does neither.

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1 MAJOR DATA GAPS. Sewage spills were not analyzed in the environmental reviews, sewage spill data were not collected, and ADEC often does not specify spill details relevant to assessing environmental impact. Sewage spills can be a recurring issue at mines and associated worker camps, resulting in potential health risks from fecal coliform. Sewage spills have been reported at Pogo, Kensington, and Greens Creek mines, including an EPA Notice of Violation which documented 21 sewage spills totaling 16,520.5 gallons in 2.5 years at Pogo Mine. None of the environmental review processes for the five mines analyzed the spill risks associated with sewage, and ADEC does not track sewage among the hazardous materials included in the spill database. While ADEC does report which mine each spill is associated with, the spill data often do not include information about where on the mine site the spill occurred, what media it impacted, and how it was cleaned up, all of which are necessary for determining the environmental significance of the spills' impacts, individually and collectively.

Fort Knox Mine. Photo: Northern Alaska Environmental Center.

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CHAPTER 1
Introduction

Selection of the mines analyzed

Alaska has a long history of mining and with it, a trove of mine permitting documents and environmental records. Hardrock mines are large industrial facilities that generate and use large volumes of hazardous and toxic materials that present a significant environmental and public health risk if spilled into the environment. The permitting process is intended to provide decision-makers and the public with accurate information about the potential risks associated with a proposed mine, including any associated pipelines and access roads. Recent proposals, such as the proposed Ambler Road, a 200-mile industrial access road that includes thousands of river and stream crossings and extends through the Gates of the Arctic National Preserve, highlight the need for accurate information about these spill risks.

This report considers five large, hard rock mines that are currently in production in Alaska: Pogo, Kensington, Greens Creek, Fort Knox/True North, and Red Dog. The five mines are mix of underground mines (Pogo, Kensington, and Greens Creek) and open pit mines (Fort Knox/True North and Red Dog) and extract different ores (Figure 1.1). Each mine can be viewed as an experiment in which predictions were made about the outcomes and effects of construction and operation in the permitting documents which can then be tested against the actual history. This report focuses on spill risks as presented in environmental assessments (EAs), environmental impact statements (EISs), or plans of operation and compares those with the spill records kept by the Alaska Department of Environmental Conservation (ADEC). The goal is to see how accurately spill risks were predicted and described in the permitting stages and see what might need to be done to improve EISs for future mines so that the public and decision-makers have more accurate information about the potential risks.

Figure 1.1. Mining activity in Alaska, 2017. Except for Usibelli, the mines marked with red stars are the case studies in this report. (Usibelli is a coal mine.) Figure credit: McDowell Group (2018).

Overview

This report focuses on hazardous materials spills associated with Alaskan hardrock mines, particularly those related to transportation as those are the risks most commonly modeled.

The first chapter defines terminology to place Alaskan mining in the larger context of what is already known about transporting hazardous materials in the United States. This introduction gives the definition of hazardous materials, an overview of the quantity of hazardous materials transported in the United States over time, and a description of transportation spill incidents as general background.

Chapter 2 contains an explanation of the shared case study structure used for all five mines. I describe how I determine which hazardous materials are used at each mine and in what quantities, and the methodology for estimating the quantities of blasting agents required when those are not otherwise specified. I also describe the model used to estimate the number and probability of transportation corridor spills related to accidents. Finally, I give a primer on the data source I used as the observed spill record.

Chapters 3-7 are the case studies for Pogo, Kensington, Greens Creek, Fort Knox/True North, and Red Dog mines. They are summarized together in Chapter 8 and compared against the spill records from other Alaskan mines in Chapter 9. In Chapter 10 I examine national spill databases to compare the incidents listed with the records kept by the ADEC.

Chapter 11 contains a more detailed look at the model used to estimate the number and likelihood of transportation spills and puts it in the context of more recent peer-reviewed research for quantitative risk assessment of transporting hazardous materials. Chapter 12 offers a very brief look at the goals of the EIS process under the National Environmental Policy Act and recommendations from the Environmental Protection Agency for using models in EISs. Based on what was predicted in the permitting documents for these five mines compared to what could have been predicted and what was observed, in Chapter 13 I make some recommendations for improving at least one aspect of the EIS process for mines, as well as for recordkeeping about spills in Alaska and nationally. Chapter 14 summarizes the findings across the entire report.

This report has several objectives:

- Assess what spill risks are addressed in the permitting documents for five large hardrock mines in Alaska;
- Use a consistent quantitative model to estimate the number of spills expected and probability of at least one spill for transportation spills, specifically trucking accidents, for all hazardous materials;
- Compare observed trucking accident spills to predicted numbers from the model, and put those spills in the larger context of transportation and other spills incidents at the mines;
- Compare the spill histories of the five case study mines to those of the other mines in Alaska;
- Offer model critiques;
- Identify data gaps; and
- Synthesize the findings and make recommendations for the environmental review process for proposed new mines and mine expansions.

This report is important because it offers a hard look at how spill risks have been presented in mining EIS/EAs, qualitatively and quantitatively, compares that with what could have been done at the time the documents were prepared, and shows how the spill predictions have held up over time. If the EIS/EAs had full and accurate pictures of spill risks, then these mines can serve as examples in assessing the potential risks of spills for future projects. If their predictions were inaccurate and presented an insufficient description of spill risks and impacts, then these mines serve as examples of how decisionmakers and community members have not received a full and representative picture of the environmental consequences of approving large mining projects. The succeeding chapters show that spill risks were severely understated for all five mines studied.

Background: Hazardous material transportation in the United States

Definition of hazardous materials

By definition, a hazardous material is

> any substance or material capable of causing harm to people, property, and the environment. … The United Nations sorts hazardous materials into nine classes according to their physical, chemical, and nuclear properties: explosives and pyrotechnics; gasses; flammable and combustible liquids; flammable, combustible, and dangerous-when-wet solids; oxidizers and organic peroxides; poisonous and infectious materials; radioactive materials; corrosive materials (acidic or basic); and miscellaneous dangerous goods, such as hazardous wastes (UN, 2001). (Erkut et al. 2007)

Substances which are potentially harmful to human health and/or the environment when released in sufficient quantities are designated as harmful by the Environmental Protection Agency (EPA) (Transportation Research Board 2005). The EPA is required to report releases, and the Department of Transportation (DOT) regulates the transportation of hazardous substances when they are shipped in quantities exceeding specific thresholds (Transportation Research Board 2005).

Transport of hazardous materials in the United States

The amount of shipping of hazardous materials in the United States is large and growing (Table 1.1). The number of truck trips carrying hazardous materials has increased from an estimated 250,000-500,000 shipments per day in 1998 (Erkut and Verter 1998) to more than 1,000,000 trips per day by 2010 (Inanloo et al. 2015), moving billions of tons (Table 1.1). Material quantities can vary from a few ounces to, as is often the case for mines, thousands of gallons or tons of materials, which can be moved through areas with huge potential risks for loss of human life or for environmental damage (Gerard 2005).

Table 1.1. Estimates of quantities and distances hazardous materials are shipped in daily and annually in the United States. Unless otherwise specified, shipments may be transported by train, pipeline, truck, and/or airplane.

Source Summary statistic	Internal reference (if any)
Erkut and Verter 1998	
• 250,000-500,000 shipments per day	
• 1.5-4 billion tons per year	
Battelle 2001	
• 74,410 million ton-miles in 1993	1993 Commodity Flow Survey
• 74,939 million ton-miles in 1997	1997 Commodity Flow Survey
• 7,763,282,762 vehicle miles in 1997	
• 1.4 billion tons/year	
• 5% of all commodity shipment miles	
• In 1996, 7.2 percent of all trucks surveyed carried HM.	Star Mountain Inc., 1997
• 769,000 hazardous truck shipments per day	US DOT, 1998
• 314,000 petroleum product shipments per day by truck	
• 445,000 chemicals and allied products shipped per day by truck	
• 1.4 billion tons in hazardous shipments by truck per year	
• 1.04 billion tons petroleum per year by truck	
• 43% of all HazMat tonnage is transported by truck	
Craft 2004	
• >800,000 truck shipments/day	
• 7.2% of trucks carry enough HazMat to warrant displaying a warning placard	Office of Motor Carriers 1996 fleet survey
Gerard 2005	
• >800,000 shipments per day	
• >3 billion tons per year	

Table 1.1. (Continued.)

Source / Summary statistic	Internal reference (if any)
Transportation Research Board 2005	
• 817,000 shipments per day	1997 Census Bureau
• almost 3 million shipments per year	
• 5.4 million tons per day	
• 2 billion tons per year	
• 768,907 truck shipments per day	
• 205 million tons-miles per day by truck	
• average shipment weight by truck = 4.82 tons	
• 94% of daily shipments are by truck	
• 69% of tonnage shipped is by truck	
• 34% of ton-miles are by truck	
• 41% of truck shipments are petroleum products; 59% are mostly chemical and allied products	
Erkut et al. 2007	
• 800,000 shipments/day	US DOT, 2000
• 9 million tons/day	
Inanloo et al. 2015	
• >15,000 incidents reported to the Pipeline and Hazardous Materials Safety Administration (PHMSA)	
• > 1,000,000 daily shipments of hazardous materials by truck	PHMSA, 2010

Definition of an incident

Erkut and Verter (1998) note that “although accident probabilities are quite low for any given trip, the sheer volume of hazmat shipments almost guarantees that there will be some accidents over a sufficiently long period of time.” The terminology surrounding “accidents” and “incidents” varies slightly between those who study transportation networks and legal definitions. For those who study the shipping of hazardous materials to model transportation networks and choose optimal routes, an accident resulting in a release of hazardous materials is called an incident (Erkut et al. 2007). Legally, “federal law has defined a hazardous materials transportation incident as an unintentional release of a hazardous material from its package during transportation, which includes periods of loading and unloading and storage incidental to transportation” (Transportation Research Board 2005). Those incidents are events in which there is “an unanticipated cost to the shipper, carrier or any other party”, including hazardous material accidents with and without releases, releases related to loading and unloading, and enroute leaks, and reserve the term “accident” for vehicular collisions (Battelle 2001). Incidents that are sufficiently large or have severe enough consequences are considered “serious”:

> The definition of “serious” incidents used by PHMSA’s Office of Hazardous Materials Safety (OHMS) for hazardous materials releases from road and railway transportation includes additional criteria. Since 2002, PHMSA/OHMS has defined "serious incidents" as incidents that involve either:
>
> - a fatality or major injury caused by the release of a hazardous material,
> - the evacuation of 25 or more persons as a result of release of a hazardous material or exposure to fire,
> - a release or exposure to fire which results in the closure of a major transportation artery,
> - the alteration of an aircraft flight plan or operation,
> - the release of radioactive materials from Type B packaging,
> - the release of over 11.9 gallons or 88.2 pounds of a severe marine pollutant, or
> - the release of a bulk quantity (over 119 gallons or 882 pounds) of a hazardous material.
>
> The number of “serious” incidents presented in the tables of this section for road and railway includes only incidents meeting the first of these criteria (incidents with fatality or injury caused by the release of a hazardous material), and no other incidents meeting the other criteria. For transmission pipelines, all serious incidents are included. (PHMSA 2010).

CHAPTER 2
General methods

Each mine is treated as its own case study. I used environmental assessments (EAs), environmental impact statements (EISs), and general plans of operation to find initial descriptions of the mines'

- Location and physical description;
- Characterization of the transportation corridor (and selection of a preferred route if there were multiple options);
- A list of the hazardous materials to be transported, along with the quantities to be moved annually and per load, and by each relevant transportation method; and
- Qualitative and quantitative descriptions of spill and other hazardous materials release risks.

The level of detail at which the hazardous materials and spill risks were described varied across the five mines considered here. The lists of hazardous materials described in the permitting documents and spill records, along with information extracted from their material safety data sheets (as available), are in Appendix A.

Estimation of material quantities

Mining requires and produces large quantities of hazardous materials. Physically reaching the ore body and extracting it and the ancillary waste rock require blasting materials. Running the mill and other equipment requires power. Since most mines are not adjacent to chemical manufacturing facilities, reagents need to be transported to the mine. Hazardous wastes need to be treated at the mine site and/or transported elsewhere. Estimating the number of expected spills and releases is possible if the individual mine scenarios are described in sufficient detail and if there are accurate spill rate estimates to apply. Spill rates will vary by size, substance, and source. That is, small spills happen more frequently than large spills; diesel, which is often used in massive quantities, may get spilled more often than water treatment chemicals; and vehicle accident and spill rates can be very different than spill rates from pipes or lines.

Knowing the list of materials and the quantities in which they will be used, as well as how they will be transported to, from, and at the mine site are all necessary to estimating the risks of potential transportation spills. EA/EISs and general plans of operations usually describe the amount of ore production and ore concentrate that are expected to result during operations. The list of reagents and water treatment chemicals varied by mine, depending on the composition of the base rock and ore. The quantities and transportation methods of at least some of those materials are often specified in permitting documents. The reagents to be used in the milling process and water treatment are often listed in less specific terms than are ore and ore concentrate, as are the amount of blasting agents.

Based on the descriptions within the permitting documents for each mine, I compiled as complete a record of hazardous materials as was given. The information I searched for included the entire list of processing reagents, water treatment chemicals, diesel, ore concentrate, blasting agents, and other hazardous materials, as well as the annual use quantities, the methods of transport, and the load size per trip. Diesel can be used in blasting, as a reagent, and/or in power generation and may have different quantities proposed in permitting documents, depending on the specifics of the alternatives analyzed.

Most mines considered in this report did not include explicit discussions of blasting materials. One of the supplies needed in substantial quantities every year is ammonium nitrate, which would be used in combination with diesel fuel oil for blasting. I estimated the amount of ammonium nitrate and fuel oil (ANFO) based on data from EISs for Pogo Mine (EPA 2003b) and the Stibnite Gold Project in Idaho (USFS 2020b) (Table 2.1).

Table 2.1. Ore production explosives usage and diesel requirements for two example mines and their relative consumption rates based on ore production.

Rate	Pogo Mine (EPA 2003b)	Stibnite Gold Project (USFS 2020b)
A. tons of ore production per day	2,500 to 3,500	20,000 to 25,000
B. tons per year of explosives	1,000 to 1,500	7,300
C. gallons of diesel per year	786,000 to 1,300,000*	5,800,000
tons of explosive per year: tons ore per day = B/A	0.40 to 0.43	0.29 to 0.36
gallons diesel per year: tons of ore per day = C/A	314 to 371	232 to 290
gallons of diesel per year: tons of explosive per year = C/B	876 to 867	794.5

*Diesel value for Pogo does not include 4.2 million gallons per year for onsite power generation.

For the mines where the amount of blasting materials was not explicitly given, I will use an estimate of 0.4 tons of ammonium nitrate per year for each ton of ore produced per day, a consumption rate that is close to that of Pogo Mine. I will use an estimate of 800 gallons of diesel for each ton of ammonium nitrate. These are rough estimates, necessitated by the lack of detail given in the EA/EISs.

As an aside, following the correct storage protocols for ammonium nitrate is critical for safety. On August 4, 2020, 2,750 tons of ammonium nitrate that had been stored at a port in Beirut, Lebanon since November 2013 exploded and a two-mile radius around the blast was flattened (*New York Times* 2020a, b, c). Domestic explosions of ammonium nitrate have also occurred. The *New York Times* (2013) described the explosion of 540,000 pounds (270 short tons) ammonium nitrate at a fertilizer storage plant in West, Texas on April 17, 2013, which registered as a 2.1 earthquake on the Richter scale. In that case the ammonium nitrate was stored on site with 110,000 pounds (55 short tons) of anhydrous ammonia.

Calculating expected numbers and probabilities of transportation corridor spills

Total exposure to truck-related incidents is usually based on the number of truck-miles traveled in a given period, which is a function of the number of annual trips for each hazardous substance multiplied by the length of the trip and the number of years. If the number of trips were constant over the production life of the mine, then

$$Truck\ miles = road\ length\ \ x\ \ total\ number\ of\ trucks/year\ \ x\ \ years\ of\ production$$

In practice, the number of trucks per year varies with production level and by the substance being transported (ore concentrate, reagents, fuel, etc.). Mathematically this can be expressed for a given time period as

$$Total\ miles = \sum_{Start\ year}^{End\ year} l\left(n_{ore\ conc,year} + n_{fuel,year} + n_{reagents,year} + n_{other\ haz\ mat,year}\right)$$

where *l* is the length of the road traveled, $n_{ore\ conc,\ year}$ is the number of ore concentrate shipments in a given year, $n_{fuel,\ year}$ is the number of fuel loads, $n_{reagents,\ year}$ is the number of deliveries of reagents for the ore processing and other process, and $n_{other\ haz\ mat,\ year}$ is the number of trips for explosives, wastes, and other hazardous materials.

The total number of truck-miles can be used with a spill rate per truck mile to estimate the number of expected spills *(E(N))* and the probability of there being at least one spill from a truck over different time frames *(P(N>1))*. Harwood and Russell (1990) estimated that 1.9×10^{-7} spills occur per truck mile for rural two-lane roads. Although this estimate predates some of the EISs, such as the 1984 EIS for Red Dog, it was cited in some of the EISs for the case study mines. For consistency of risk comparison across mines, I will use the Harwood and Russell (1990) spill rate for all the large mines considered here. Using this estimated spill rate, the expected number of spills (E(*N*)) associated with the mine over a given time period is

$$E(N) = spill\ rate\ per\ mile\ \ x\ \ total\ miles\ traveled = RT$$

where *R* = 1.9×10^{-7} spills per truck mile and the total miles traveled, *T*, depends on which years of production and operation are considered. If we assume that spills follow Poisson distribution (as is commonly done for independent, randomly occurring events that are relatively rare), then the probability of at least one spill during a certain period is

$$P(N \geq 1) = 1 - P(N = 0) = 1 - exp\ (-RT)$$

We can estimate the number of truck miles based on data given in the EISs and other documents and compare *E(N)* with the actual number of spills from trucking accidents in the ADEC database (ADEC 2021). (But see *Chapter 11: Reconsidering the* N = RT *model* for further discussion of the rate and model.)

Data collection

Spills and releases are reported across a combination of sources. The most comprehensive for Alaska is the Alaska Department of Environmental Conservation (ADEC) database (ADEC 2021). Other sources include supplemental EISs, general plans of operations for the mines, environmental audits, EPA notices of violations, the Coast Guard National Response Center (NRC) database, and the Pipeline and Hazardous Materials Safety Administration (PHMSA) database. The individual mine case studies draw on the incident records from ADEC, EPA notices of violation, and any spills records in permitting documents, environmental audits, and general plans of operations. (For further discussion of the record of Alaska spills in the NRC and PHMSA databases, see *Chapter 10: CHAPTER 10 NRC and PHMSA* spill records.)

ADEC Spill Reporting Requirements

Alaskan spill reporting requirements can be found at https://dec.alaska.gov/spar/ppr/spill-information/reporting (accessed on July 20, 2021; emphasis in the original):

> Notification requirements
>
> Hazardous Substance Releases
>
> > *Any* release of a hazardous substance ***must be reported*** as soon as the person has knowledge of the discharge.
>
> Oil/Petroleum Releases
>
> > **To Water:**
> >
> > - ***Any*** release of oil to water *must be reported* as soon as the person has knowledge of the discharge.
> >
> > **To Land:**
> >
> > - ***Any*** release of oil in ***excess of 55 gallons*** must be reported as soon as the person has knowledge of the discharge. Any release of oil in ***excess of 10 gallons but less than 55 gallons*** must be reported within 48 hours after the person has knowledge of the discharge. A person in charge of a facility or operation shall maintain, and provide to the Department on a monthly basis, a written record of discharge of oil from *1 to 10 gallons*.
> >
> > **To Impermeable Secondary Containment Areas:**
> >
> > - Any release of oil in ***excess of 55 gallons*** must be reported within 48 hours after the person has knowledge of the discharge.

Spill records associated with each mine can begin in the exploration and construction phase, as well as occurring during operations. I collected spill and release records from the ADEC Spill Prevention and Response (SPAR) Prevention Preparedness and Response (PPR) Spills Database (ADEC 2021). The data span from July 1995 to the present and are searchable. ADEC divides Alaska into 10 subareas. I downloaded the spills for each subarea from 1995 to 2020. For each spill, there are up to 30 descriptors that can be completed (Table 2.2).

Table 2.2. Spill incident fields in the ADEC spill database.

Spill ID	Source type	Location	Affiliate role
Spill name	Address 1	Substance type	Responsible party
Spill number	Address 2	Substance subtype	Facility name
Spill date	City	Quantity released	Latitude
Case closed date	ZIP code	Substance unit	Longitude
Response	Area	Quantity potential	Location data
Facility type	Subarea	Cause subtype	
Facility subtype	Region	Cause type	

Most of the fields are self-explanatory, and I have added descriptions below. Terms from ADEC (2021) are in *italics* here and throughout this report.

Response: *took report or phone follow-up*

Facility type: There were 42 facility types listed, including *Air transportation, Bulk fuel terminals, Chemical manufacturing/storage, Mining operations, Oil exploration, Vehicle, Vessel,* and *Unknown*.

Facility subtype: Often blank but could define a vessel spill as coming from a *barge* or an air transportation incident as coming from an *aircraft*

Source type: Often blank. For mining operations spills, the sources included *containers*, *drums*, *pipes or lines*, *heavy equipment*, *tanks*, *fuel pumps*, and *tankers/trailers*.

Substance type: *Crude oil, extremely hazardous substances, hazardous substances, non-crude oil, process water,* and *unknown*. (See below.)

Substance subtype: varied by substance type.

Within this report, "hazardous materials" refers to the aggregate of all the substance classes recorded by ADEC, with *hazardous substance* defined below. (That is, *hazardous substance* is a subset of the hazardous materials spill records.) Further clarification can be found in ADEC (2007), which defines:

Accidents (cause): Spills caused by accidents may be categorized as follows: collision/allision; derailment; grounding; rollover/capsize; and well blow-out.

Hazardous substance: means (A) an element or compound that, when it enters into or on the surface or subsurface land or water of the state, presents an imminent and substantial danger to the public health or welfare, or to fish, animals, vegetation, or any part of the natural habitat in which fish, animals, or wildlife may be found; or (B) a substance defined as a hazardous substance under 42 U.S.C. 9601-9657 (Comprehensive Environmental Response, Compensation, and Liability Act of 1980); "hazardous substance" does not include uncontaminated crude oil or uncontaminated noncrude (refined) oil in an amount of 10 gallons or less.

Extremely hazardous substance: Although there is no definition for extremely hazardous, the Senate Report on the Clean Air Act provides criteria EPA may use to determine if a substance is extremely hazardous. The report expressed the intent that the term "extremely hazardous substance" would include any agent "which may or may not be listed or otherwise identified by any Government agency which may as the result of short-term exposures associated with spills to the air cause death, injury or property damage due to its toxicity, reactivity, flammability, volatility, or corrosivity". The term "EHS" otherwise includes substances listed in the appendices to 40 CFR part 355, Emergency Planning and Notification.

Process water (mining operations): Process water for mining operations include water taken from tailing ponds for the milling process (reclaim water), water that has been through the water treatment plant but not the sand filter (process water), water that has been through both the water treatment and sand filter (discharge water), water mixed with ground ore materials (slurry), or water used in the milling and product recovery process (process solution water).

I removed duplicate listings based on spills that matched for all fields except *cause type*, *cause subtype*, *affiliate role*, and *responsible party*. Some incidents released more than one substance, in which case each substance has its own spill record. I determined which spills were attributable, directly and indirectly, to each of the mines by examining a combination of the *facility type*, *source type*, *location*, and *responsible party*.

For each mine, I examined ADEC spill records by substance and spill size class, by year and substance type, by month and substance type, and by cause. I also examined how many spills were related to transportation within mine sites and going to and from them along the transportation corridor from accidents and from other causes.

I compared the recorded transportation accidents with the number of spills predicted in the permitting documents (if any) and the number of expected spills that can be estimated using the $N = RT$ model shown above for truck accident spills (explained in the *Calculating expected numbers and probabilities of transportation corridor spills* section). Within ADEC (2021) "*collision/allision"* and "*rollover/capsize"* are two forms of accidents; *collision* and *rollover* generally refer to trucks, while *allision* and *capsize* are more applicable to marine vessels. The distinction between "collision" and "allision" for marine vessels is that collisions involve two moving vessels and "allision" refers to a vessel impacting a non-moving object. Based on the definition of a transportation incident from federal guidelines and of an accident from ADEC, I included only *collision/allision* and *rollover/capsize* spills in my comparison of projected transportation incidents based on the $N= RT$ model and the actual count of spill incidents for each mine.

It is not always clear from ADEC (2021) if a transportation spill occurred while moving materials around the mine site or transporting them to or from the mine. Some spills incidents list mile markers or have more detail in their spill names, but it is difficult to know with precision where all the transportation spills occurred and how much they may have affected the environment outside the mine. Many spills within the mine site, whether associated with transportation or related to other processes, will still generate some waste or contaminated materials associated with clean-up. The frequency of those spills and the fates of those substances may have impacts on the environment in and around the mine, especially if hazardous wastes are created. The spill data about where on the mine site the spill occurred, what media it impacted, and how it was cleaned up are all necessary for determining the environmental significance of the spills' impacts, individually and collectively.

I also summarize state or federal notices of violations or other enforcement actions related to environmental issues, including any sewage spills.

Summary

The Alaska Department of Environmental Conservation maintains a public database of hazardous materials spills dating from July 1995 to the present. Spill data include location information, spill size and substance, and spill causes. Hazardous materials are divided into the substance classes *crude oil*, *non-crude oil*, *extremely hazardous substances*, *hazardous substances*, and *process water*.

The five mines studied in this report are three underground mines: Pogo, Kensington, and Greens Creek, and two open pit mines: Fort Knox/True North and Red Dog. I examined EIS/EAs for each mine, as well as environmental audits and General Plans of Operations when available to examine what spills risks were considered, what hazardous materials were transported, and any records of spills discussed.

Most of the quantitative spill estimates in mine EISs are for truck accidents, and the model $N = RT$, where N is the number of expected spills, T is the total miles traveled by hazardous materials, and R is the spill rate per truck mile, is most commonly used. The widely cited value for R is 1.87×10^{-7} spill per truck miles for two-lane rural roads (Harwood and Russell 1990), and T varies by mine. I applied the $N = RT$ model to all five mines in this report for all hazardous materials transported by truck to compare the model predictions of truck accident spills with the observed spill record since the mines began construction and operation.

CHAPTER 3
Pogo Mine

Location and description

Pogo Mine is an underground gold mine approximately 38 miles northeast of Delta Junction in the interior of Alaska (Figure 3.1), predicted in its EIS to process 2,500 to 3,500 tons of ore per day (tpd). The mine components, such as the "mill and camp complex, a dry-stack tailings pile and recycle water tailings pond, an airstrip, gravel pits, laydown and fuel storage areas, and a local network of roads … [are] located within a large block of roadless, multiple-use State of Alaska land" (EPA 2003b) (Figure 3.2). Pogo Mine was permitted in 2003, with construction planned for 2-3 years and an expected mine life of 11 years at an ore production rate of 2,500 tpd (EPA 2003b). As of 2017, the projected mine life at a milling rate of 3,000 tons per day was six years (Sumitomo Metal Mining Pogo, LLC 2017). "The underground mining method requires that mined-out areas be backfilled with material to help provide ground support while the adjacent ore panel is mined. Mill tailings mixed with cement (paste backfill) provide part of the necessary support" (Sumitomo Metal Mining Pogo, LLC 2017).

Pogo by the numbers

The expected ore production and associated needs for reagents, blasting agents, and fuel under two production scenarios are shown in Table 3.1. If the ore production rate was 2,500 tpd, the mine life was expected to be 11 years if no further ore was discovered. Based on that rate and project length, a 3,500 tpd production rate would mine the same quantity of ore in 8 years. One of the issues considered in the EIS was the relative impacts of having a 50-mile power line bring electricity to the mine site or trucking in the diesel required along a 49.5 mile road (Figure 3.2) (EPA 2003b).

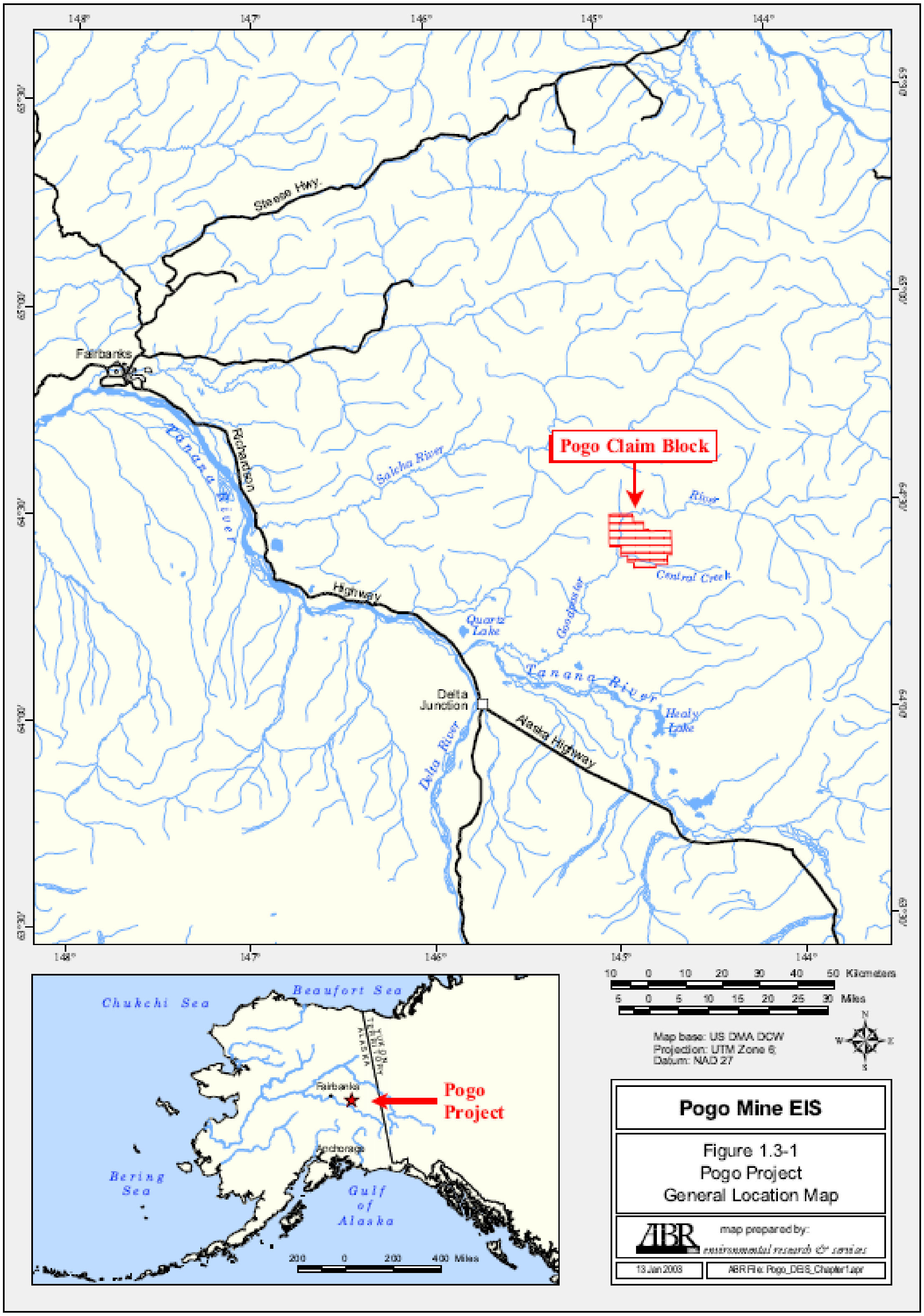


Figure 3.1. Figure S-1 from EPA (2003) showing the Pogo Project general location map.

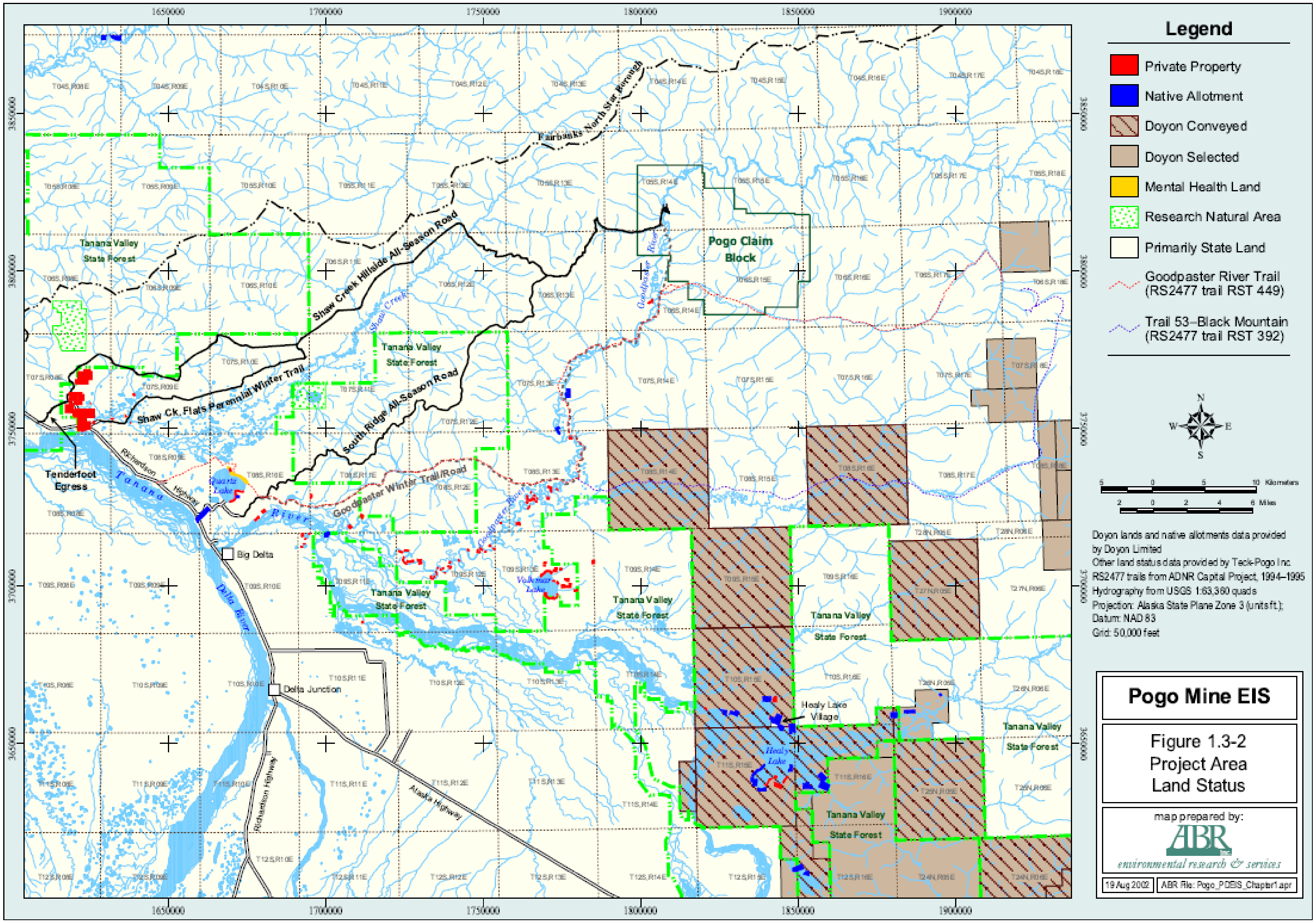


Figure 3.2. Figure 1.3-2 from EPA (2003) showing the land status of the area around the Pogo Mine project.

Table 3.1. Quantitative descriptions of ore production, reagent use, fuel use, the transportation corridor, and waste rock and tailings produced from the Pogo Mine EIS (EPA 2003b).

Quantity	Description	Page number(s)
	Ore	
2,500	tons of ore per day = initial production	p. 1-1, 2-2
375,000	ounces (oz) of gold annually = initial output	p. 1-1, 2-2
3,500	tons of ore per day = increased production	p. 1-1, 2-2
500,000	oz annually = increased production	p. 1-1, 2-2
11	years of operating life (starting in 2005 or 2006) at 2,500 tons per day	p. 1-1, 2-2
	Reagents	
3,833	tons per year of mill reagents at 2,500 tpd	p. 2-34
2,000	tons/yr of grinding media and liners at 2,500 tpd	p. 2-34
1,000	tons/yr explosives at 2,500 tpd	p. 2-34
50	trucks/yr for lime at the 2,500 tpd scenario	p. 4-53
50	trucks/yr for cyanide at the 2,500 tpd scenario	p. 4-53
50	trucks/yr for sodium metabisulfite at the 2,500 tpd scenario	p. 4-53
25	trucks/yr for sulfuric acid at the 2,500 tpd scenario	p. 4-53
20	trucks/yr for remaining reagents in Table ___ at the 2,500 tpd scenario	
5,729	tons per year of mill reagents at 3,500 tpd	p. 2-34
3,000	tons/yr of grinding media and liners at 3,500 tpd	p. 2-34
1,500	tons/yr explosives at 3,500 tpd	p. 2-34
75	trucks/yr for lime at the 3,500 tpd scenario	inferred
75	trucks/yr for cyanide at the 3,500 tpd scenario	inferred
75	trucks/yr for sodium metabisulfite at the 3,500 tpd scenario	inferred
38	trucks/yr for sulfuric acid at the 3,500 tpd scenario	inferred
29	trucks/yr for remaining reagents in Table ___ at the 3,500 tpd scenario	inferred

Table 3.1. (Continued.)

Quantity	Description	Page number(s)
	Fuel (and energy equivalent)	
8	20,000 gallon tanks for diesel storage at exploration camp during construction	p. 2-30
15	20,000 gallon tanks for diesel storage at airstrip during construction	p. 2-30
2	20,000 gallon tanks for diesel storage at main permanent diesel storage during construction	p. 2-30
50,000	gallons of total on-site diesel storage capacity (should be (8+15+2) x 20,000 = 500,000 gal)	p. 2-30
50,000	gallons propane storage at 1525 portal and 1875 portal	p. 2-30
5,000	gallons propane storage near the mill	p. 2-30
105,000	gallons propane storage total	p. 2-30
5,000	gallons per truck for propane or diesel (Goodpaster Winter Trail)	p. 2-30
8,000	gallon trucks (refills over all season road)	p. 2-30
10	MW at 2,500 tons/day	p. 2.2
4,200,000	gallons diesel/yr at 2,500 tons/day (for power generation)	p. 4-50
786,000	gallons diesel/yr at 2,500 tons/day (for operating usage)	p. 2.2
100	trucks/year for diesel (no on-site power generation) for the 2,500 tpd scenario	p. 4-53
525	trucks/year for diesel for on-site power generation for the 2,500 tpd scenario	p. 4-7, 4-50, 5-34
930,000	gallons propane/yr at 2500 tons/day	p. 2.2
2,000	tons/year propane at 2500 tpd	p. 2-34
14	MW at 3,500 tons/day	p. 2.2
5,880,000	gallons diesel/yr at 3,500 tons/day (for power generation)	inferred
1,300,000	gallons diesel/yr at 3,500 tons/day (for operating usage)	p. 2.2
163	trucks/year for diesel (no on-site power generation) for the 3,500 tpd scenario	inferred
735	trucks/year for diesel for on-site power generation for the 3,500 tpd scenario	inferred
1,850,000	gallons propane/yr at 3,500 tons/day	p. 2.2
4,000	tons/year propane at 3,500 tpd	p. 2-34

Table 3.1. (Continued.)

Quantity	Description	Page number(s)
	Transportation corridor	
49.5	mile access road; two lane, all season	p. 1-1, 2-9
50	mile power line	p. 1-1
6	single span, single lane bridges between 60 and 85 feet long	p. 2-9
100	ton design capacity for bridges	p. 2-9
21	tons of cargo on highway truck-trailers, with two 10.5 ton containers per truck	p. 2-33
30,000-40,000	tons of freight to the mine annually	pp. 2-11, 12
5 to 10	large truck round trips/day	pp. 2-11, 12
3,000	foot long gravel airstrip	p. 2-13
15,000	gallons fuel per week for aviation	p. 2-13
	Waste rock, tailings and wastewater	
11,000,000	tons tailings storage (surface and underground)	p. 2.2, 2-15
1,900,000	tons development rock generated during mine life	p. 2.2

Process

The EIS described the mining, milling, gravity/flotation/cyanide vat leach process, and tailings storage (EPA 2003b):

> Gold would be recovered from the mined ore in the mill situated in Liese Creek Valley (Figure 2.3-1 and 2.3-1 c). The milling process would consist of grinding the ore to a fine particle size (similar to fine sand), gold recovery through gravity separation, concentrating the remaining gold and sulfide minerals by flotation, and then recovering the gold from the flotation concentrate by cyanide vat leaching. The gravity concentration process would account for approximately 60 percent of gold recovery, with the flotation and cyanide vat leaching process accounting for approximately 40 percent. The gold from both processes would be combined and then melted to produce gold bars.
>
> The milling process for Pogo would isolate the cyanide process from any contact outside the mill. Free cyanide and metallocyanide complexes in the thickened tailings would be oxidized in a cyanide destruction tank by means of a sulfur dioxide (SO_2)/air process. This process would reduce cyanide concentrations in the tailings pore water to less than 2 milligrams per liter (mg/L) of total cyanide (Teck-Pogo Inc., 2002b). Any residual cyanide-bearing tailings material would be placed underground in the mine in a paste (cemented) backfill. Although it would result in 1 to 2 percent lower gold recovery, the gravity/flotation/cyanide vat leach method was selected over the more conventional whole-ore cyanidation approach to minimize the environmental impact. Specifically, the Applicant chose not to use whole-ore cyanidation for the following reasons:
>
> - Whole-ore cyanidation would result in treatment of all the tailings with cyanide. After cyanide destruction these tailings would contain low levels of residual cyanide (less than 2 parts per million [ppm]). Even low levels, however, would present an environmental management issue. Thus, conventional milling was not selected.
> - The flotation process selected would concentrate the sulfide- and arsenic-bearing minerals into the gold concentrate. Only this concentrate would be leached for gold recovery and become cyanidation tailings, which then would be incorporated into the mine paste backfill. As such, the sulfide and arsenic would be returned to their original underground location.
> - The flotation and vat leach method would reduce the size of the cyanidation circuit and the quantity of cyanide required on site or present in solution.
>
> The operation of a small cyanidation circuit processing only 250 to 350 tpd of flotation concentrate would allow the separate production and handling of two types of tailings: the tailings from the flotation circuit and tailings from the cyanidation circuit. Flotation tailings would make up approximately 90 percent of the total tailings produced. This material would contain no cyanide and low levels of sulfide. (Sulfides are potentially acid-generating minerals contained in the rock.) About half of these tailings would be filtered and trucked to the surface

site for drystack storage. The other half would be used to make the paste backfill for the mine, along with the cyanidation tailings.

Tailings from the cyanidation circuit would make up only 10 percent of the total tailings flow. These “carbon-in-pulp” (CIP) tailings would contain approximately 90 percent of the sulfides released in the process. These tailings would be submitted to a cyanide destruction process, then mixed with roughly 50 percent of the flotation tailings and cement to make the paste backfill for mine support.

Characterization of transportation corridor

Access to Pogo Mine was described as being via a road and an airport. The planned road for the Shaw Creek Hillside was as a 49.5-mile, two-lane, all-season road, with grades up to 7 or 8%, and a speed limit of 35 miles per hour (EPA 2003b). The road would have six single-lane bridges, each 60-85 feet long, that would cross Rosa (two crossings), Keystone, Caribou, Gilles, and Shaw Creeks (EPA 2003b). The airport would have a 3,000-foot-long airstrip and be used during initial construction of the mine and for the entire life of mine operations (EPA 2003b). The number of flights would vary by mine phase, aircraft type, and what (or who) was being transported (Table 3.2).

Table 3.2. Flight frequencies and loads for Pogo Mine (EPA 2003b).

Mine project phase	Aircraft type(s)	What/who transported	Flight frequency
Construction	Twin Otter and Cessna Caravan	130 workers in each direction weekly	15 flights per week
Construction	Cessna 206 and Cessna 207	Personnel	average ~10 flights per week
Operations	SkyVan, Caribou, DC3, CASA 212, Caravan, and King Air	Air freight	100 flights per year, or ~2 per week
Operations	DC-3, C-46, Caribou, and SkyVan aircraft	15,000 gallons fuel per week	30 trips per week by SkyVan or 15 trips per week by “larger aircraft”
Operations	Various	50 tons per week supplies	15 trips per week

List of hazardous materials to be transported

Ore concentrate would not be shipped from Pogo Mine as the final process results in gold bars (EPA 2003).

Reagents

Nearly 5,000 tons of reagents and explosives were called for annually under the 2,500 tpd scenario, a figure that increases to more than 7,200 tons per year under the 3,500 tpd production rate (Table 3.3). Reagent use does not scale linearly with ore production rate. The environmental and toxicological properties of the 12 reagents listed are not discussed in the EIS (EPA 2003b). The descriptions of reagent and explosive handling given in the EIS are reproduced in full below.

EPA (2003), p. 2-34:

> Reagents typically would be purchased in normal commercial bulk containers or packaging, such as tote bins, barrels, palletized sacks, and Super Sacks, and would be loaded into shipping containers at the point of origin and shipped to the mine site. Cyanide would be transported only as dry pellets inside plastic bags inside wooden boxes inside metal shipping containers in conformance with all federal and state hazardous materials transportation regulations. Reagents would be stored in a covered building adjacent to the mill. All storage areas would be diked for collection of spillage and cleanup to prevent loss to the environment. Reagents would be mixed in steel or other tanks inside the mill building and be pumped to their addition points in the process. Any spills would be contained within the concrete dikes of the reagent area and collected in a sump for disposal or for return to the process tanks.
>
> A spill response plan for shipment of hazardous materials, including cyanide, would be required as an ADEC permit condition.

and

EPA (2003), pp. 2-34 to 2-35:

> Explosives would be transported to site by means of conventional truck haulage, and would be used on site, in accordance with U.S. Bureau of Alcohol, Tobacco, and Firearms regulations.
>
> Explosives would be stored underground in an explosives magazine. Locked storage magazines would be provided for caps, detonating cord, primers, and boosters. Secure storage would be provided for blasting agents such as emulsion, and bagged ammonium nitrate or ammonium nitrate/fuel oil. Any spills would be collected in a containment area and disposed of in accordance with applicable federal and state standards and regulations.
>
> A controlled firing area (CFA) would be established in which explosive activities would be conducted in a controlled manner to prevent any hazard or impact on aircraft. Within the CFA, the Applicant would keep watch for passing aircraft and immediately terminate the hazardous activity if an aircraft approached the area. Also, certain visibility conditions would be adhered to. There would be two controlled firing areas, one with horizontal boundaries which would approximate the millsite lease boundaries, the other which would approximate the road

construction corridor, with a vertical distance between ground level and 500 feet above ground level. Blasting activities within the CFA could potentially occur 24 hours per day throughout the project life.

There are brief descriptions in the 2017 and 2020 Pogo Plans of Operation (Sumitomo Metal Mining Pogo LLC, 2017, Northern Star Resources Limited 2020) of the reagents' uses at the mine and the methods by which many of the reagents would be transported (Table 3.3). (For more information about the reagents and the substances spilled at Pogo Mine, see Appendix A.) Several of the reagents mentioned in the Plans of Operations (Sumitomo Metal Mining Pogo, LLC 2017, Northern Star Resources Limited 2020), mostly various Aero Promoters that may have been substituted for Aero Promoter 208, were not specifically listed in the EIS (EPA 2003b) (Table 3.4). Unlike several of the other mines considered in this report, Pogo explicitly stated the amount of explosives that would be used under different mining rate scenarios.

Table 3.3. Reproduction of "Table 2.3-3 Annual Commodities Transport Quantities During Operations (tons)" (EPA 2003b, p. 2-34).

	Commodity	2,500 tpd Scenario	3,500 tpd Scenario
Mine	Cement	14,000	21,000
	Propane	2,000	4,000
	Consumables	4,000	6,000
	Explosives	1,000	1,500
	Subtotal	21,000	32,500
Mill	Grinding Media & Liners	2,000	3,000
Mill Reagents	Lime	1,000	1,500
	Sodium cyanide	1,000	1,500
	Potassium amyl xanthate	41	57
	Aero Promoter 208	68	96
	MIBC	64	89
	Flocculant	55	77
	Sulfuric acid	500	750
	Sodium metabisulfite	1,000	1,500
	Copper sulfate	50	75
	Activated carbon	5	10
	Nitric acid	20	30
	Sodium hydroxide	30	45
	Subtotal	3,833	5,729
Fuel	Gallons	786,000	1,300,000
	Tons	2,800	4,620
Spare Parts		250	400
Food & Camp Supplies		290	500
Total (tons)		30,173	46,749
Personnel		10,000	14,700
Bus Round Trips		330	490

Source: Teck-Pogo Inc. (2002i)

Table 3.4. Reagents listed in the 2017 and 2020 Pogo Plans of Operation (Sumitomo Metal Mining Pogo, LLC 2017, pp. 48-50; Northern Star Resources Limited 2020 pp. 25-26). Text in italics was present in Sumitomo Metal Mining Pogo, LLC (2017) only. Text in bold was in Northern Star Resources Limited (2020) only. Reagents are listed in the same order as in Table 3.3 with shaded rows indicating reagents not mentioned in the EIS (EPA 2003b).

Reagent	Transport method	Use
Lime		controlling the slurry pH during leaching, water treatment, and cyanide detoxification
Sodium cyanide	dry briquettes	dissolving gold
Potassium amyl xanthate		a flotation reagent to collect sulfide and gold-bearing minerals
MIBC		used as a frothing agent in the flotation circuit
Flocculant	2,000 lb bags	assisting with solids settling in the thickeners of the milling process
Sulfuric acid		*pH control in the cyanide detoxification circuit*
Sodium metabisulfite	2,000 lb supersacks	for use in the cyanide detoxification circuit
Copper sulfate	2,000 lb supersacks	catalyst in cyanide detoxification
Activated carbon	1,000 lb bulk bags	capturing dissolved gold from the leached slurry
Nitric acid	returnable stainless-steel drums containing approximately 100 lbs of concentrated acid solution per drum	acid washing the carbon (after stripping) to remove calcium scale buildup
Sodium hydroxide	pellets packaged in steel drums containing 500 lb	raising the pH in the carbon stripping circuit and neutralizing after carbon acid washing

Table 3.4. (Continued.)

Reagent	Transport method	Use
AGEFLOC WT2902		*fines depressant for controlling the flotation of silt-like particles, resulting in improved thickening and flotation performance*
Aero Maxigold 900 Promoter		a flotation reagent to promote the recovery of gold-bearing minerals
Aero 5688 Promoter		flotation reagent to promote the recovery of gold-bearing minerals
Aero 6697 Promoter		flotation reagent to promote the recovery of gold-bearing minerals
Aerfroth 549		used as a frothing agent in the flotation circuit
Fluxes (anhydrous borax, sodium nitrate, soda ash, manganese dioxide, and graded silica)	50 to 100 lb bags or drums	refine gold concentrates into bullion
Water softening and anti-scalant agents	prepared concentrated solutions in drums	treat process water and prevent scaling in pipes
Clear 215		**fines depressant for controlling the flotation of silt-like particles, resulting in improved thickening and flotation performance**

Fuel

Two main fuels were listed for use at Pogo Mine: diesel and propane. Depending on the ore production rate, diesel use would range from 786,000 to 1,300,000 gallons annually for all purposes other than power generation (EPA 2003b). An additional 4,200,000 gallons would be needed annually for power generation (enough for 10 MW) at the 2,500 tpd production rate (EPA 2003b). Although it as not stated in the EIS, I estimate that the 14 MW power generation needs for the 3,500 tpd production rate would require 140% of the diesel needed for 10 MW. If that is the case, the 3,500 tpd scenario would use 5,880,000 gallons of diesel each year. In addition, 930,000 to 1,850,000 gallons of propane would be needed each year for the 2,500 and 3,500 tpd production rates, respectively (EPA 2003b).

As proposed in the EIS, a total of 25 20,000-gallon diesel tanks would be placed at various locations around the mine site (eight near the 1525 Portal, 15 at the airstrip, and two near the maintenance shop) (EPA 2003b). Although the EIS reports that "[t]he total on-site capacity for diesel fuel storage during operations would be approximately 50,000 gallons" (EPA 2003b, p. 2-30), 25 x 20,000 gallons is a total of 500,000 gallons of diesel, a quantity that is an order of magnitude higher than stated in the EIS and more in keeping with a diesel use rate of 786,000 to 1,300,000 gallons per year. Propane storage was described as two 50,000 gallons locations and one 5,000-gallon location, for a total of 105,000 gallons of propane storage (EPA 2003b).

Hazardous wastes

Pogo Mine's most recent Plan of Operations acknowledges that mining generates substantial amounts of hazardous waste. Specifically, "Pogo Mine is a large quantity generator. All hazardous waste is temporarily stored in a designated hazardous waste storage area and shipped off-site for disposal" (Sumitomo Metal Mining Pogo, LLC 2017). Presumably, the shipping is by truckload, but annual quantities, load sizes, and frequencies or further details about the types of hazardous materials were not provided.

Load sizes and methods

Load sizes were given for six mine commodities, four of which were mill reagents (EPA 2003b) (Table 3.5). No load details were given for propane and the remaining reagents explicitly, but it may be assumed that propane transport is in the same load sizes as diesel. According to the EIS (EPA 2003b):

> Diesel and propane would be transported to the site over the initial Goodpaster Winter Trail in 5,000-gallon tanker trucks. The tanks then would be refilled as necessary by 8,000-gallon tanker trucks using the all-season road for the life of the project.

For the purposes of later estimations, I will assume that the milling reagents not shown in Table 3.5 are hauled in 20-ton quantities.

Table 3.5. Reproduction of "Table 4.3-15 Commodity Transport Frequency" (EPA 2003b, p. 4-53). These annual trucks needs are for the 2,500 tpd ore production scenario and only trips for reagents used in quantities of at least 500 tons per year are shown. The total annual number of trucks was not part of the table in the EIS.

Commodity	Quantity per Truck	Annual Number of Trucks
Fuel	8,000 gallons	100
Cement	27 tons	520
Lime	20 tons	50
Cyanide	20 tons	50
Sodium metabisulfite	20 tons	50
Sulfuric acid	20 tons	25
Total		795

Load frequency

According to the EIS (EPA 2003b):

> Based on these estimates, there would be approximately one truck each week transporting lime, cyanide, and sodium metabisulfite; approximately two tankers per week for fuel; and approximately 10 trucks per week transporting cement. Sulfuric acid would be transported at an average of one truckload every 2 weeks.

Note that the annual number of trucks shown in Table 3.5 not only excludes propane, explosives, and at least eight reagents, but also shows the annual number of trucks for the 2,500 tpd production scenario and not the 3,500 tpd scenario. The list of hazardous materials transported shown in Table 3.5 is incomplete and does not reflect the potential number of trips per year for the commodities which are shown in Table 3.3. Furthermore, the number of annual trips for all hazardous materials is not represented. Table 3.5 shows 275 trips to transport fuel, lime, cyanide, sodium metabisulfite, and sulfuric acid. Once propane, explosives, and the remaining reagents are included, there are 461 trips per year for hazardous chemical materials when 2,500 ore are to be processed, and 759 such trips under the 3,500 tpd ore processing rate (Table 3.6). If grinding media are included as hazardous materials, as they were for the proposed Stibnite Gold Project in Idaho (USFS 2020b), the number increases to 561 annual trips with hazardous materials under the 2,500 tpd scenario and 909 annual trips under the 3,500 tpd scenario. These are the trips required if diesel is not trucked to the mine for power generation.

The depiction of "one truck each week transporting lime, cyanide, and sodium metabisulfite; approximately two tankers per week for fuel; and approximately 10 trucks per week transporting cement. Sulfuric acid would be transported at an average of one truckload every 2 weeks" (EPA 2003b) for the 2,500 tpd ore production rate is technically correct, but it failed to look at the total number of trips per week or day for the five materials listed, did not include propane, explosives, or grinding media, omitted many hazardous chemicals used is lesser quantities, and there was not a corresponding analysis for the number of trips associated with the 3,500 tpd production rate. With 561 to 909 annual trips carrying hazardous materials (Table 3.6), the transportation of hazardous materials occurs at an average frequency of 1.5-2.5 trips per day, depending on the production rate. Overall, at Pogo Mine trucks with hazardous materials account for 42.9 to 44.7% of the vehicles, depending on the amount of ore processed per day (Table 3.6).

Table 3.6. Pogo Mine supplies and hazardous material quantities and annual truck trips (EPA 2003b, Table 2.3-3 and Table 4.3-15). Values in bold are from EPA (2003). Shaded rows represent hazardous materials. Propane use is measured in gallons rather than tons and moved from "Mine" to "Fuel".

Commodity	2,500 tpd scenario			3,500 tpd scenario		
Mine	tons/yr	tons/truck	trucks/yr	tons/yr	tons/truck	trucks/yr
Cement	14,000	27	520	21,000	27	780
Consumables	4,000	20	200	6,000	20	300
Explosives	1,000	20	50	1,500	20	75
Subtotal	19,000		770	28,500		1,155
Mill						
Grinding Media and Liners	2,000	20	100	3,000	20	150
Mill Reagents	tons/yr	tons/truck	trucks/yr	tons/yr	tons/truck	trucks/yr
Lime	1,000	20	50	1,500	20	75
Sodium cyanide	1,000	20	50	1,500	20	75
Sodium metabisulfite	1,000	20	50	1,500	20	75
Sulfuric acid	500	20	25	750	20	38
Aero Promoter 208	68	20	4	96	20	5
MIBC	64	20	4	89	20	5
Flocculant	55	20	3	77	20	4
Copper sulfate	50	20	3	75	20	4
Potassium amyl xanthate	41	20	2	57	20	3
Sodium hydroxide	30	20	2	45	20	3
Nitric acid	20	20	1	30	20	2
Activated carbon	5	20	1	10	20	1
Subtotal	3,833		195	5,729		290
Fuel	gal/yr	gal/truck	trucks/yr	gal/yr	gal/truck	trucks/yr
Diesel	786,000	8,000	100	1,300,000	8,000	163
Propane	930,000	8,000	116	1,850,000	8,000	231
	tons/yr	tons/truck	trucks/yr	tons/yr	tons/truck	trucks/yr
Spare Parts	250	20	13	400	20	20
Food & Camp Supplies	290	20	15	500	20	25
Total HazMat trucks/yr			561			909
% Haz Mat trucks/yr			42.9%			44.7%
Total trucks/year			1,309			2,034

Spill risks, impacts, and records discussed

The scoping comments of the EIS identified 17 major issues related to Pogo Mine (EPA 2003b):

- Surface and groundwater quality
- Wetlands
- Fish and aquatic habitat
- Wildlife
- Air quality
- Noise
- Safety
- Reclamation
- New industrial and commercial uses
- Recreational resources and uses
- Existing privately-owned lands and existing recreational and commercial uses
- Subsistence and traditional uses
- Cultural resources
- Socioeconomics
- Cumulative impacts
- Technical feasibility
- Economic feasibility

Of those, spills of hazardous materials were considered as risks to water quality, wetlands, fish, wildlife, and subsistence (EPA 2003b), and the metrics for rating the impact levels of accidental or unplanned chemical or fuel releases was (EPA 2003b):

- *No or low impact*: No planned release or low likelihood of occurrence; if an accidental release or spill occurred, the potential for impacts to environment or public interests would be negligible.
- *Moderate impact*: There is a risk of accidental release, or a release has a low likelihood of occurrence but the impacts could be high.
- *High impact*: A high potential for accidental release exists, and the severity of the release would be high.

Spills at the mill site were assumed to pose little environmental risk because of designed containment, including concrete dikes, blind sumps, secondary containment (EPA 2003b). Furthermore, "[h]azardous and toxic materials such as reagents, petroleum products, acids, and solvents would be moved off site by licensed transporters for return to vendors or disposal at licensed facilities" (EPA 2003b).

The Pogo Mine EIS (EPA 2003b) used an estimate of 1.9×10^{-7} spills per truck-mile for hazardous material spill rates on rural two-lane roads (Harwood and Russell 1990). The number of tanker loads of diesel per year and miles to travel were used to calculate diesel spill probabilities, which depended on the specifics of the project options and were estimated to be 1 or 6% (Table 3.7) and was noted as "an order-of-magnitude estimate because the conditions on the Pogo mine road would be different than those for which the statistics were developed (more difficult driving and road conditions)" (EPA 2003b). While a 1% chance of a diesel spill was not considered to be a high risk, the increased possibility of a spill when on-site power generation required transporting more truckloads (6%), elicited a different response (EPA 2003b, p. 5-34):

> On-site generation, however, would require an additional approximately 4.2 million gallons of fuel to be trucked to and stored at the mine site. For five resources (water quality, wetlands, fish, wildlife, and subsistence), the risks of spills from the seven-fold increase in fuel volume that would be trucked to the mine site were considered high.

Spill risk probabilities for individual reagents or the cumulative number of reagent truck-miles were not calculated. Instead, the implication was the risks of associated with spills of lime, cyanide, and sodium metabisulfite as individual supplies being transported to the mine would be less than those associated with fuel transportation because fewer trips would be required to haul them, and thus they were too small to warrant quantitative attention. The aggregated risk from all reagent transportation was not considered explicitly. It was noted that fuel spills near a wetland could have an impact, that a major diesel spill near a creek could result in a high impact in a large area of the watershed, and that a substantial release of cyanide into surface water would have a high impact (EPA 2003b).

Table 3.7. The Pogo Mine EIS included estimates of the probability of diesel spills under different alternatives using a "probability of truck accidents and release was reported as 1.9 x10^{-7} spills per mile of travel for rural two-lane roads (Harwood and Russell 1990)", an 11-year project life, and a 49-mile transportation corridor (EPA 2003b).

Scenario	Amount (in gallons)	Truck loads	Probability of ≥1 spill
without on-site power generation	786,000 gallons per year	100 tanker trucks (8,000 gallons each) each year	1%
with on-site power generation	an additional 4.2 million gallons of diesel fuel per year	an additional 525 tanker trucks (8,000 gallons each), for a total of 625 fuel trucks each year	~6%

Example quantitative spill probabilities and expected numbers of spills

I estimated the number of truckloads per year for reagents and supplies for two different daily processing rates at Pogo. I used a default capacity of 20 tons per truckload for everything but cement and (diesel) fuel. Assuming that mine "consumables" for Pogo are not hazardous materials, 561 truckloads of hazardous materials were slated to be brought to Pogo Mine annually under the 2,500 tpd scenario, a figure that increases to 909 truckloads per year in the 3,500 tpd scenario when diesel is not used for on-site power generation (Table 3.6). Again, a 1% chance of a diesel spill was not considered to be a high risk, but a ~6% chance was "considered high" (EPA 2003b). Both the 2,500 and 3,500 tpd production scenarios have spill probabilities near the high-risk level once all the hazardous materials transported are aggregated, even without the inclusion of the 4.2 million gallons of diesel that would have been necessary for on-site power generation (Table 3.8).

Table 3.8. Expected number of truck trips, miles traveled, spill numbers, and probabilities for the 2,500 tpd and 3,500 tpd scenarios, with and without on-site power generation.

Production rate	2,500 tpd	3,500 tpd
Number of years	11	8
Trucks/year		
Grinding media and liners	100	150
Reagents	195	290
Propane	116	231
Explosives	50	75
Diesel	100	163
Diesel (for on-site power generation)	525	735
Total truck trips/yr		
without on-site power generation	561	909
with on-site power generation	1,086	1,644
Total truck trips = trips/year x years		
without on-site power generation	6,171	7,272
with on-site power generation	11,946	13,152
Total truck miles = trips x 49 miles		
without on-site power generation	302,379	356,328
with on-site power generation	585,354	644,448
Expected spills = miles x 1.9 x 10^{-7} spills/mile = N		
without on-site power generation	0.057	0.068
with on-site power generation	0.111	0.122
Probability of at least one spill = 1 – e^{-N} (as a %)		
without on-site power generation	5.6%	6.5%
with on-site power generation	10.5%	11.5%

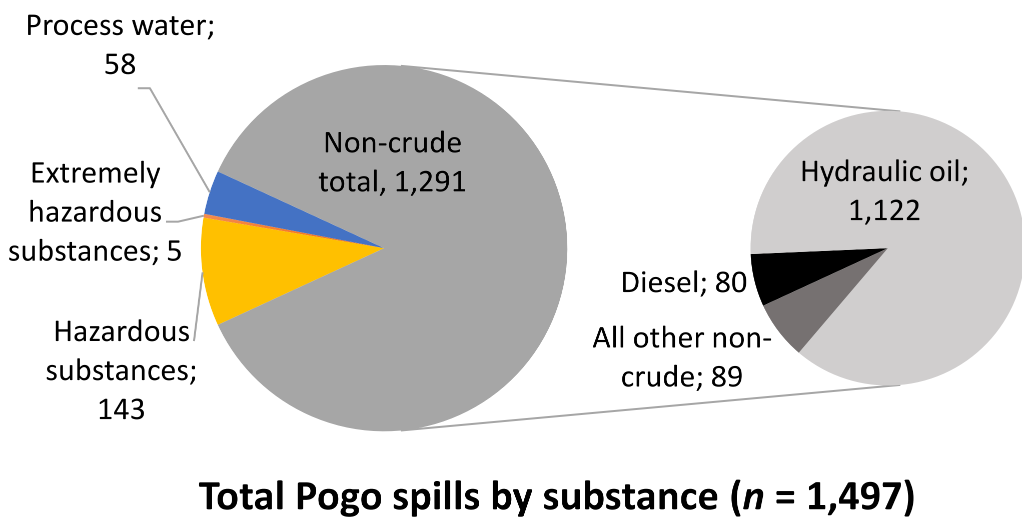
Spill record from ADEC

To find the number of spills associated with Pogo Mine, I searched the ADEC Prevention Preparedness and Response database (ADEC 2021) using Pogo Mine and Delta Junction as the locations (Appendix B1). I removed spills not related to mining and duplicate spill listings. There were 1,503 spills associated with Pogo Mine in the database. The spills include *hazardous* and *extremely hazardous substances*, *non-crude oil*, and *process water*. Almost 1,300 of those spills were of *non-crude oil*, especially hydraulic oil (Table 3.9, Figure 3.3). There were 1,122 spills of hydraulic oil with a total volume of 4,066 gallons; those spills represent 74.9% of the recorded incidents but only 1.5% of the volume released (Table 3.9, Figure 3.3). There were 80 spills of diesel, ranging from 0.5-1,500 gallons (Table 3.9). The largest spill was 135,000 gallons of mill slurry due to a line failure. The cumulative volume of all the spills is over 267,000 gallons. While more than 95% of the spills were of <100 gallons (Table 3.10), the 5% of spills that were ≥100 gallons accounted for 97.5% of the volume released (Table 3.11, Figure 3.4). Although *non-crude oil* spills accounted for 86.1% of the number of recorded incidents (Table 3.10), accidental releases of *hazardous substances* represented 89.6% of the volume spilled (Table 3.11, Figure 3.5).

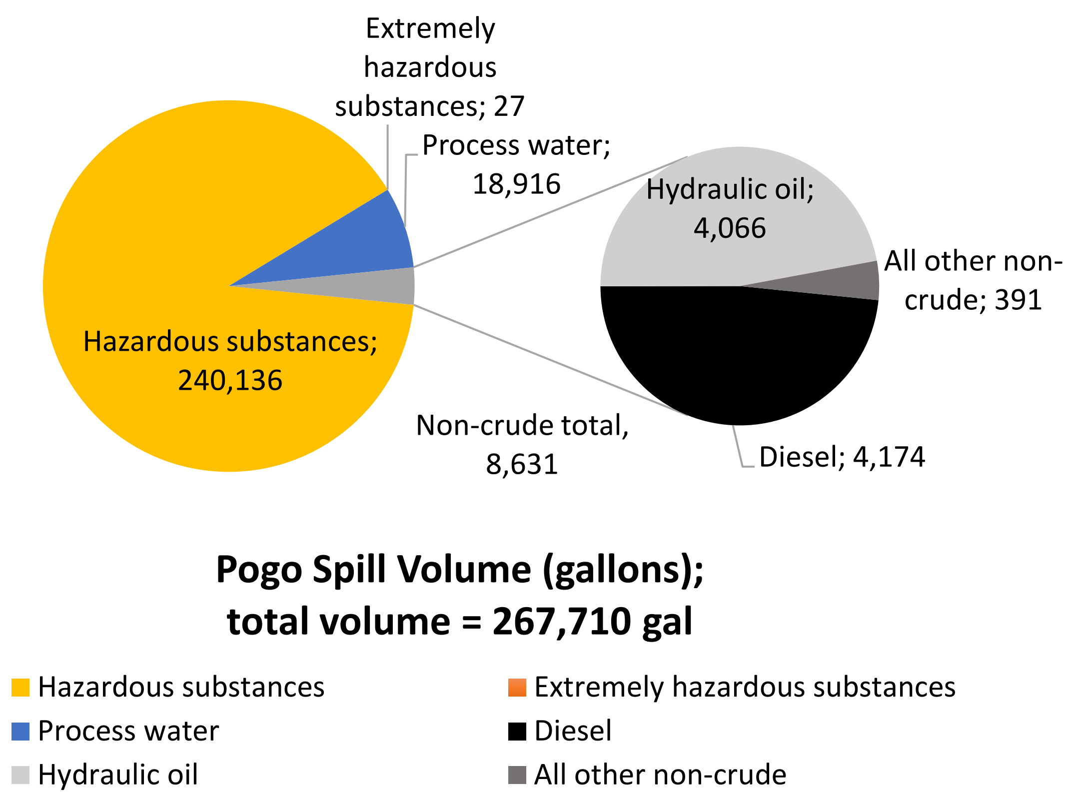
Table 3.9. Spills associated with Pogo Mine by substance, number of spills, volume range, and total volume. This table does not include four spills of "other" hazardous substances with quantities given in pounds (weights ranged from 0.5 to 25 pounds).

Substance	Number of spills	Spill volume range (gallons)	Total volume spilled (gallons)
Extremely hazardous substances			
Hydrogen cyanide	1	5	5
Sodium cyanide	2	1-20	21
Sulfuric acid	2	0.25-1	1.25
Total	5		27.25
Hazardous substances			
Acid, other	1	0.004	0.004
Drilling muds	1	6,000	6,000
Ethylene glycol	51	0.063-30	246
Propylene glycol	4	0.75-30	41
Glycol, other	12	1-15	70
Mill slurry	21	0.5-135,000	152,297
Zinc slurry	5	1-35	60
Other*	48	0.032-40,000	81,422
Total	143		240,136
Non-crude oil			
Diesel	80	0.5-1,500	4,174
Engine lubricant	41	1-40	159
Gasoline	2	1-10	11
Grease	1	1	1
Hydraulic oil	1,122	1-150	4,066
Transmission oil	31	1-20	133
Used oil (all)	10	1-30	51
Other	4	3-25	36
Total	1,291		8,631
Process water			
Process water	49	0.5-6,000	15,315
Produced water	5	10-500	1,085
Source water	4	1-2,500	2,516
Total	58		18,916
Unknown	2	100-275	375

**The substance spilled was sometimes specified in the spill names field. "Other" hazardous substances included ferric chloride, leach pump slurry, CIP tails thickener, RTP water, CIP slurry, paste backfill, slurry cement, and drainage water.*


Process water; 58
Non-crude total, 1,291
Extremely hazardous substances; 5
Hazardous substances; 143
Hydraulic oil; 1,122
Diesel; 80
All other non-crude; 89
Total Pogo spills by substance (*n* = 1,497)

a.


Extremely hazardous substances; 27
Process water; 18,916
Hydraulic oil; 4,066
All other non-crude; 391
Hazardous substances; 240,136
Non-crude total, 8,631
Diesel; 4,174
Pogo Spill Volume (gallons); total volume = 267,710 gal
Hazardous substances
Extremely hazardous substances
Process water
Diesel
Hydraulic oil
All other non-crude

b.

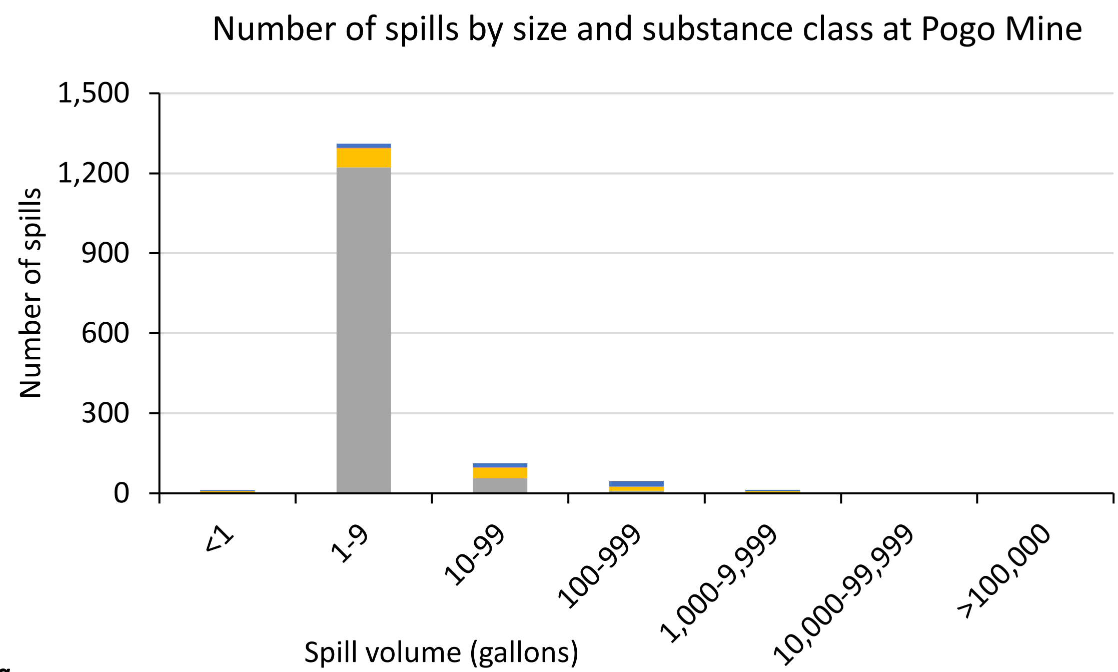
Figure 3.3. Relative proportions of (a) number and (b) volume from different substance classes at Pogo Mine from 1995-2020 with non-crude oil spills further broken down to show the amounts due to diesel and hydraulic oil spills.

Table 3.10. Counts of Pogo Mine spills with quantities given in gallons from July 1995-December 2020 by substance class and size category (ADEC 2021).

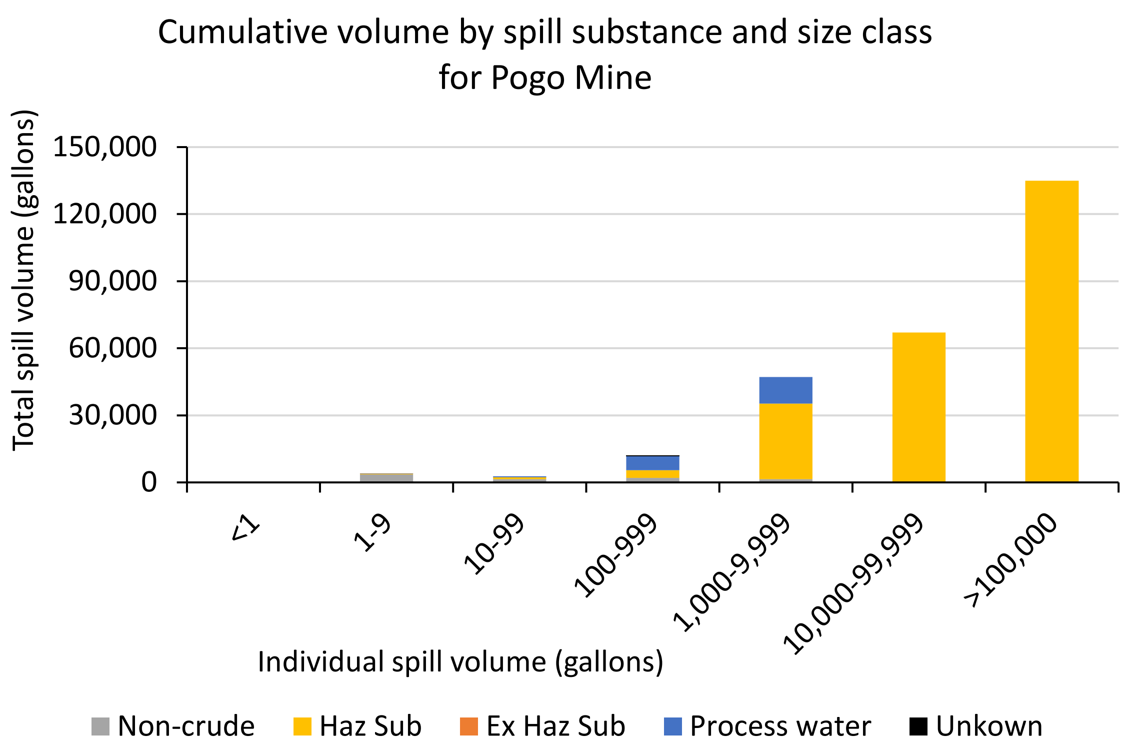
Substance class	Number of spills								Percent
	Spill size class (gallons)							Total	
	<1	1-9	10-99	100-999	1,000-9,999	10,000-99,999	≥100,000		
Ex Haz Sub	1	3	1					5	0.3%
Haz Sub	7	71	39	15	7	3	1	143	9.5%
Non-crude	1	1,222	57	10	1			1,291	86.1%
Process water	3	15	16	19	5			58	3.9%
Unknown				2				2	0.1%
Total	12	1,311	113	46	13	3	1	1,499	
Percent	0.8%	87.5%	7.5%	3.1%	0.9%	0.2%	0.1%		

Table 3.11. Total volume of Pogo Mine spills with quantities given in gallons from July 1995-December 2020 by substance class and size category (ADEC 2021).

Substance class	Cumulative volume of spills								Percent
	Spill size class (gallons)							Total	
	<1	1-9	10-99	100-999	1,000-9,999	10,000-99,999	≥100,000		
Ex Haz Sub	0.3	7.0	20.0					27	0.0%
Haz Sub	1.4	209.3	813.0	3,407	33,705	67,000	135,000	240,136	89.6%
Non-crude	0.5	3,660.0	1,464.5	2,005	1,500			8,630	3.2%
Process water	1.5	54.0	510.0	6,350	12,000			18,916	7.1%
Unknown				375				375	0.1%
Total	3.7	3,930.3	2,807.5	12,137	47,205	67,000	135,000	268,083	
Percent	0.0%	1.5%	1.0%	4.5%	17.6%	25.0%	50.4%		



a.



b.

Figure 3.4. Number of spill incidents (a) and cumulative gallons spilled (b) for non-crude oil, hazardous substances, extremely hazardous substances, and process water in different spill size classes for Pogo Mine from July 1995-December 2020 based on ADEC (2021).

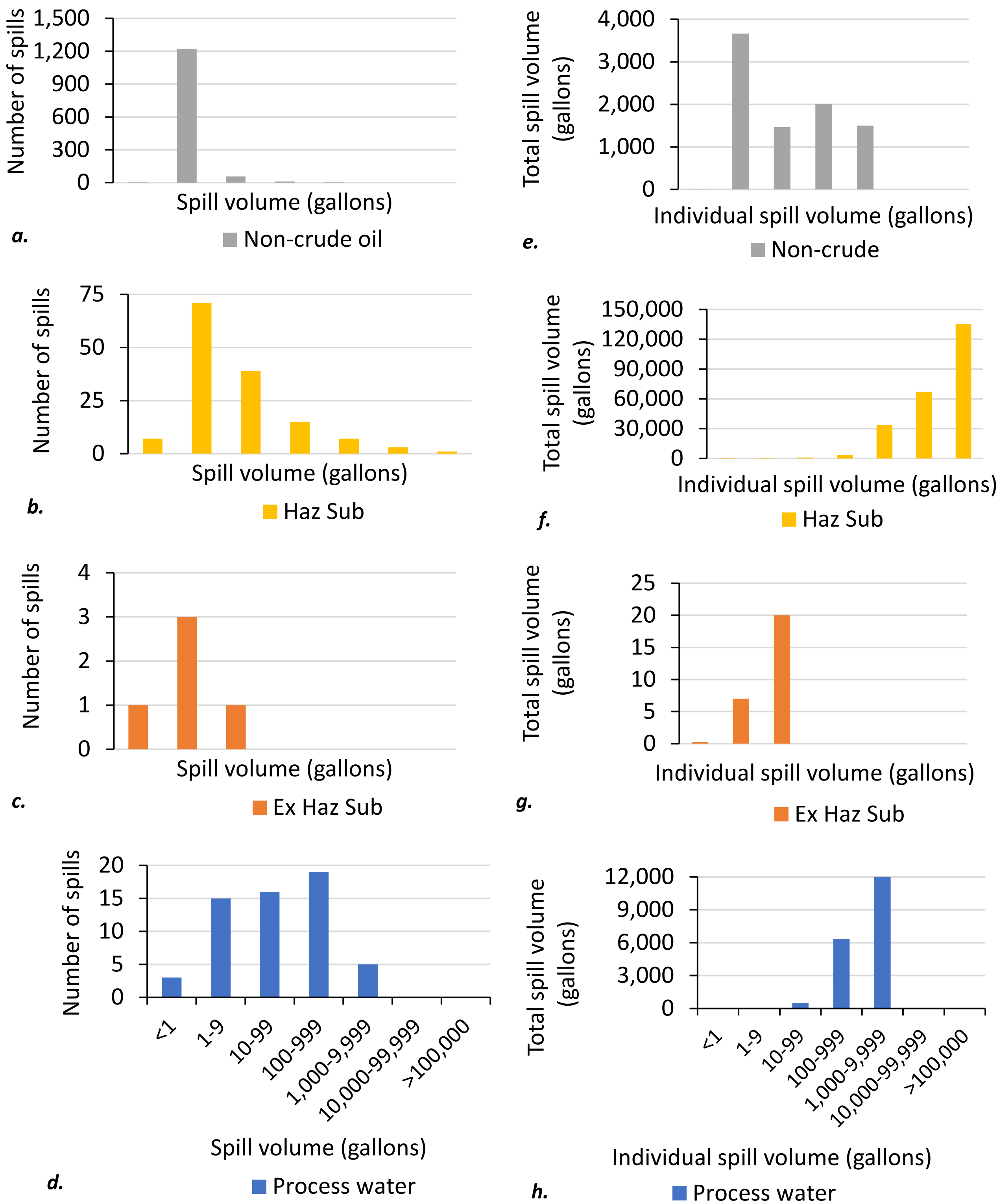


Figure 3.5. Number of spill incidents (a-d) and cumulative gallons spilled (e-h) for non-crude oil (a, e), hazardous substances (b, f), extremely hazardous substances (c, g) and process water (d, h) in different spill size classes for Pogo Mine from July 1995-December 2020 based on ADEC (2021). All subfigures have the same x-axes.

The ADEC issued the *Summary of Oil and Hazardous Substances Spills by Subarea (July 1, 1995 – June 30, 2005)* in 2007 (ADEC 2007). While ADEC (2007) only recorded a single spill of at least 1,000 gallons from Pogo Mine from 1995-2005 (a 7,500 release of "other" on February 8, 2006), ADEC (2021) listed 17 spills of at least 1,000 gallons or pounds, two of which occurred prior to 2007 and did not appear in ADEC (2007) (Table 3.12). Most of the spills ≥1,000 gallons were mill slurry/paste backfill and process water.

Table 3.12. There were 17 spills of at least 1,000 gallons of hazardous products at Pogo Mine by the end of 2020 (ADEC 2021). The shaded row indicates the spill listed in ADEC (2007). Rows in bold occurred before July 2005 but were not listed in ADEC (2007).

Date	Spill name	Product	Gallons
5/7/2015	Pogo Mine Paste Backfill Release	Mill Slurry	135,000
3/8/2009	Teck, Pogo Mine Drainage Water	Other	40,000
8/20/2007		Mill Slurry	15,000
3/15/2008		Other	12,000
2/8/2006		Other	7,500
2/18/2017	Pogo Mine, 7069gal Paste Backfill	Other	7,069
12/21/2009	Pogo Paste Release	Drilling Muds	6,000
5/3/2010	RTP Head Tank	Process Water	6,000
10/22/2006	**Pogo Mine Monthly 10/22/2006**	**Other**	**4,500**
5/4/2009	slurry cement line failure	Other	3,636
1/29/2016	Pogo Mine Paste Line #2 3500gal Paste Backfill	Other	3,500
4/29/2009	Monthly	Source Water	2,500
4/8/2016	Pogo Mine 1,500 gal CIP Tails Slurry	Mill Slurry	1,500
9/3/2020	Northern Star Pogo, TTLA, 1500gal Diesel	Diesel	1,500
1/16/2020	Pogo Mine, RTP Head Tank, 1500gal Process Water	Process Water	1,500
12/11/2006	**Monthly**	**Process Water**	**1,000**
1/9/2007	Pogo Mine Process Water 1/9/2007	Process Water	1,000

I identified transportation spills by looking at a combination of *facility type*, *source type*, and *cause subtype* (Table 3.13). For Pogo Mine, I estimate that there were 65 spills related to transportation, of which 35 were from *heavy equipment* (Table 3.13). More than 1,300 gallons of *non-crude oil* were spilled, 85.7% of which was diesel released over the course of 14 spills (Table 3.14). There were also spills of *hazardous* and *extremely hazardous substances* totaling to nearly 300 gallons (Table 3.14). There were 12 transportation spills related to *collision/allision* and *rollover/capsize* accidents (Table 3.15).

Table 3.13. Transportation related spills from Pogo Mine from June 1995-December 2020.

Facility type	Source type	Cause subtype	*n*
Maintenance yard	Tank, other, mobile	Human error	1
Mining operation	Container, other	Cargo not secured	3
Mining operation	Container, other	Rollover/Capsize	1
Mining operation	Drum(s)	Cargo not secured	3
Mining operation	Heavy equipment	Cargo not secured	3
Mining operation	Heavy equipment	Collision/allision	3
Mining operation	Heavy equipment	Rollover/Capsize	3
Mining operation	Heavy equipment	Vehicle leak, all	25
Mining operation	Other	Rollover/Capsize	1
Mining operation	Other	Vehicle leak, all	1
Mining operation	Pipe or line	Vehicle leak, all	5
Mining operation	Tank, other, mobile	Human error	1
Mining operation	Trailer, tanker	Leak	1
Mining operation	[blank]	Vehicle leak, all	1
Other	Drum(s)	Cargo not secured	1
Other	Tank, other, mobile	Leak	1
School*	Heavy equipment	Rollover/Capsize	1
Vehicle	[blank]	Various	10
			65

** Spill name = "Delta Jct Sch Complex Diesel Spill", responsible party = "Arctic Drilling", and facility name = "Delta School Complex". I assumed this spill was associated with the Delta Mine Training Center.*

Table 3.14. Transportation spills associated with Pogo Mine by substance, number of spills, volume range, and total volume.

Substance	Number of spills	Spill volume range (gallons)	Total volume spilled (gallons)
Extremely hazardous substances			
Sulfuric acid	1	0.25	0.25
Hazardous substances			
Ethylene glycol	3	2-15	32
Propylene glycol	2	0.75-30	30.75
Glycol, other	1	5	5
Mill slurry	1	15	15
Other	3	0.5 lb – 185 gal	210
Total	10		292.75
Non-crude oil			
Diesel	14	0.5-500	1,122.5
Engine lubricant	6	1-7	20
Gasoline	1	10	10
Hydraulic oil	30	1-25	151.5
Used oil (all)	3	1-3	6
Total	54		1,310

The most common causes of the 143 *hazardous substance* spills were *equipment failure* (64 spills), *containment overflow* (21 spills), and *line failure* (15 spills) (Table 3.15). The 1,291 *non-crude oil* spills were overwhelming attributed to *equipment failure* (971 spills), followed by *line failure* (136 spills) and *leaks* (67 spills). *Process water* spills were most often due to *human error* (20 spills) and *containment overflow* (14 spills).

Table 3.15. Spills associated with Pogo Mine by cause sub-type and substance category. There were also two spills of unknown substances: a 100-gallon spill caused by equipment failure and a 275-gallon spill due to human error. This table does not include 4 spills of "other" hazardous substances with quantities given in pounds (weights ranged from 0.5 to 25 pounds).

Cause subtype	Extremely Hazardous Substances		Hazardous Substances		Non-crude oil		Process Water	
	n	volume range (gal)	*n*	volume range (gal)	*n*	volume range (gal)	*n*	volume range (gal)
Cargo not secured	1	0.25	2	15-25	6	2-55		
Collision/allision			2	15	2	10-120		
Containment overflow	1	20	21	1-175			14	3-6,000
Corrosion					1	1		
Crack	1	1			1	5		
Equipment failure	1	1	64	0.004-40,000	971	1-130	6	0.5-500
External factors							2	500-2,500
Gauge/site glass failure			2	100-4,500			3	20-500
Human error	1	5	9	0.1-7,500	24	1-125	20	0.5-600
Leak			9	1-18	67	1-150		
Line failure			15	1-135,000	136	1-200	6	4-1,000
Overfill			9	4-335	13	1-400	4	2-1,000
Puncture					2	5-15		
Rollover/capsize			2	0.75-185	6	0.5-500		
Seal failure			2	1-122	10	1-30	1	4
Tank failure					1	20	1	1,500
Valve failure			1	1,500	4	1-20		
Vehicle leak, all			1	2	31	1-25		
Other			3	0.3-50	3	5-30	1	3
Unknown			1	1-25	13	1-1,500		
Total spills and volume range	5	0.25-20	143	0-135,000	1,291	1-1,500	58	0.5-6,000

Pogo Mine's spill record began even before permitting was completed in 2003 (Table 3.16). There was a dramatic increase in the number of spills reported per year starting in 2016 (Table 3.16 and Figure 3.6). For the entire record from 1998-2020, there was an average of ~65 spills per year, but this value does not show how much the number of spills occurring each year has changed.

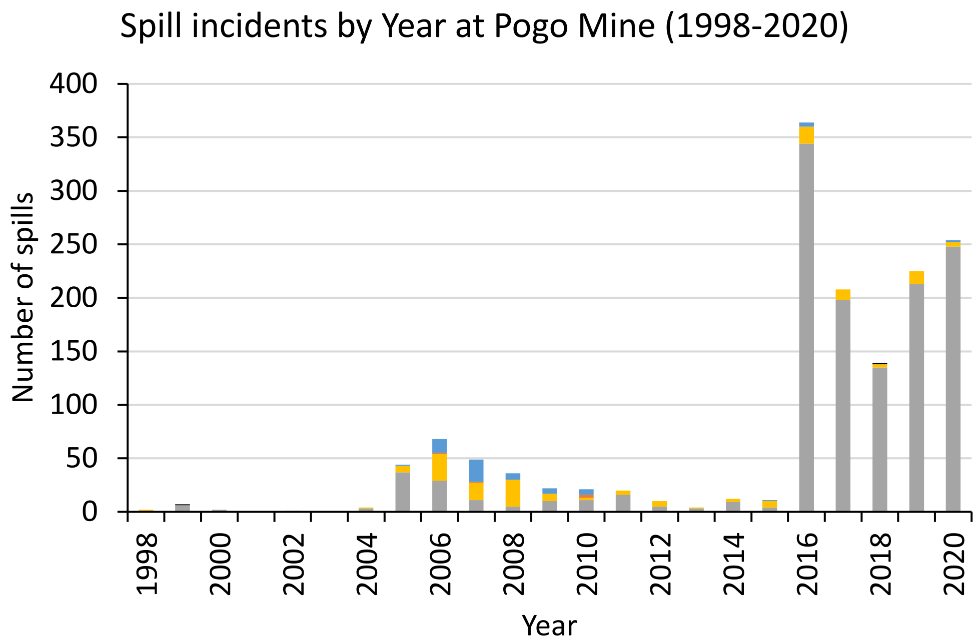
According to Teck (undated) there were 66 reportable spills at Pogo in 2005 and 76 in 2006, both of which exceed the number of incidents shown in ADEC (2021) (Table 3.16). Most recently, the average number from 2016-2020 was 268 spills per year. Most of that increase came from spills of *non-crude oil*, which made the relative proportion of recorded *hazardous substances* releases smaller from 2016-2020 than it had been for the preceding decade, even though the numbers of *hazardous substances* spills did not change as dramatically. Although January and December are the months with the fewest average spill occurrences, there was little evidence of a seasonal aspect to spill frequency at Pogo (Table 3.17 and Figure 3.6).

Table 3.16. Spills per year by substance type at Pogo Mine from July 1995-December 2020 based on ADEC (2021). Spills in the shaded rows predated permitting.

	Spills					
Year	Ex Haz Sub	Haz Sub	Non-crude	Process water	Unknown	Total
1998		1	1			2
1999			6		1	7
2000			2			2
2001						0
2002			1			1
2003						0
2004		1	3			4
2005		6	37	1		44
2006	1	25	29	13		68
2007	1	16	11	21		49
2008		25	5	6		36
2009		7	10	5		22
2010	3	2	11	5		21
2011		4	16			20
2012		5	5			10
2013		1	3			4
2014		3	9			12
2015		6	4	1		11
2016		16	344	4		364
2017		10	198			208
2018		3	135		1	139
2019		12	213			225
2020		4	248	2		254
total	5	147	1,291	58	2	1,503
mean	0.22	6.39	56.13	2.52	0.09	65.35
sd	0.67	7.60	98.44	5.10	0.29	100.91

Table 3.17. Total spills per month by substance type at Pogo Mine from 1998-2020 based on ADEC (2021).

	Spills					
Month	Ex Haz Sub	Haz Sub	Non-crude	Process water	Unknown	Total
January		12	67	6	1	86
February	1	15	141	4		161
March	1	12	131	8		152
April		12	118	7		137
May		6	118	5		129
June	1	13	120	8	1	143
July		19	84	4		107
August		8	100	2		110
September		14	108	3		125
October	2	11	105	4		122
November		15	113	4		132
December		10	86	3		99
Total	5	147	1,291	58	2	1,503



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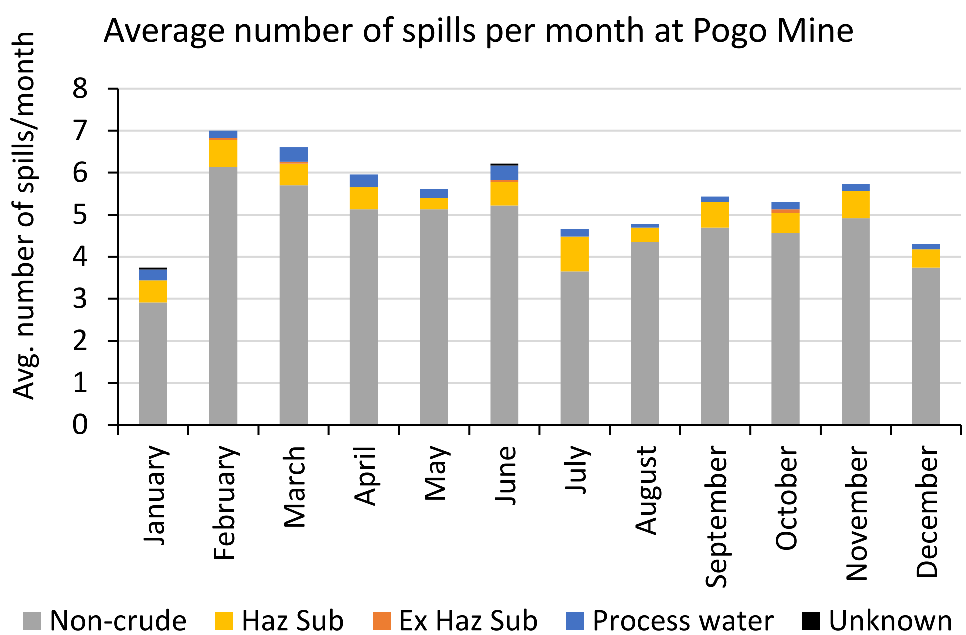

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Figure 3.6. Annual (a) and average monthly (b) spill incidents at Pogo Mine based on ADEC records from 1998-2020 and broken down by substance type.

Sewage spills and notices of violations

ADEC does not track sewage and grey water among the hazardous materials included in the spill database, but sewage spills can be a recurring issue at mancamps associated with mines. In Pogo's case, an EPA Notice of Violation (NOV) letter dated April 12, 2007, lists 31 releases occurring between September 8, 2004, and March 2, 2007 (EPA 2007) (Table 3.18). There were 21 releases of raw sewage in that time, for a total volume of 16,520.5 gallons in 2.5 years. While further records of specific events are sparse, there are indications that sewage spills continued to be an issue at Pogo. In 2006 fecal coliform exceeded permit limits (Teck undated). An ADEC Notice of Violation letter dated December 5, 2011, found fecal coliform maximum daily and monthly values were exceeded 15 times between March 9, 2011, and September 12, 2011 (ADEC 2011). ADEC noted that Pogo has "reported numerous sewage releases and fecal coliform exceedances" and that "ADEC is concerned about the number, frequency, and continuing nature of these noncompliance events." In November 2018, an ADEC Alaska Pollutant Discharge Elimination System (APDES) inspection report noted sewage spills on February 21, 2017, and on May 13, 2018, as areas of concern (ADEC Division of Water 2018a).

Table 3.18. Releases noted in the EPA NOV letter from April 2007. Shaded rows indicate incidents also included in ADEC (2021).

Date	Amount (gallons)	Substance	Incident description
9/8/2004	10,000	Raw sewage	From buried wastewater line
9/6/2004	200	Raw sewage	From newly installed and not yet operating lift station
12/23/2004	150	Raw sewage	During transfer from a pumper truck
2/24/2005	17	Raw sewage	From a damaged sewer line
6/5/2005	3,000	Raw sewage	From an underground domestic wastewater line
6/25/2005	55	Raw sewage	Malfunctioning sewage lift station
7/28/2005	300	Raw sewage	From the process tank
7/29/2005	1.5	Raw sewage	From the transfer hose
9/20/2005	Unknown	Drill water	HDPE water line
11/4/2005	52	Raw sewage	From a vacuum truck
11/9/2005	500	Untreated mine water	
12/6/2005	5,000	Drill water	Due to an overturned truck
3/6/2006	1,000	Raw sewage	Instrumentation failure
6/24/2006	1,500	Storm water	Leak at the 12" flange gasket
6/25/2006	20,000	Storm water	Due to catastrophic failure of welded flange adaptor
10/9/2006	800	Partially treated mine drainage and recycle tailings pond water	
10/21/2006	60	Raw sewage	At a lift station
10/22/2006	4,500	Untreated mine drainage	
11/9/2006	400	Raw sewage	Near the mine dry lift station
12/12/2006	1,000	Recycle tailings pond water	6" pipeline near the 1690 portal
12/15/2006	43,000	Treated water	Pogo industrial water treatment plant
12/15/2006	50	Raw sewage	At a lift station
1/6/2007	50	Raw sewage	At a lift station
1/24/2007	450	Raw sewage	Imbalance of influent and effluent rates
1/27/2007	475	Raw sewage	Imbalance of influent and effluent rates
1/29/2007	145	Raw sewage	Sequential batch reactor tank overflowed
2/16/2007	10	Raw sewage	Inlet valve of a sewage pump truck
2/18/2007	30	Raw sewage	Lift station overflowed
2/19/2007	50	Raw sewage	Equalization tank overflowed
2/23/2007	25	Raw sewage	Transfer from one truck to another
3/2/2007	150	Treated effluent	From the discharge line

A chronological look at Pogo shows numerous other violations from 2005 to the present. Since discharges commenced in July 2005, average monthly cadmium exceeded the designated levels 8.8% of the time and average monthly cyanide values were in non-compliance 10.5% of the time over the course of 57 months (ADEC Water Discharge Authorization Program 2010). An EPA Notice of Violation letter dated December 1, 2010, notes violations in that 1) an inspection team was not allowed entry to the facility for five hours; 2) Pogo monitored pH, turbidity, biochemical oxygen demand, and total suspended solids percent removal more frequently than required but did not include all the sample results in the reporting and calculations in the discharge monitoring report, 3) Pogo's calculations of fecal coliform monthly averages used the arithmetic mean instead of a geometric mean, and 4) Pogo did not attain minimum levels for cadmium for January, February, July, November, and December 2009 and January-July 2010 (EPA 2010b). The inspection report which the letter was based on listed seven areas of concern, including cyanide issues in which "the facility continues to exceed monthly cyanide average limitations" (EPA 2010a).

EPA (2011) details the findings from an unannounced inspection in July 2011. As noted in the Regulatory Status/Compliance History section of the report:

> a total five EPA and/or ADEC inspections have been conducted at he Mine during the past five years and the facility was found to be in significant non-compliance due to reporting and effluent violations for twelve quarters during that period. That history also showed that, two Notices of Violations (NOVs) and a formal enforcement action have been issued to SMMP by the EPA since 2009. These enforcement actions were based upon inspections which documented the following violations: effluent limit exceedances (predominantly WAD cyanide), failure to properly operate and maintain systems of treatment, monitoring and reporting issues, and failure to allow entry to the facility.

The inspection report listed 41 instances of effluent limitation exceedances between December 5, 2010, and September 12, 2011. Values for pH, iron, manganese, fecal coliform, weak acid dissociable (WAD) cyanide, and total suspended solids all fell outside of acceptable ranges listed for the outfalls in Pogo's individual permit. Specifically, the inspection found violations at Pogo related to 1) WAD cyanide daily and monthly maximum values in excess of effluent limits in April 2011, 2) manganese concentrations greater than the monthly average effluent limit, 3) the pH was less than the effluent (minimum) limit of 6.5 standard units at Outfall 001 on five occasions between December 2011 and March 2011, 4) the pH was less than the effluent (minimum) limit of 6.0 standard units at Outfall 011 on seven occasions in February and March 2011, 5) iron concentration was in excess of maximum daily and monthly effluent limits on four occasions between March and June 2011, 6) the maximum daily value for total suspended solids was exceeded on July 31, 2011, 7) there were 14 instances of maximum daily fecal coliform above the maximum daily limit of 400 #/100mL with values between 570 to 200,000 #/100 mL, and 8) ADEC also noted that Pogo's Water Treatment Plant #2 discharges effluent at 400 gallons per minute when the discharge rate should be at least 600 gallons per minute. The findings of the report formed the basis for a Notice of Violation from ADEC (ADEC Division of Water 2011). In June 2012, ADEC and Pogo entered a compliance order by consent (COBC) which included increasing the gallons per minute at Wastewater Treatment Plant #2 (ADEC 2012). The COBC was amended in 2013 to allow Pogo to plan a third wastewater treatment plant (ADEC 2014). In November 2015, ADEC Division of Water conducted an inspection of Pogo and found that Pogo had exceeded effluent limits for flows in May 2012, for dilution factor in November 2013, and for lead and copper in August 2014 (ADEC Division of Water 2015).

At Pogo, gold recovery includes cyanide leaching. According to Sumitomo Metal Mining Pogo, LLC (2017), "The cyanide process is isolated from any contact with the environment. The cyanide slurry is detoxified, and the residual cyanide contacted material contained underground in the paste backfill." On May 7, 2015, 90,000 gallons of paste backfill, which consist of milled tailings mixed with cement, were released primarily from an 8" line used to inject the paste backfill underground and secondarily from a valve inside the Tank 32B Pump House (*Anchorage Daily News* 2015; ADEC DSPR 2015). An estimated 36,000 gallons of the paste backfill, which contained 1-3 ppm WAD cyanide and had a pH of 10-12, was released outside of the impermeable secondary containment. In ADEC (2021) this is listed as a 135,000-gallon spill of mill slurry due to a line failure.

In November 2018, the same ADEC APDES inspection report that noted the sewage spills at Pogo also found violations regarding the instrument calibration logs and effluent limitation exceedances for turbidity, cyanide, cadmium, copper, and iron (ADEC Division of Water 2018a). This inspection was followed by a Compliance Letter in December of that year (ADEC Division of Water 2018b).

EPA ECHO indicates there were violations of the Clean Water Act dating to November 2018 and to the RCRA in June 2019 (EPA ECHO 2021c). Clean Water Act Violations were identified in the fourth quarter of 2018 (a permit schedule violation), the second quarter of 2020 (a turbidity limit violation), and the first quarter of 2021 (a permit schedule violation). Resource Conservation and Recovery Act Violations have been noted from the first quarter of 2020 to the present (EPA ECHO 2021c). The EPA ECHO site also lists any informal or formal enforcement actions in the last five years. Pogo had six types of informal action noted since 2018. These included two warning letters regarding the Clean Air Act in 2018 and 2020, and a Letter of Violation/Warning Letter in 2018, and a Notice of Violation in 2020 concerning the Clean Water Act (EPA ECHO 2021c).

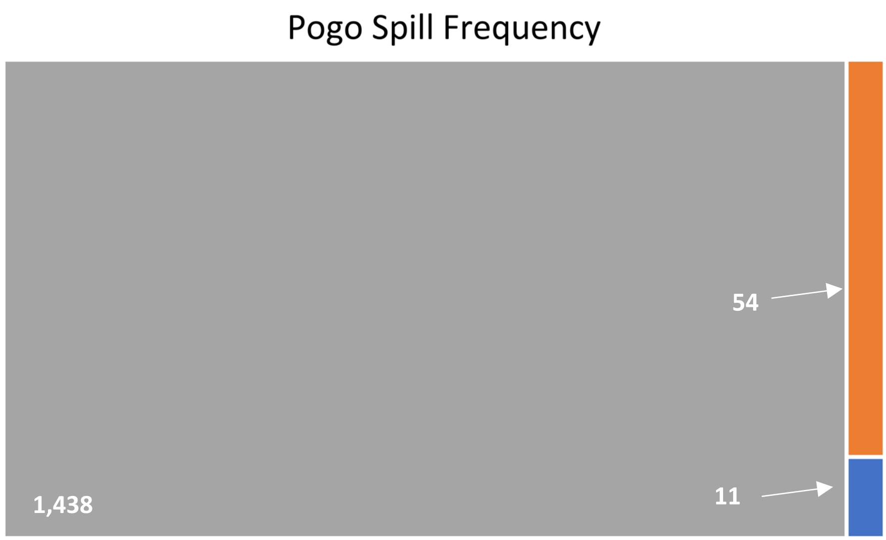
How well were the recorded spills predicted?

The only quantitative spill predictions concerning Pogo Mine in the EIS were about diesel being transported by truck (Table 3.19). I was able to reproduce the estimates based on Harwood and Russell's (1990) rate of spills per truck mile that was given in EPA (2003). That estimate was that there was only a 1% chance of a diesel release over the stated life of the project if diesel were not transported to the mine for power generation. No other hazardous material transport or any other types of spill releases were modeled in the EIS. I extended the model of transportation spills to include all hazardous materials and found that if the Harwood and Russell (1990) rate is correct for the Pogo Mine transportation corridor, there would have been a 5.6-6.5% chance of a spill along the transportation corridor without bringing in diesel for power generation and a 10.5-11.5% chance of such a spill when the additional diesel was brought to the mine, depending on the mining rate (Table 3.8). The Pogo Mine has had more than 1,500 spills across a wide range of hazardous materials, spill volumes, and spill sources, with 65 spills from vehicles representing 4.3% of that number and an even smaller part of the quantity released (Figure 3.7).

Data from the Pogo Mine illustrate that hazardous materials spills are frequent, can be sizable, and that transportation spills are only a small fraction of mine-related spill incidents and volume. Spills are inevitable, and modeling spill risk based on a single chemical reagent, spill source, or cause will vastly underestimate the spills that may occur.

Table 3.19. Predicted and observed spills associated with transportation to Pogo Mine. Transportation spill causes included collision/allision and rollover/capsize, as well as cargo not secured, equipment failure, human error, leak, line failure, overfill, and vehicle leak (all).

Predicted spills for the life of the mine (8 to 11 years, depending on production rate)		Observed spills (1998-2020)
EPA (2003)	based on data in EPA (2003)	
Diesel spills (collisions/allisions and rollovers/capsizes)		
• 0.010 for the 2,500 tpd scenario, no on-site power generation • 0.012 for the 3,500 tpd scenario, no on-site power generation • 0.064 for the 2,500 tpd scenario, with on-site power generation • 0.067 for the 3,500 tpd scenario, with on-site power generation		4
Diesel spills (other transportation causes, not collisions/allisions or rollovers/capsizes)		
none	no data or model given	10
Other non-crude oil (collisions/allisions and rollovers/capsizes)		
none	no data or model given	3
Other non-crude oil transportation-related spills (not collisions/allisions or rollovers/capsizes)		
none	no data or model given	37
Hazardous reagents (collisions/allisions and rollovers/capsizes)		
none	• 0.047 for the 2,500 tpd scenario • 0.056 for the 3,500 tpd scenario	4
Other spills of hazardous and extremely hazardous materials from transportation related spills (not collisions/allisions or rollovers/capsizes)		
none	no data or model given	7



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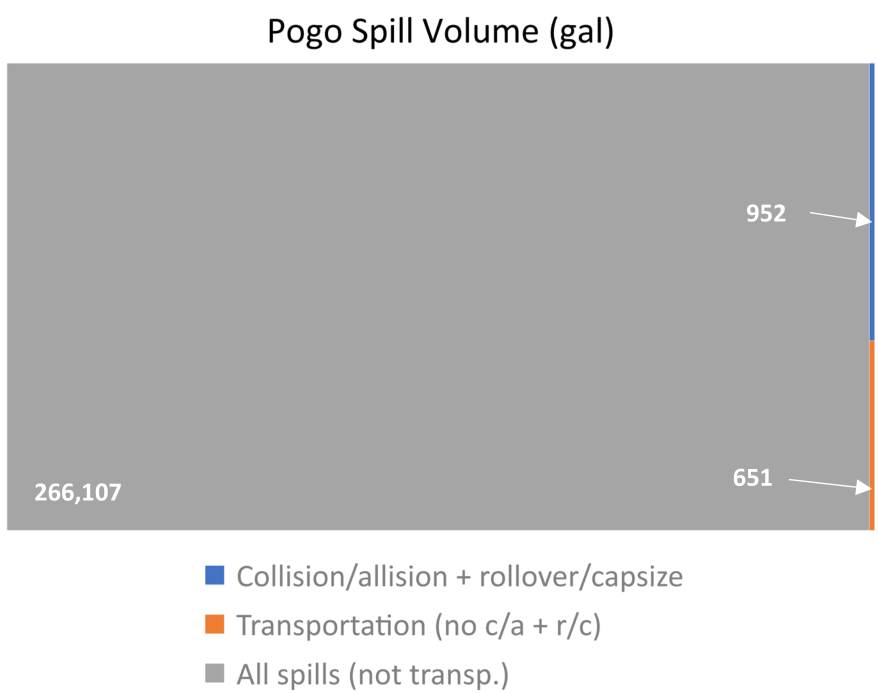

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Figure 3.7. A comparison of the relative (a) number and (b) cumulative volume of (collision/allision and rollover/capsize spills) compared to the remaining transportation spills and non-transportation spills at Pogo Mine from 1995-2020.

Pogo Mine Summary

Pogo Mine is an underground gold mine approximately 38 miles northeast of Delta Junction in the interior of Alaska, predicted in its EIS to process 2,500 to 3,500 tons of ore per day (tpd).

Pogo Mine was permitted in 2003 and had an expected mine life of 11 years at an ore production rate of 2,500 tpd (EPA 2003b). As of 2017, the projected mine life at a milling rate of 3,000 tons per day was six years.

Pogo Mine has a 49.5-mile transportation corridor used to supply the mine with the necessary blasting agents, fuel, and reagents for a gravity/flotation/cyanide vat leach process. The cyanidation circuit was projected to process 250-350 tpd of flotation concentrate.

Nearly 5,000 tons of reagents and explosives were called for annually under the 2,500 tpd scenario, a figure that increases to more than 7,200 tons per year under the 3,500 tpd production rate. Under the 2,500 tpd production rate, Pogo Mine would require 1,000 tons each of explosives, lime, sodium cyanide, and sodium metabisulfite per year; those quantities increase to 1,500 tons annually under the 3,500 tpd ore production rate. Those values do not include diesel fuel (786,000 to 1,3000,000 gallons needed annually, depending on ore production) or other reagents needed in smaller quantities.

Transportation of the reagents, fuel, explosives, and grinding media and liners were estimated to require 561 to 909 (loaded, one-way) trips per year, again depending on ore production, along a two-lane, all-season road with grades up to 7 or 8% that would have six single-lane bridges over five creeks. There were an estimated 100-161 loads required for diesel and 116-231 loads of propane to be delivered annually.

Based on the $N = RT$ model and using the Harwood and Russell (1990) estimate of $R = 1.9 \times 10^{-7}$ spills/mile, the 2003 EIS (EPA 2003b) estimated that there was a 1% chance of spill over the 11-year project life at the 2,500 tpd ore production rate. Once the remaining hazardous materials (propane, explosives, reagents, etc.) are included, the estimate of the expected number of spills along the transportation corridor was 0.057 to 0.068, and the probability of at least one spill was 5.6% for the 2,500 tpd ore production scenario and 6.5% for the 3,500 tpd ore production rate. (In the EIS, EPA (2003b) did not consider 1% to be a high risk, but a 6% chance of a spill was considered high.)

Based on data from ADEC (2021) there were 12 spills due to *collision/allision* and *rollover/capsize* incidents attributed to Pogo Mine from 1998-2020, four of which were diesel spills, four which were other forms of *non-crude oil* (gasoline and engine lube oil), and four spills of *hazardous substances* (ethylene glycol, propylene glycol, and “other”). There were an additional 53 transportation-related spills associated with Pogo Mine, for a total of 65 transportation spills.

There were an estimated 1,503 spills related to Pogo Mine from 1995-2020 in ADEC (2021). Spills related to *vehicle* or *heavy equipment* accidents (*collisions/allisions* + *rollover/capsizes*) represent less than 1% of the total incidents. Transportation spills from all causes were estimated to account for 4.3% of the spills associated with Pogo Mine.

Almost 1,300 of the spills at Pogo Mine were of *non-crude oil*. The cumulative volume of all the spills is over 260,000 gallons. The largest spill was 135,000 gallons of mill slurry due to a line failure in May 2015. While more than 95% of the spills were of <100 gallons, the 5% of spills that were ≥100 gallons accounted for 97.5% of the volume released. There were 17 spills of at least 1,000 gallons. More than 8,600 gallons of *non-crude oil* were spilled at Pogo Mine, including more than 4,000 gallons of hydraulic oil in more than 1,100 incidents. Although *non-crude oil* spills accounted for 86.1% of the number of recorded incidents, accidental releases of *hazardous substances* represented 89.6% of the volume spilled.

The most common causes of the 143 *hazardous substance* spills were *equipment failure* (64 spills), *containment overflow* (21 spills), and *line failure* (15 spills). The 1,291 *non-crude oil* spills were overwhelming attributed to *equipment failure* (971 spills), followed by *line failure* (136 spills) and *leaks* (67 spills). *Process water* spills were most often due to *human error* (20 spills) and *containment overflow* (14 spills).

The number of recorded incidents of *non-crude oil* spills increased dramatically in 2016 from fewer than 40 spills per year from 1998-2015 to 135-344 per year from 2016-2020.

In addition to the spill record from ADEC (2021), Pogo Mine has a history of raw sewage, drill water, storm water, treated water, and treated effluent spills, with 31 such releases totaling to 16,520 gallons from September 2004-March 2007 alone.

CHAPTER 4
Kensington Mine

Location and description

Kensington Gold Mine is an underground gold mine roughly 45 miles north-northwest of Juneau, Alaska (USFS 2004) (Figures 4.1, 4.2, and 4.3). Kensington had a complicated permitting history and the 2004 Final Supplemental EIS (SEIS) is the third time that the mine underwent NEPA review (USFS 2004), with prior EISs in 1992 and 1997. The 2004 FSEIS included Alternatives A (the no action alternative, corresponding to the 1997 SEIS Alternative D), A1 (reduced mining rate dry tailings facility), B (the proposed action), C, and D. Alternative D was selected in the Record of Decision, although the EPA identified Alternative A as both the Environmentally Preferred Alternative and the Preferred Alternative (USFS 2004). Alternative D infrastructure included (USFS 2004):

- a tailings storage facility (TSF)
- mill facilities
- access roads with four bridges, a 1-mile cutoff road, and a 3.5-mile pipeline access road
- a tunnel to connecting the Kensington Mine with ore processing facilities on private land near the Jualin Mine in the Johnson Creek drainage
- permanent waste rock disposal facilities near the Kensington 850-foot portal and the Jualin Mine process area
- surface water diversions will be built above the Kensington Mine 850-foot portal and waste rock disposal area, the Jualin process area and mine portal, and the diversion pipeline around the TSF.

The rationale for the decision was that “Alternative D provides the best combination of components to minimize ground disturbance, reduce impacts to wetlands, provide safe and efficient transportation of workers, and reduce on-site fuel storage with the related risk of fuel spills within the framework of existing laws, regulations, and policies while meeting the stated purpose and need” (USFS 2004).

Compared to the No Action Alternative, Alternative D would mine a smaller amount of ore with a higher average gold concentration at a production rate of roughly 2,000 tons of ore per day and include the development of a tunnel to connect the Kensington and Jualin areas of the mine. Kensington Mine is accessed from marine terminals built in Slate Creek Cove for supply staging and at Comet Beach for personnel (Figure 4.3).

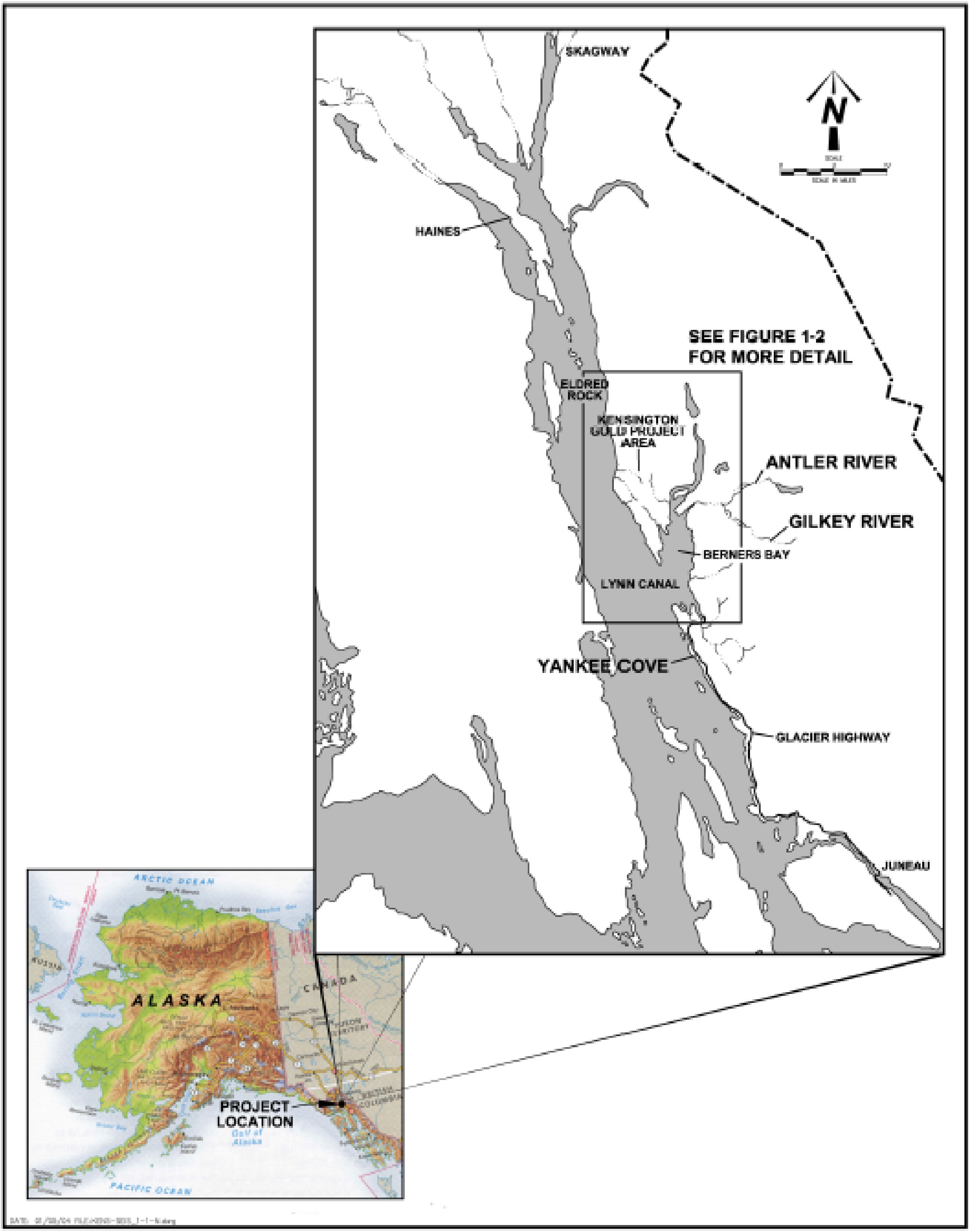
The EPA summarized Kensington and its proposed amended plan of operations as:

> The Kensington Mine is located in Southeast, Alaska, in the Tongass National Forest on a peninsula above Berners Bay and Lynn Canal within the Juneau Borough. Coeur Alaska, Inc. POA-1 for the Kensington Mine would expand the existing mine facility by 150 acres, extend

the active mine life an additional 10 years, and increase mill production from 2,000 tons to 3,000 tons per day. The Proposed Action includes the following project components: (1) construction of a Lower Slate Lake Tailings Treatment Facility (Stage 4) dam raise (36-ft) of the existing TTF (Stage 3) dam (88-ft) to provide for an additional 4 million tons of tailings, which would increase the overall TTF tailings capacity to 8.5 million tons; (2) expansion of three existing Waste Rock Storage Facilities (Kensington, Pit #4, and Comet) and construction of one new WRS Facility (Pipeline Road) to provide an additional 5 million tons of waste rock storage, which would increase the overall WRS Facilities capacity to 34 million tons; (3) a Back Dam (40-ft high) to separate the TTF and Upper Slate Lake; (4) relocation of some ancillary facilities, including TTF area water treatment plants, seepage collection sumps, access road, power line, pipelines, and storm water diversion channels; and (5) construction of a road, river deltas for Dolly Varden spawning habitat, a new stream channel to reroute Fat Rat Creek into South Creek and replacement of culverts for fish passage to mitigate Slate Creek resident fish spawning habitat losses. (EPA 2021)

By the numbers

Kensington Mine has now undergone a fourth EIS process for an amended plan of operations (USFS 2021). The numeric values for ore processing, reagent and fuel use, the transportation corridor, and waste and tailings generation for the 2004 and 2021 EISs are shown in Table 4.1.



Source: Forest Service, 1997a

Figure 4.1. USFS (2004) "Figure 1-1: General Project Area (Approximately 45 northwest of Juneau)".

Source: U.S. Geological Survey, 1985

Figure 4.2. USFS (2004) "Figure 1-2: Specific Project Area".

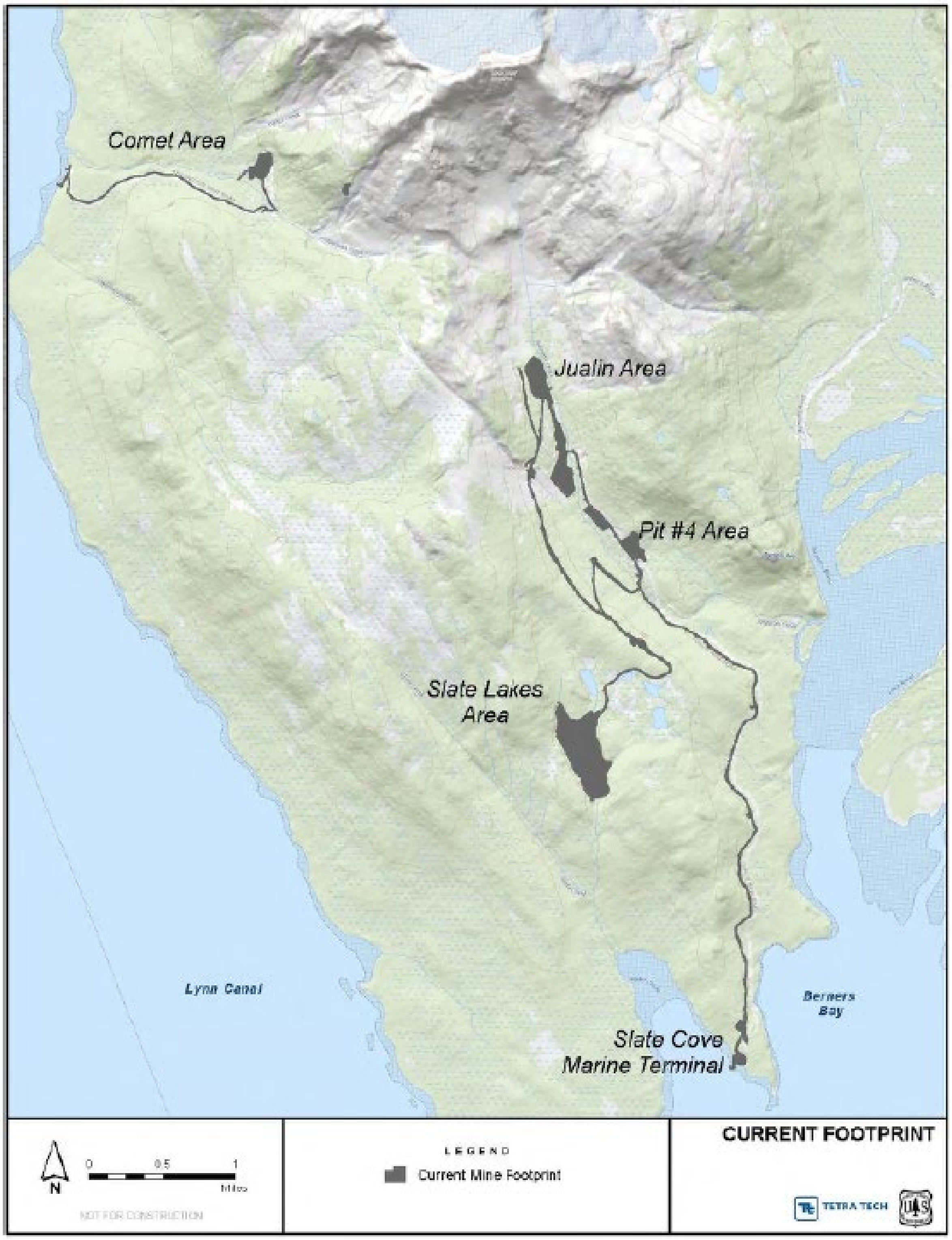


Figure 4.3. USFS (2021) "Figure 2.2-1: Current Layout (No Action Alternative) Footprint".

Table 4.1. Quantitative descriptions of ore production, reagent use, fuel use, the transportation corridor, and waste rock and tailings produced from the Kensington Gold Mine.

Value	Description	Reference
	Ore, ore concentrate	
2,000	tons of ore per day production rate	USFS (2004)
10	year project life under Alt D (selected in the ROD)	USFS (2004)
700	tons per week ore concentrate production level average	USFS (2004)
80 to 140	tons of flotation concentrate per day	USFS (2004)
~100	tons of flotation concentrate generated daily	USFS (2004)
20	containers per week ore concentrate production level average	USFS (2004)
3,000	tons per day expanded milling rate under the POA	EPA (2021)
10	years additional mine life under the POA	EPA (2021)
	Reagents	
0.5	tons PAX per day used under Alt D	USFS (2004)
0.2	tons MIBC per day used under Alt D	USFS (2004)
0.1	tons flocculant per day used under Alt D	USFS (2004)
0.01	tons polymer per day used under Alt D	USFS (2004)
0.02	tons surfactant per day used under Alt D	USFS (2004)
0.05	tons flotation scale inhibitor per day used under Alt D	USFS (2004)
1	tons lime per day used under Alt D	USFS (2004)
~1	per day for blasting during construction and at the quarry in the Jualin mine site area	USFS (2004)
	Fuel and energy	
6,500	gallon isotainers for transporting fuel (Alt D)	USFS (2004)
5,000	gallons per load in Alts A and A1	USFS (2004)
3.2 million	gallons of diesel annually (Alt D)	USFS (2004)
3.5 million	gallons of diesel annually (Alt D)	USFS (2004)
9	isotainers delivered to Slate Creek Cove every week	USFS (2004)
80,000	barrels per fuel barge	USFS (2004)

Table 4.1. (Continued.)

Value	Description	Reference
	Transportation corridor	
5	mile-long access road	USFS (2004)
3.5	mile pipeline and pipeline access road	USFS (2004)
20	tons of flotation concentrate per container	USFS (2004)
5	containers of flotation concentrate per day	USFS (2004)
3 to 4	barge trips per week on Berners Bay	USFS (2004)
1.5	mile access road from Comet Beach to the process area (Alt A) for moving fuel, supplies, and ore concentrate	USFS (2004)
10,500	vehicle round trips per year would be made on the access road (Alt A)	USFS (2004)
6.30%	chance of an accident along the access road (annual) (Alt A)	USFS (2004)
88%	chance of an accident along the access road (over the 14-year project life) (Alt A)	USFS (2004)
5	mile road from Slate Creek Cove to Jualin (Alts B, C, D)	USFS (2004)
7	barge deliveries per week (Alts B, C, D)	USFS (2004)
5,350	vehicle round trips per year would be made on the access road (Alt D)	USFS (2004)
9.00%	chance of an accident along the access road (annual) (Alts B, C, D)	USFS (2004)
1	accident expected over the 10-year life of the project	USFS (2004)
<0.04%	annual chance of a diesel spill for Alts B, C, D	USFS (2004)
<0.4%	chance of a diesel spill over the 10-year life of the project (Alts B, C, D)	USFS (2004)
5.5	mile Jualin Road from the Slate Cove Marine Terminal to the Jualin area	USFS (2021)
34 to 37	round trips per day using tractor-trailer trucks estimated in the 2004 SEIS	USFS (2021)
21-24	round trips per day using tractor-trailer trucks current road traffic	USFS (2021)
0.7	mile road from the filter plant to the filtered tailings facility	USFS (2021)
37	trucks/day would haul tailings	USFS (2021)
25	ore concentrate trucks/day estimated in the 2004 SEIS	USFS (2021)
12	ore concentrate trucks/day currently	USFS (2021)

Table 4.1. (Continued.)

Value	Description	Reference
	Waste rock, tailings, and wastewater	
400	tons of waste rock per day	USFS (2004)
4.5 million	tons of tailings at an underwater TSF within Lower Slate Lake	USFS (2004)
20 million	tons of tailings in the dry tailings facility	USFS (2004)
from 23 to 56	acres of increase in the size of Lower Slate Lake to accommodate the tailings storage	USFS (2004)
40%	tailings will be backfilled into underground workings	USFS (2004)
31.5	acre site for permanent waste rock disposal facility near the Kensington 850-foot portal	USFS (2004)
7.5 million	tons of tailings over the life of the mine	USFS (2004)
4.5 million	tons tailings would be disposed of in the TSF	USFS (2004)
3 million	tons tailings would be backfilled	USFS (2004)
4 million	tons (additional) tailings under the POA	EPA (2021)
5 million	tons (additional) waste rock storage	EPA (2021)
88	foot high TFF dam currently	EPA (2021)
36	foot extension to TTF dam proposed under the POA	EPA (2021)
4.0 million	ton storage capacity at the filtered tailings facility	USFS (2021)

Production and process

As described in the 2004 EIS, production at Kensington Mine was estimated at 2,000 tons of ore per day (730,000 tons per year) under Alternative D, with 7,500,000 tons of tailings produced during the 10-year life of the project (USFS 2004). Forty percent of the tailings were slated for disposal in the mine backfill, with the remaining 60% placed in a tailings storage facility. The ore would be processed into ore concentrate at a rate that produces an average of 700 tons of ore concentrate per week (36,400 tons per year). The amended plan of operation requests that Kensington's ore production rate be increased to 3,000 tons per day (1,095,000 tons per year) for an additional 10 years (USFS 2021).

Kensington's processing facility is "a conventional milling gold froth flotation recovery circuit. The major components include crushing, grinding, gravity separation, flotation, thickening, and filtering" (USFS 2021). The steps were described in more detail in the 2004 EIS (USFS 2004). Extracts describing the process under Alternative D are shown below:

USFS (2004), pp. 2-21, 22

> Processing steps include crushing, grinding, flotation, thickening, and filtration. …all steps would be done in buildings. …
>
> The mill would be located at the Jualin process area…. The material would then be sent through the primary crusher, which would reduce the size of the ore to less than 6 inches. The crushed ore would then be hauled by truck to the coarse ore stockpile Jualin side … of the operation. There, the ore would be fed into a hopper with a vibrating feeder and then onto a belt that would discharge into a semiautogenous grinding (SAG) mill.

USFS (2004), p. 2-22

> The SAG mill would be set up in a closed circuit with a horizontal vibrating screen and a ball mill. Oversized material would be fed back into the SAG mill, while undersized material (minus 100 mesh) would be directed to hydrocyclones. Hydrocyclones use centrifugal force to separate coarse material from fine material. The heavy material (underflow) from the cyclones would be directed to a gravity concentrator used to recover coarse gold. Lighter materials from the cyclones would be fed back to the cyclone circuits, eventually overflowing from the cyclones to a conditioning tank feeding the flotation circuit.
>
> The flotation process would involve separating the gold from the barren material in a froth flotation. A slurry would be fed from the cyclones to the conditioning tank, where conditioners (e.g., potassium amyl xanthate) and frothing agents would be added. These materials would cause the sulfide and telluride minerals (both gold-bearing) in the slurry to attach to air bubbles once air was pumped through the system. The bubbles containing the mineralized portion of the slurry, including the gold, would form a froth on top of the flotation tank. The gold-bearing froth would then be skimmed off and collected. This "concentrate" would flow through additional flotation tanks to further concentrate the gold. The flotation process would separate approximately 93 to 96 percent of the non-gold material from the ore fed into the

> system, leaving … 80 to 140 tons …of flotation concentrate per day. Most of the chemicals added to the system would stay in the flotation tanks or be removed with the flotation concentrate as opposed to being discharged with the tailings. Most of the metals associated with the ore body would be removed from the system with the gold concentrate.

USFS (2004), p. 2-25

> Before the slurry left the mill, a polymer and flocculant would be added to agglomerate the small particles and enhance settling once the tailings were deposited into the TSF. …The tailings slurry would be discharged into the TSF through perforations in a portion of the tailings delivery pipeline submerged in the TSF.

Characterization of transportation corridor

As described in the 2004 EIS, Kensington Mine's infrastructure includes a tunnel between Kensington Mine and Jualin Mine, roads, a tailings pipeline, and marine transportation (USFS 2004).

Tunnel

A 12,000-foot tunnel connects Kensington Mine to Jualin Mine and is the primary access for workers and materials into the mine, as well as ore haulage between the mine and mill (USFS 2004). The Jualin tunnel is large enough to accommodate 40-ton haul trucks.

Roads

There are two roads from the coast to mine facilities: the 5.5-mile Jualin Road from the Slate Cove Marine Terminal and the 1.8-mile Comet Beach Road which connects Comet Beach to the Comet Portal (USFS 2021). The Jualin Road was initially expected to have 34-37 daily roundtrip tractor-trailer truckloads, but current traffic is usually between 21-24 roundtrips per day (USFS 2021). The Jualin Road has two bridges crossing Johnson Creek, and the Comet Beach Road crosses Sherman Creek twice (USFS 2021). The tailings treatment facility access road has single-lane access from the Jualin Road to the tailings treatment facility area; it is approximately 2.1 miles long, with an additional 0.7 miles to be constructed to haul tailings from the filter plant to the filtered tailings facility (USFS 2021). There is also a 3.5-mile long Tailings Pipeline Access Road (USFS 2021).

Pipeline

There is a 3.5-mile line buried tailings pipeline from the mill near the Jualin Mine portal to the tailings storage facility at Lower Slate Lake (USFS 2004).

Marine transport of supplies and products

Kensington Mine uses barges to transport ore concentrate from the mine and to deliver reagents and other supplies USFS (2004, 2021). The export of ore concentrate from the mine was described in the 2004 EIS (USFS 2004)

> The concentrate would be shipped by barge approximately four to five times per month from the Slate Creek Cove marine terminal to an off-site gold recovery processing facility.

This is consistent with the anticipated load frequency under the amended Plan of Operations, which anticipates ore concentrate being transported from Slate Cove Marina to Juneau or Seattle roughly once per week, although the language in USFS (2021) regarding the previous transportation estimate is confusing:

> The 2004 SEIS estimated 4 concentrate shipments out of the terminal per week; however, the current number of concentrate shipments is approximately 1 per week. Transportation to and from the mine is by boat from the Yankee Cove ferry landing to the Berners Bay terminal or from Echo Cove when Yankee Cove is not available due to weather … Barges are used to transport concentrate, and for the delivery of supplies, goods, and material weekly.

List of hazardous materials to be transported

Ore concentrate

Under the 2,000 ton per day ore production rate, there would 25 round trips per day of tractor-trailer trucks carrying 20 tons of ore concentrate (USFS 2004). The ore concentrate would then be shipped on barges four or five times each month to an off-site gold recovery processing facility (USFS 2004).

The number of concentrate containers was not specified in the 2021 FEIS when the ore production rate is expected to increase to 3,000 tons per day (USFS 2021). The number of truck-trips on the road was not expected to increase above the amount of transportation impacts analyzed previously because "[c]urrently, approximately 12 loads of concentrate are transported per day from the mill to the port laydown facility with a tractor-trailer truck" (USFS 2021). If the ore concentrate production scales at the same rate with ore production for the ore produced in the next 10 years as it has to date, it would be expected that there would be 18 truck trips per day bringing ore concentrate to the marine terminal, which is less than the 25 per day considered in the earlier EIS.

Reagents and blasting materials

The original EIS projected that "[a]pproximately four barges per week would transport supplies, fuel, and concentrate to and from the project" (USFS 2004), an estimate that has dropped to an average of one barge per week for equipment transport (USFS 2021). The initial list of chemicals and reagents that were slated to be delivered from Seattle, Washington to Slate Creek Cove are presented in Table 4.2 along with an estimate of the reagents that would be needed based on a more recent estimate of the daily ore production rate. Only two reagents' properties were listed in the initial EIS (USFS 2004) and are reproduced in full here:

> Sodium hydroxide: A common laboratory reagent that is strongly alkaline when in solution with water.

> Xanthates: A class of chemicals known as "collector" chemicals that attach to floating minerals, making them normally incapable of adhering to the froth in a flotation circuit.

(See Appendix A for extracts from safety data sheets for the chemicals listed for and spilled at the mine.) The amount of blasting agents to be used was not specified. Therefore, I will use an estimate of 0.4 tons of ammonium nitrate per year for each ton of ore produced per day. Under Alternative D, with 2,000 tons of ore produced per day, that would be 800 tons of ammonium nitrate per year and under the POA, with 3,000 tons of ore produced per day, that would 1,200 tons of ammonium nitrate per year.

Table 4.2. Modification of "Table 2-4: Chemical and Material Use Approximate Daily Use (tons)" from USFS (2004). Shaded cells were not part of the original.

	Alternative A		Alternatives A1, B, C, and D		2020 POA (USFS 2021)	
Ore production rate	4,000 tons per day		2,000 tons per day		3,000 tons per day	
Milling Process Reagent or Material (shipping and storage container)						
	Use (tons)		Use (tons)		Use (tons) (estimated)	
	Daily	Annually	Daily	Annually	Daily	Annually
Grinding Steel balls (10-ton steel bins)						
	5–6	*1,825-2,190*	*4–5*	*1,460-1,825*	*5*	*1,825*
Potassium amyl xanthate (50-gallon drum)						
	1	*365*	*0.5*	*182.5*	*0.75*	*273.75*
MIBC (frother) (50-gallon drum)						
	0.4	*146*	*0.2*	*73*	*0.3*	*109.5*
Flocculant (1-ton Flo-bin)						
	0.2	*73*	*0.1*	*36.5*	*0.15*	*54.75*
Polymer (50-gallon drum)						
	0.02	*7.3*	*0.01*	*3.65*	*0.015*	*5.48*
Surfactant (50-gallon drum)						
	0.04	*14.6*	*0.02*	*7.3*	*0.03*	*11.0*
Flotation Scale inhibitor (50-gallon drum)						
	0.1	*36.5*	*0.05*	*18.3*	*0.075*	*27.4*
Lime (1,000-lb bags)*						
	2	730	1	365	1.5	547.5
Total	8.76-9.76	3,197.4-3,562.4	5.88-6.88	2,146.25-2,511.25	7.82	2,854.38

* Lime is also used in concentrate thickening.

Fuel

Estimates of annual fuel use varied by Alternative and within the 2004 FSEIS (USFS 2004). Alternative A was described as requiring 6.5 million gallons of diesel each year when the production rate was expected to be 4,000 tons per day. Alternative A1, with a production rate of 2,000 tons per day, was expected to use "proportionally less fuel than Alternative A although storage requirements would remain the same." Alternatives B and C each were expected to need 3.0 million gallons each year, and Alternative D would use 3.2 million gallons annually, with the additional 200,000 gallons each year used for the reverse osmosis treatment system (USFS 2004, p. 2-36). Later in the FSEIS (USFS 2004, p. 4-136), Alternatives B and C were described as needing 3.4 million gallons of diesel annually and Alternative as using 3.5 million gallons of diesel each year.

USFS (2004), p. 2-36

> One 300,000- gallon tank would be located at Comet Beach and a second in the laydown area. Two additional 300,000-gallon tanks would be located near the generators in the process area. Two 20,000-gallon tanks would be located near the Kensington portal. A 5,000-gallon fuel truck would transport fuel\ from the laydown area to the process area. The tank in the laydown area would be filled through a pipeline from the tank at Comet Beach. A 5,000-gallon tank of aviation fuel for helicopter use would be located at Comet Beach within the secondary containment provided for the 300,000-gallon tank. Barges would deliver diesel fuel to the site. Transfers would be conducted using a shore-based platform raft that would include spill control materials and secondary containment. Hoses would connect the barge to the raft and then to the 300,000-gallon tank at Comet Beach. Alternative A1 would use proportionally less fuel than Alternative A although storage requirements would remain the same.
>
> …
>
> Under Alternatives B, C, and D, diesel fuel would be delivered to the site in 6,500-gallon isotainers, off-loaded from the barge, and initially stored in the laydown area near the Slate Creek Cove marine terminal. The isotainers would be moved by truck to the power plant and fueling areas where they would be connected to pipe headers, such that they would function as storage tanks. Consequently, there would be no diesel fuel tanks. All isotainers would be stored in HDPE-lined and bermed storage areas at the Slate Creek Cove laydown area, the power plant, and the mine portal on the Jualin side. The Slate Creek Cove laydown area would have the capacity to store up to 16 isotainers; at the power plant near the process area, up to 4 isotainers could be stored and used at any time; and at the mine portal, 2 isotainers could be stored and used at any time. All fuel transfers would take place within lined, bermed areas. Aviation fuel would also be delivered to the site in 6,500-gallon isotainers. Approximately 6,500 gallons of aviation fuel would be stored on-site at any time. Gasoline would be brought to the site in 55-gallon drums or isotainers.
>
> The crew shuttle boat would be fueled at Cascade Point under Alternatives B and D and at Echo Cove under Alternative C. A fuel truck would meet the crew shuttle approximately once a week and be parked within a contained area during the fueling operation. Under Alternatives B and D, CBJ's Allowable Use Permit would place restrictions on fueling, including surrounding

> the crew shuttle with a boom during fueling operations between April 15 and June 15 each year. An additional stipulation would require fueling to take place at a U.S. Coast Guard-approved facility outside Berners Bay between April 15 and May 15 each year when herring are observed within 250 meters of the marine terminal. The BMPs described in Appendix E would be employed to reduce the likelihood of spills or leaks associated with fueling.

USFS (2004), p. 4-136

> Annual fuel consumption is estimated at 3.4 million gallons for Alternatives B and C and 3.5 million gallons for Alternative D. Approximately nine isotainers would be delivered to the Slate Creek Cove marine terminal weekly (Earthworks, 2003a). The isotainers would be unloaded like other cargo and would be stored in lined and bermed laydown areas at Slate Creek Cove, the mine portal, and the process area. Flatbed trucks would deliver the isotainers to the mine portal area and process area. The isotainers would be connected to pipe headers, such that they would become the storage tanks feeding the power plant and fueling islands throughout the mine. An advantage provided by the proposed Slate Creek Cove site is that barge traffic could be scheduled with greater regularity, allowing the project to reduce the required on-site storage quantities of expendable substances, including fuel. In addition to diesel fuel, approximately 6,500 gallons of aviation fuel (in isotainers) and a maximum of 5,000 gallons of gasoline (in isotainers or 55-gallon drums) would be stored at the Jualin Mine site. Secondary containment would also be provided for these fuels.

Filtered tailings

In addition to ore concentrate, reagents, fuel, and blasting agents being hauled by truck, Kensington Mine would also transport filtered tailings over a short length of road. According to the amended plan of operations "filtered tailings would be hauled by truck from the filter plant to the Filtered Tailings Facility. This would require constructing 0.7 miles of road suitable for haul trucks, potentially double wide with appropriate geotechnical foundation to support haul trucks. …. An estimated 37 trucks per day would haul tailings" (USFS 2021, p. 2-41).

Load size, method, and frequency

Load sizes were specified for diesel (6,500 gallons in Alternative D) and flotation concentrate (20 tons per container) (USFS 2004). I estimated a load size of 20 tons for the remaining materials. Based on the annual quantities that would be used and the load sizes, the number of annual loads can be estimated for Alternative D (Table 4.3) and the POA scenario with an increases ore production rate and trucking the filtered tailings (Table 4.4). Under Alternative D, there were a predicted 5,350 vehicle trips on the access road annually (USFS 2004), of which I estimated that 2,472 would be of hazardous materials (Table 4.3). If the supply trips below are roughly accurate (Table 4.3), then the trips with hazardous materials represented 46.2% of the mine traffic annually, which is similar to the percentage seen at Pogo Mine. If the POA with 37 daily trips trucking filtered tailings goes into effect with the same load sizes, then more than 17,200 trips per year (47 trips per day) would be hauling hazardous materials (Table 4.4). The proportion of hazardous material transportation trips will be a larger fraction, but the total vehicular traffic under the POA scenario was not shown and the transportation would be split along the access road from the port to the mine and the road to the filtered tailings facility. Because the POA scenario also includes an increase in production rate, it might have a concomitant increase in personnel and non-hazardous materials, but they were not shown in the FSEIS (USFS 2021).

Table 4.3. Loads per year of hazardous materials for Alternative D. "Reagents and other materials" includes the supplies listed in Table but not ammonium nitrate, which was estimated separately.

	Quantity per year	Quantity per load	Loads per year
Flotation concentrate	36,500 tons	20 tons	1,825
Reagents and other materials	2,300 tons	20 tons	115
Diesel	3.2 million gallons	6,500 gallons	492
Ammonium nitrate	800 tons	20 tons	40
Total			2,472

Table 4.4. Loads per year of hazardous materials for the POA (USFS 2021), when ore production is expected to increase from 2,000 tons per day to 3,000 tons per day, and filtered tailings may be trucked to the tailings facility.

	Quantity per year	Quantity per load	Loads per year
Flotation concentrate	54,750 tons	20 tons	2,738
Reagents and other materials	3,450 tons	20 tons	172
Diesel	4.8 million gallons	6,500 gallons	738
Ammonium nitrate	1,200 tons	20 tons	60
Filtered tailings	270,100 tons	20 tons	13,505
Total			17,213

The frequency of barge loads bringing supplies through the Slate Cove Marine Terminal was estimated, but the total contents and compositions of the loads were not addressed:

USFS (2004), pp. 2-36, 37

> Overall, the barge traffic would have a minor effect on Lynn Canal. In Berners Bay, however, the barge traffic (three to four trips per week) and crew shuttle traffic (four round trips per day) represent traffic that was not present before.

Spill risks discussed and calculated in the permitting documents

Kensington Mine's EIS contained discussions about the potential impacts of spills on many aspects of the environment, including groundwater, surface water, the marine environment, marine mammals, and fish for each Alternative considered (USFS 2004). The comments that were specific to Alternative D are reproduced in Table 4.5. Some issues were described more than once with slightly different language in different parts of the EIS, with both shown here. In addition, Kensington Mine's EIS specifically calculated the number of vehicle trips for that might result in accidents, injuries, fatalities, or fuel spills. The fuel spill risks for all Alternatives were based on the Harwood and Russell (1990) spill rate per mile. The risks were estimated both for a single year and over the life of the project (Table 4.6). Kensington's EIS also included quantitative risks associated with the tailings slurry pipeline, although no rate per mile (or other exposure variable) was stated (Table 4.7).

Spill risks in the mill site were presumed to be of minimal concern environmentally:

> Within the mill, the concrete floor would be sloped to sumps so that any spillage could be recovered and returned to the processing circuit. Required processing reagents would be prepared and stored in the building. Therefore, any spillage of reagents in the mill building would likely be very small and easily recovered by the sumps. (USFS 2004)

Table 4.5. Potential impacts from spills relevant to Alternative D of the Kensington Mine EIS (USFS 2004).

Resource	Potential Spill Impact
Barge traffic	Deliveries to Comet Beach early in construction phase, after which deliveries to Slate Creek Cove. Up to seven barges weekly during construction and three or four during operations.
Employee Transportation	Three to five crew shuttle trips daily between Slate Creek Cove and Cascade Point.
Vehicle trips/ accident risk	5,350 vehicle trips on access road annually; accident probability 9 percent per year.
Fuel release due to accident	Risk of spill less than 0.04 percent per year; typically would be significantly less than 6,500 gallons.
Surface water quality: spills	Portions of access road parallel Johnson Creek. Low potential for spills of concentrate and supplies. Isotainers further reduce risk of diesel spills compared to Alternative A.
Surface water quality	Portions of access road parallel Johnson Creek. Potential for spills of concentrate and supplies. Isotainers reduce risk of diesel spill compared to Alternative A.
Water quality	Leaks from the crew shuttle boat and barges more likely at Slate Creek Cove than large-scale spills because of the use of isotainers. At Cascade Point, the possibility of fueling-related spills, plus leakage from the crew shuttle boat, exists. Could range from drops to tens of gallons. Potential increase in low levels of hydrocarbons in the water column at Slate Creek Cove and more so at Cascade Point.
Aquatic resources: marine water quality	Leaks from the crew shuttle boat and barges more likely at Slate Creek Cove than large-scale spills because of use of isotainers. At Cascade Point, the possibility of fueling-related spills exists, as well as leakage from the crew shuttle boat. Potential increase in low levels of hydrocarbons in the water column at Slate Creek Cove and Cascade Point minimized by the use of BMPs.
Aquatic resources: Nearshore marine organisms	Contaminants spilled at Cascade Point would dissipate quickly due to wave action and flushing. Likelihood of a spill would be small. Diesel spills in Slate Creek Cove unlikely due to the use of isotainers. Spills of process chemicals could have short-term acute effects in vicinity of spill

Table 4.5. (Continued.)

Resource	Potential Spill Impact
Nearshore Marine organisms	Contaminants spilled at Cascade Point and, to a lesser extent, Slate Creek Cove would dissipate quickly due to wave action and flushing. Potential short-term impacts on nearshore organisms at Slate Creek Cove if materials were spilled during loading/ unloading operations.
Aquatic resources: marine organisms	Temporary displacement during dredging at Cascade Point and permanent loss in above-MLLW portion of Cascade Point breakwater. Risk of acute and chronic exposure of nearshore benthic organisms to hydrocarbon toxicity from fueling and spills.
Aquatic resources: marine mammals	Leaks from crew shuttle or barges unlikely to affect marine mammals. Catastrophic spill, although highly unlikely, could affect sea lions, seals, and whales, depending on timing.
Fish	Potential for chronic exposure to hydrocarbons from vessel leaks at Cascade Point and Slate Creek Cove. A fuel spill at Cascade Point could contaminate herring spawn at Cascade Point, minimized by prohibition on fueling during herring spawning period.
Aquatic resources: Fish	Very low potential for acute or chronic exposure of sensitive life history stages to hydrocarbons from vessel leaks at Cascade Point and Slate Creek Cove, further minimized by using BMPs. Fueling operations expected to be prohibited at Cascade Point from herring spawning through egg hatching.
Aquatic resources: Commercial fisheries	Indirect impacts based on effects on larval/juvenile commercial species or prey species (herring/eulachon).
Commercial fisheries	Indirect impacts based on effects on larval/juvenile commercial species or prey species (herring/eulachon). Petroleum spill could affect commercial troll, gill net, and other limited fisheries within Berners Bay in similar manner as Alternative A. (Alt A impacts: A spill occurring during a fishing opening could result in at least the perception of a contaminated catch. Potential impacts on juvenile pink salmon near shoreline.)

Table 4.6. Estimated risks for diesel spills from trucks for the different Kensington Mine Alternatives (USFS 2004).

Alter-native	Load size (gal)	Loads/year	Length (mi)	Risk (spills/mi)	Years of exposure	Risk (%): per year, for the project life
A	5,000	6,500,000 gal/ 5,000 gal/load = 1,300	1.5	1.87×10^{-7}	1 14	0.036%, 0.5%
A1	5,000	"proportionally less fuel than Alternative A"	1.5	1.87×10^{-7}	1 10	0.013%, 0.13%
B-C	6,500	3,000,000 gal/ 6,500 gal/load = 462	5	1.87×10^{-7}	1 10	<0.043%, <0.43%
D	6,500	3,200,000 gal/ 6,500 gal/load = 492	5	1.87×10^{-7}	1 10	<0.046%, <0.46%

Table 4.7. Pipeline risks for tailings slurry spills (USFS 2004).

Alternative	Length (mi)	Risk per mi	Years of exposure	Risk (%)
A	1.5	not shown	1	0.14%
			14	2.0%
A1	1.5	not shown	1	0.13%
			10	1.3%
B-D	3.5	not shown	1	0.3%
			10	3%

EPA responses to the Kensington Plan of Operations Amendment 1 DSEIS

The EPA (2021) listed nine key concerns and nine other recommendations related to mine facilities and operations in response to the Kensington Mine Plan of Operations Amendment 1 DSEIS (USFS 2020a). Specifically, the EPA (2021) recommended that the FSEIS:

- Provide an adequate level of project detail and NEPA analysis for the Proposed Action and Action Alternatives in order to evaluate and compare alternatives and their consequences;
- Disclose changes to water quality in Ophir Creek, Sherman Creek, and East Fork Slate Creek due to mining activities and include mitigation to avoid and reduce water quality impacts.
- Include a section that meaningfully evaluates impacts to groundwater.
- Avoid and minimize impacts to water quality and wetlands at the Comet WRS Facility and the proposed expansion by evaluating other options or mitigation measures, such as disposal of the sludge from the Comet WTPs with the paste backfill underground (instead of in the unlined WRS facility) and/or improved seepage collection measures.
- Defer the decision regarding the TTF tailings cap at closure until further monitoring and testing are conducted closer to the end of the active life of the TTF.
- Remove the addition of dilution water (from the Slate Creek clean water diversion) to the TTF water treatment plant or demonstrate how this practice complies with the Clean Water Act.
- Avoid or minimize graphitic phyllite excavation or disturbance until appropriate treatments are confirmed to minimize acid rock drainage/metal leaching to surface and groundwater.
- Provide wetlands compensatory mitigation concurrent or prior to construction activities to offset spatial and temporal losses and cumulative impacts to wetlands and their functions rather than delaying mitigation until post-closure of the mine.
- Identify the Environmentally Preferable Alternative based on criteria that address the significant issues of tailings dam geotechnical stability and protection of surface water and aquatic resources. EPA recommends that the environmentally preferable alternative includes components of the Filtered Tailings Facility Alternative and the Reduced Water at Closure Alternative since, compared to the Proposed Action and other alternatives, this combination alternative would best comply with best available technology for tailings facilities, have the lowest geotechnical risk, release the lowest volume of tailings and process water in the event of a TTF dam failure, and would have the least adverse impacts on wetlands and aquatic resources.

and that the FSEIS should:

(1) Provide a map or schematic depicting the cross-section of the underground mine workings, such as the tunnels, shafts, portals, adits, ore bodies, paste backfill areas, etc. for the Kensington, Jualin, and Comet ore bodies;

(2) Identify the locations and additional capacity for paste backfill material placement in the underground workings;

(3) Describe potential impacts of expanded mining activities on the historic, current, and proposed underground mine workings, such as potential for instability, caving, and subsidence of underground workings on surface resources and proposed project facilities and activities;

(4) Identify the depth of the groundwater table and discuss the need to pump, treat, test, and monitor the groundwater, and evaluate potential impacts to groundwater during operations and closure;

(5) Evaluate the geotechnical/seismic stability analysis conducted for the underground mine workings, and the potential for subsidence and risks to worker safety;

(6) Identify and discuss past accidents, incidents, spills, and/or releases occurring in the underground workings;

(7) Discuss any emergency response planning efforts to address potential geotechnical and seismic failures and safety hazards associated with the underground mine workings;

(8) Identify mitigation measures to minimize the risk of potential failures, caving, and/or subsidence associated with the underground mine workings; and

(9) Discuss how the underground mine workings would be reclaimed at closure, and any planned post-closure, long-term monitoring of groundwater and stability.

The EPA also raised concerns regarding the new treated tailings facility identified in the Proposed Action, asked for a summary of the major recent tailings dams failures and the lessons to be learned from them, and requested a more thorough evaluation of the impacts on Berners Bay, a full description of the marine traffic in Slate Cove Marine Terminal and the potential for impacts on marine mammals, and an explanation of exceedances of effluent limits with a summary of baseline water quality for the treated tailing facility pond and seepage water quality (EPA 2021).

Example quantitative spill probabilities and expected numbers of spills

I estimated the number of truckloads per year for flotation concentrate, diesel, ammonium nitrate, and reagents and other materials for two different daily processing rates at Kensington Mine (Table 4.3 and 4.4). I also found the number of annual trips per year for filtered tailings under the amended plan of operations (Table 4.4). Based on the number of loads per year, the miles per load, and the years for the two different production scenarios, I calculated the risk of truck accident spills at Kensington Mine (Table 4.8). The $N = RT$ model estimate is that from 2006-2020, there was a 3.4% chance of a spill from a trucking accident, and that there is a 5.1% chance of a trucking accident spill in the next 10 years.

Table 4.8. The expected number for spills for Alternative D and the POA with trucked filtered tailings can be calculated on an annual basis, for the lengths of the respective project time periods, and for their combined project life.

Scenario	Alternative D	POA	Alt D and POA
Material	Trips per year	Trips per year	
Flotation concentrate	1,825	2,738	
Reagents and other materials	115	172	
Diesel	492	738	
Ammonium nitrate	40	60	
Total trips per year	2,472	3,708	
Road length (miles)	5	5	
Miles traveled per year	12,360	18,540	
Material	Trips per year	Trips per year	
Filtered tailings		13,505	
Road length (miles)		0.7	
Miles traveled per year		9,453.5	
Miles traveled per year (total)	12,360	27,993.5	
Spill rate per mile (Harwood and Russell 1990)	0.000000187	0.000000187	
$E(N) = RT$ (one year)	0.0023	0.0052	
Years of project	2006-2020: 15 years inclusively	10	
Miles traveled over the project life (total)	185,400	279,935	465,335
$E(N) = RT$	0.0347	0.0523	0.087
$P(\geq 1$ spill over the project life) (%)	3.41%	5.10%	8.3%

Reported spills from annual reports and the 2021 FSEIS

An example spill log from the 2005 Kensington annual report (Coeur Alaska 2006) reported eight hydrocarbon spills (Table 4.9) and was accompanied the following text:

> During 2005, all other project activities were in full compliance with authorizing permits and plans. One component of these plans is the reporting of hydrocarbon spills. Spills that occurred during 2005 were all very small, yet each release was taken very seriously and all site resources were brought to bear on clean-up – as appropriate – one each occurrence. A total of eight incidents were reportable during 2005 (Table 2-3).

I found the analogous text and tables in annual reports dating through 2020. Although the language about spill reporting specified hydrocarbon spills in 2005-2007, the spill reports broadened to other substances starting in 2008. In comparing the spills listed in the annual reports and the ADEC database from 2005-2019, it is evident that there are mismatches in the listings (Table 4.10). Neither record is complete. Many of the non-hydrocarbon spills listed in the annual reports were grey water and/or sewage and were not included in the ADEC (2021) listing of spill incidents (Table 4.11). Two annual reports from Kensington (those for 2006 and 2020) did not include a table with the spills even though tables were referred to in the text. There were 63 spills listed in the annual reports that were not in ADEC (2021), with 28 of them sewage/grey water spills, and 77 spills listed in ADEC (2021) that had no details in the annual reports (56 of them from 2006 and 2020) (Table 4.10 and Table 4.11).

The amended Plan of Operations FSEIS characterized Kensington Mine's spill record through 2017 (USFS 2021):

> The ADEC spills database was reviewed for a required environmental audit in 2017 (HDR, Inc., 2018a) listed chemical and fuel spills which occurred through 2017. … The majority of spills were small in volume, generally ranging from 2 to 35 gallons from mobile vehicles where secondary containment was not feasible. The largest spill noted prior to the environmental audit in 2017 was 600 gallons of diesel fuel.

This description did not fully utilize the data available from ADEC (2021) and failed to mention the largest recorded spill at Kensington Mine, an 800-gallon release of process water in August 2018 due to a coupler failing in Slurry Pond 1. (See *Spill Record from ADEC*.)

Table 4.9. Reproduction of "Table 2-3 2005 Spill History" from Coeur Alaska, Inc. (2006). Shaded rows are spills not listed in ADEC (2021) for that year.

Date	Description	Quantity	Units	Hydrocarbon
12/13/2005	Camp generator injector break	<1	gallon	diesel
11/5/2005	Hose slipped off pump while pumping used oil from 850 generator	1	gallon	used oil
9/29/2005	Slate Creek drill rig hydraulic hose break	3	gallon	hydraulic oil
9/28/2005	Skid mounted core drill dropped while offloading in Slate Creek Cove, puncturing fuel tank.	2.5	gallon	diesel
9/28/2005	Skid mounted core drill dropped while offloading in Slate Creek Cove, puncturing fuel tank. (Same incident as above)	1	gallon	hydraulic oil
9/11/2005	Forklift dropped generator into Slate Creek Cove on unloading from landing lift	2	gallon	diesel
9/10/2005	Veco contractor – unspecified	<1	gallon	diesel
8/24/2005	Aviation fuel bladder leaked on offloading at Comet Beach	2-3	ounces	aviation fuel
8/20/2005	Severed transmission cooler line	4-5	quarts	transmission oil

Table 4.10. Summary from Kensington Spill logs and comparison to ADEC (2021) records from that year. Details of the spills listed in one source but not the other are given in Table 4.11.

Year	Number of spills in Coeur Alaska annual reports for Kensington Mine			Spills in ADEC but not in the annual report for that year	Number in ADEC records	Spills in the annual report but not in ADEC for that year	Total spills
	Hydro-carbon	Non-hydro-carbon	Total				
2005	9	-	9	0	3	6	9
2006	12*	-	0	8	8	0	≥8 or 12
2007	24	-	24	3	18	9	27
2008	14	6	20	1	8	13	21
2009	5	4	9	0	6	3	9
2010	10	10	20	2	12	10	22
2011	11	1	12	2	11	3	14
2012	16	2	18	1	19	1	19 or 20
2013	7	2	9	2	11	0	11
2014	15	2	17	0	16	1	17
2015	16	5	21	2	20	3	23
2016	23	4	27	0	23	4	27
2017	20	7	27	4	27	4	31
2018	15	4	19	3	20	2	22
2019	29	8	37	1	34	4	38
2020	-	-	0	48	48	-	≥48
Total	226	55	269	77	284	63	346

* In the text but not in a table for that year, so spill listing could not be compared to incidents listed in ADEC (2021).

Table 4.11. Spill listing discrepancies from Coeur Alaska annual report and ADEC spill listings for Kensington Mine from 2005-2020. Five spills marked with asterisks indicate that ADEC may have duplicate spill listings.

Year	Date	Description/location	Quantity	Unit	Substance
2005	Spills in Coeur Alaska annual report but not in ADEC				
	12/13/2005	Camp generator injector break	<1	gallon	Diesel
	11/5/2005	Hose slipped off pump while pumping used oil from 850 generator	1	gallon	Used oil
	9/29/2005	Slate Creek drill rig hydraulic hose break	3	gallon	Hydraulic oil
	9/28/2005	Skid mounted core drill dropped while offloading in Slate Creek Cove, puncturing fuel tank.	2.5	gallon	Diesel
	9/11/2005	Forklift dropped generator into Slate Creek Cove on unloading from landing lift	2	gallon	Diesel
	8/20/2005	Severed transmission cooler line	4-5	quarts	Transmission oil
2006	Spills in ADEC but not in Coeur Alaska annual report (Table 3 was missing from Coeur Alaska 2007)				
	3/20/2006	Kensington hydraulic 20Mar06	1	gallons	Hydraulic oil
	5/1/2006	Kensington Mine vehicle fuel tank	40	gallons	Diesel
	5/25/2006	Kensington Mine monthly report	1	gallons	Diesel
	6/26/2006	Kensington monthly report	2	gallons	Hydraulic oil
	8/17/2006	Kensington/Comet Frontend loader	20	gallons	Diesel
	11/5/2006	Kensington Mine, Jualin mill site	5	gallons	Diesel
	11/22/2006	Kensington Mill Pad forklift	5	gallons	Hydraulic oil
	12/12/2006	Kensington - Jualin Generator	5	gallons	Diesel
2007	Spills in Coeur Alaska annual report but not in ADEC				
	2/05/2007	Comet Beach Shop fuel tank	<1	gallon	Diesel fuel
	6/13/2007	Comet – Development rock pile	<1	quart	Hydraulic oil
	6/13/2007	Jualin – AIC office area	<0.5	gallon	Diesel fuel
	7/10/2007	Comet – Ophir Creek to Sherman Creek below outfall area	<5	yd^3	Sediment release
	7/11/2007	Jualin – 30,000 gal. fuel tank on mill bench	<1	cup	Diesel fuel
	7/13/2007	Jualin – east side of mill at eastern most edge of road	6	ounces	Motor oil

Table 4.11. (Continued.)

Year	Date	Description/location	Quantity	Unit	Substance
2007	Spills in Coeur Alaska annual report but not in ADEC (cont'd.)				
	7/13/2007	Jualin – 30,000 gal. fuel tank on mill bench	<1	ounce	Diesel fuel
	7/26/2007	Milling building, inside east door	2	ounces	Hydraulic fluid
	9/21/2007	Comet Maintenance Shop	~1	cup	Diesel
	Spills in ADEC but not in Coeur Alaska annual report				
*	4/20/2007	Day tank Comet, Kensington Mine	30	gallons	Diesel
*	7/6/2021	Kensington Hydraulic spill	4	gallons	Hydraulic oil
	11/24/2007	Kensington used oil tank, Comet	100	gallons	Diesel
2008	Spills in Coeur Alaska annual report but not in ADEC				
	3/6/2008	Slate Lake seep project road	1	quart	Diesel fuel
	3/11/2008	Portal Hill Road near warehouse	4.5	gallons	Hydraulic oil
	3/13/2008	Underground – 850 main haulage	5.5	gallons	Hydraulic oil
	4/8/2008	kitchen lift station	2	gallons	Sewage
	4/13/2008	Jualin Heights pad	0.5	pints	Engine oil
	5/1/2008	Underground – 780 vent drift	3	gallons	Hydraulic oil
	5/3/2008	Helipad	0.5	gallons	Engine oil
	5/4/2008	Main road, mile 2	0.5	quarts	Hydraulic oil
	5/22/2008	mill shop	1.5	quarts	Brake fluid
	5/24/2008	850 drift	4	gallons	Hydraulic oil
	6/11/2008	wash car lift station	2.5	gallons	Grey water
	6/13/2008	wash car lift station	2.0	gallons	Grey water
	8/13/2008	Jualin STP	75	gallons	Grey water
	Spills in ADEC but not in Coeur Alaska annual report				
	4/16/2008	Coeur Jualin engine oil leak	0.1	Gallons	Engine lube oil

Table 4.11. (Continued.)

Year	Date	Description/location	Quantity	Unit	Substance
2009	Spills in Coeur Alaska annual report but not in ADEC (cont'd.)				
	7/10/2009	Jualin sewer treatment plant	5	gallons	Grey water
	9/19/2009	Jualin sewer treatment plant	5	gallons	Grey water
	9/24/2009	Jualin sewer water lift station	0.5	gallons	Grey water
2010	Spills in Coeur Alaska annual report but not in ADEC				
	2/18/2010	Jualin sewer treatment plant	20	gallons	Grey water
	3/1/2010	Jualin sewer treatment plant	70	gallons	Grey water
	4/17/2010	Slate Cove lay down yard	50	gallons	Grey water
	5/7/2010	Jualin sewer treatment plant	50	gallons	Grey water
	5/17/2010	Slate Cove lay down yard	950	gallons	Grey water
	6/14/2010	Jualin sewer treatment plant	300	gallons	Grey water
	7/12/2010	Jualin sewer treatment plant	10	gallons	Grey water
	7/19/2010	Jualin sewer treatment plant	75	gallons	Grey water
	11/17/2010	Portal Bench	4	gallons	Hydraulic oil
	12/5/2010	Lift station located adjacent to kitchen and dining facility	50	gallons	Grey water
	Spills in ADEC but not in Coeur Alaska annual report				
	8/5/2010	Slate Creek sheen	10	gallons	Diesel
	11/12/2010	Coeur hydraulic oil spill	4	gallons	Hydraulic oil
2011	Spills in Coeur Alaska annual report but not in ADEC				
	8/1/2011	Underground working adjacent to 840 work area	5	gallons	Diesel
	8/1/2011	Port area	150	gallons	Grey water sewage
	11/17/2011	Underground workings	15	gallons	Hydraulic oil

Table 4.11. (Continued.)

Year	Date	Description/location	Quantity	Unit	Substance
2011	Spills in ADEC but not in Coeur Alaska annual report				
	2/2/2011	Kensington Underground Site 990/263N Drift	2	gallons	Hydraulic oil
	4/17/2011	Kensington Mine Diesel Spill	5	gallons	Diesel
2012	Spills in Coeur Alaska annual report but not in ADEC				
	2/7/2012	Upper camp area	5	gallons	Grey water sewage
	Spills in ADEC but not in Coeur Alaska annual report				
	4/14/2012	Kensington Hydraulic Leak	3	gallons	Hydraulic oil
2013	Spill incident on 9/13/2013 spilled 3 substances which are jointly recorded in the annual report and individually in ADEC.				
2014	Spills in Coeur Alaska annual report but not in ADEC				
	3/2/2014	Sewer treatment plant	50	gallons	Grey water
2015	Spills in Coeur Alaska annual report but not in ADEC				
	3/25/2015	Tailings treatment facility	1	quart	Grey water sewage
	5/25/2015	Sewer treatment plant	3	gallons	Grey water
	6/30/2015	Sewer treatment plant	8	gallons	Grey water
	Spills in ADEC but not in Coeur Alaska annual report				
*	10/27/2015	Kensington sodium Hypochlorite spill	9	gallons	Sodium hypochlorite
*	11/25/2015	Kensington Hyd Hose Rock Pick	20	gallons	Hydraulic oil
2016	Spills in Coeur Alaska annual report but not in ADEC				
	2/5/2016	Pit-4 maintenance shop	5	gallons	Grey water
	4/1/2016	Pit-4 maintenance shop	3	gallons	Coolant
	7/2/2016	Underground water treatment plant (480 foot elevation)	2	pints	Coolant

Table 4.11. (Continued.)

Year	Date	Description/location	Quantity	Unit	Substance
2016	Spills in Coeur Alaska annual report but not in ADEC (cont'd.)				
	10/25/2016	Access road between upper and lower camp	40	gallons	Grey water
2017	Spills in Coeur Alaska annual report but not in ADEC				
	1/17/2017	Jualin access road between Spur Road and Port (4 miles)	900	gallons	Grey water
	4/30/82017	Upper camp parking lot	1.5	gallons	Coolant
	7/15/2017	Portal ore pad	5	gallons	Hydraulic oil
	7/19/2017	Jualin heights	4	gallons	Hydraulic oil
	Spills in ADEC but not in Coeur Alaska annual report				
*	4/13/2017	Kensington Mine Mthly (2 of 3)	20	gallons	Hydraulic oil
	10/5/2017	Kensington Mine Portal Pad Leak Hyd Oil	20	gallons	Hydraulic oil
	10/24/2017	Kensington Hose Failure Portal Bench Ore Pad	5	gallons	Hydraulic oil
	11/18/2017	PMS Kensington Mine Tank Overfill	20	gallons	Diesel
2018	Spills in Coeur Alaska annual report but not in ADEC				
	2/24/2018	Sewage treatment plant	5	gallons	Wastewater sewage
	10/31/2018	Waste rock stockpile	15	gallons	Hydraulic oil
	Spills in ADEC but not in Coeur Alaska annual report				
	8/4/2018	Kensington Coupler Failing Slurry Pond 1	800	gallons	Process water
	10/9/2018	Hydraulic Oil spill Kensington Mine JNU	15	gallons	Hydraulic oil
	12/22/2018	KSG Hydraulic Line Leak Pit 2	3	gallons	Hydraulic oil
2019	Spills in Coeur Alaska annual report but not in ADEC				
	3/14/2019	Isocontainer located inside the containment at the Port laydown	1	gallon	Wastewater sewage
	6/18/2019	Sewer Treatment Plant	1.5	gallon	Wastewater sewage

Table 4.11. (Continued.)

Year	Date	Description/location	Quantity	Unit	Substance
2019	Spills in Coeur Alaska annual report but not in ADEC (cont'd.)				
	7/10/2019	Comet Mine water treatment plant	15	gallons	Sludge material
	7/23/2019	North end of mill in front of pebble reject bunker and grind bay door	5	gallons	Hydraulic oil
	Spills in ADEC but not in Coeur Alaska annual report				
	8/16/2019	Coeur Alaska Kensington Diesel Generator JNU	1	gallon	Diesel
2020	Spills in ADEC but not in Coeur Alaska annual report (Table 4 was missing from Coeur Alaska 2021)				
	1/10/2020	Kensington UD-09 Hyd UG 105 JNU	10	gallons	Hydraulic oil
	1/14/2020	Kensington UD-09 Hyd UG 105 JNU	4	gallons	Hydraulic oil
	1/15/2020	Kensington UD-12 Hyd UG Down Ramp 180 JNU	5	gallons	Hydraulic oil
	1/16/2020	Kensington Forklift Hyd Core Yard Laydown JNU	2	gallons	Hydraulic oil
	1/19/2020	Kensington US-15 Coolant UG Passing Bay 3 JNU	2	gallons	Ethylene glycol
	1/20/2020	Kensington UB-05 Hyd UG Elmira 850 JNU	30	gallons	Hydraulic oil
	1/21/2020	Kensington Haul Truck Hyd Ore Pad JNU	2	gallons	Hydraulic oil
	1/24/2020	Coeur Kensington Underground Hyd Oil Release JNU	330	gallons	Hydraulic oil
	1/25/2020	Kensington UH-15 Hyd Waste Rock Pad JNU	1	gallons	Hydraulic oil
	1/26/2020	Coeur Kensington Potassium Hydroxide Release JNU	325	gallons	Other
	2/2/2020	Kensington SL-09 Hyd Mill Building JNU	5	gallons	Hydraulic oil
	2/4/2020	Kensington UH-02 Hyd Ore Rock Pad JNU	5	gallons	Hydraulic oil
	2/7/2020	Kensington Antifreeze UG Raven 710 JNU	4	gallons	Ethylene glycol
	2/7/2020	Kensington Permanganate Comet Water JNU	0.5	gallons	Other
	2/7/2020	Kensington UL-12 Hyd UG Raven 710 JNU	35	gallons	Hydraulic oil
	2/12/2020	Kensington UD-05 Hyd UG 1280 JNU	10	gallons	Hydraulic oil
	2/12/2020	Kensington UH-02 Transmission Oil UG Portal JNU	2	gallons	Transmission oil
	2/16/2020	Kensington UB-05 Hyd UG Elmira 850 JNU	5	gallons	Hydraulic oil
	2/16/2020	Kensington UL-15 Hyd UG Cross-Cut JNU	3	gallons	Hydraulic oil

Table 4.11. (Continued.)

Year	Date	Description/location	Quantity	Unit	Substance
2020	Spills in ADEC but not in Coeur Alaska annual report (Table 4 was missing from Coeur Alaska 2021) (cont'd.)				
	3/11/2020	Kensington SE-02 Hyd N. Portal JNU	2	gallons	Hydraulic oil
	3/12/2020	Coeur Kensington Underground Hyd Oil Release JNU	20	gallons	Hydraulic oil
	3/13/2020	Kensington UD-05 Hyd UG 105-225 JNU	6	gallons	Hydraulic oil
	3/27/2020	Kensington UL-14 Hyd UG Jualin 115 JNU	2	gallons	Hydraulic oil
	3/28/2020	Kensington Permanganate Comet Water Treatment JNU	5	gallons	Other
	3/31/2020	Kensington Haul Truck Hyd Ore Pad JNU	1	gallons	Hydraulic oil
	4/3/2020	Kensington UD-15 Hyd UG Jualin JNU	1	gallons	Hydraulic oil
	4/13/2020	Kensington Haul Truck Hyd Ore Pad JNU	2	gallons	Hydraulic oil
	4/29/2020	Kensington UD-12 Hyd UG JNU	5.5	gallons	Hydraulic oil
	4/29/2020	Kensington SE-02 Hyd Ore Pad JNU	5	gallons	Hydraulic oil
	5/3/2020	Kensington SL-12 Hyd Mill Bench	4	gallons	Hydraulic oil
	5/6/2020	Kensington UH-22 Hyd UG Main Access	6.5	gallons	Hydraulic oil
	5/29/2020	Kensington UD-13 Hyd UG Jualin	1	gallons	Hydraulic oil
	6/5/2020	Coeur Kensington Diesel Pump Johnson Ck JNU	5	gallons	Diesel
	6/10/2020	Kensington HYD UG Elmira Laydown	1	gallons	Hydraulic oil
	6/18/2020	Kensington HYD Pit-1	2	gallons	Hydraulic oil
	6/28/2020	Kensington HYD UG	4	gallons	Hydraulic oil
	7/10/2020	Kensington HYD UG	2	gallons	Hydraulic oil
	7/20/2020	Kensington Engine Oil Mile .5 Access Rd	1.5	gallons	Engine lube/gear oil
	7/28/2020	Kensington HYD UG 010 Level	2	gallons	Hydraulic oil
	9/12/2020	Coeur Kensington Hydraulic Pit 4 Stockpile JNU	1	gallons	Hydraulic oil
	9/15/2020	Coeur Kensington Hydraulic Underground JNU	10	gallons	Hydraulic oil
	10/5/2020	Kensington HYD UG Cross Cut 4	4	gallons	Hydraulic oil
	10/17/2020	Kensington HYD UG 180-228	4	gallons	Hydraulic oil
	10/25/2020	Kensington HYD UG Mine Portal Pad	5	gallons	Hydraulic oil
	11/27/2020	Kensington HYD UG 1635 Level	1	gallons	Hydraulic oil
	11/29/2020	Kensington HYD UG 1710 Level	1	gallons	Hydraulic oil
	11/30/2020	Kensington HYD UG Main	1	gallons	Hydraulic oil
	12/28/2020	Kensington HYD UG 1635 Level	1	gallons	Hydraulic oil

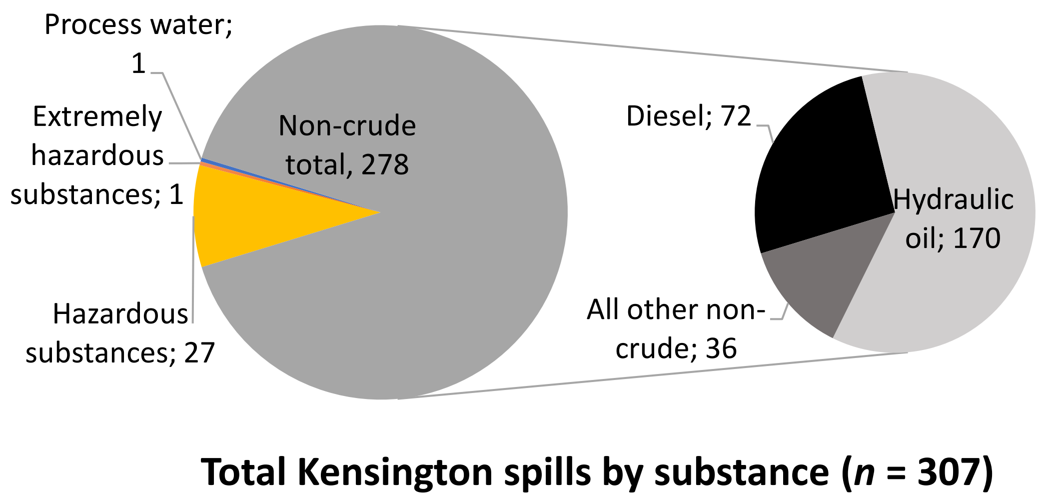
Spill record from ADEC

To find the number of spills associated with Kensington Mine, I searched the ADEC Prevention Preparedness and Response database (ADEC 2021) using Kensington Mine/Berners Bay as the location, and Kensington Gold Mine and Coeur Alaska (and variations) as the responsible parties (Appendix B2). I removed spills not related to mining and duplicate spill listings. There were 308 spills associated with Kensington Mine in the database. The spills include *hazardous* and *extremely hazardous substances*, *non-crude oil*, and *process water*. There were 18 different substances spilled at Kensington in 308 recorded incidents listed in ADEC (2021) (Table 4.12). Most of the substances spills were not mentioned in the permitting documents. The greatest percentage (90.6%) of spill incidents involved *non-crude oil* products, mostly diesel fuel and hydraulic oil (Tables 4.12, 4.13, and 4.14, Figure 4.4). *Non-crude oil* products were also 69.4% of the total volume released (Figure 4.4). Although 95.4% of the spills were <100 gallons, the remaining 4.6% of the spills (those ≥100 gallons) accounted for 64.1% of the volume released (Tables 4.13 and 4.14, Figure 4.4). The largest single spill incident was a release of 800 gallons of process water due to a coupler failing at slurry pond 1 on August 4, 2018.

Table 4.12. There were 308 recorded spill incidents at Kensington Mine from July 1995-2020 with quantities given in gallons (ADEC 2021). Total values for each substance subtype have been rounded to the gallon. Substances in shaded rows were not discussed in USFS (2004) or USFS (2021). In addition to the 307 spills with quantities given in gallons, there was also a spill of 4 lb of hydraulic oil from a blown hose in December 2012.

		Volume (gallons)	
	n	Range	Total
Extremely hazardous substances			
Hydrochloric acid	1	200	200
Hazardous substances			
Caustic alkali liquids	1	50	50
Ethylene glycol	14	0.5-9	37
Glycol	1	15	15
Sodium hypochlorite	2	9	18
Urea (solid)	1	100	100
Other*	8	0.5-325	696
Total	27		921
Noncrude oil			
Diesel	72	0.015-600	2,218
Engine lube oil	11	0.1-250	273
Engine lube/gear oil	3	1.5-100	109
Hydraulic oil	170	0.25-330	1,609
Kerosene	1	1	1
Transformer oil	1	10	10
Transmission oil	11	2-10	51
Used oil	6	3-27.5	75
Other	3	1-2	5
Total	278		4,351
Process water	1	800	800

* Other hazardous substances listed in the spill names include permanganate, ferric chloride, and potassium hydroxide.



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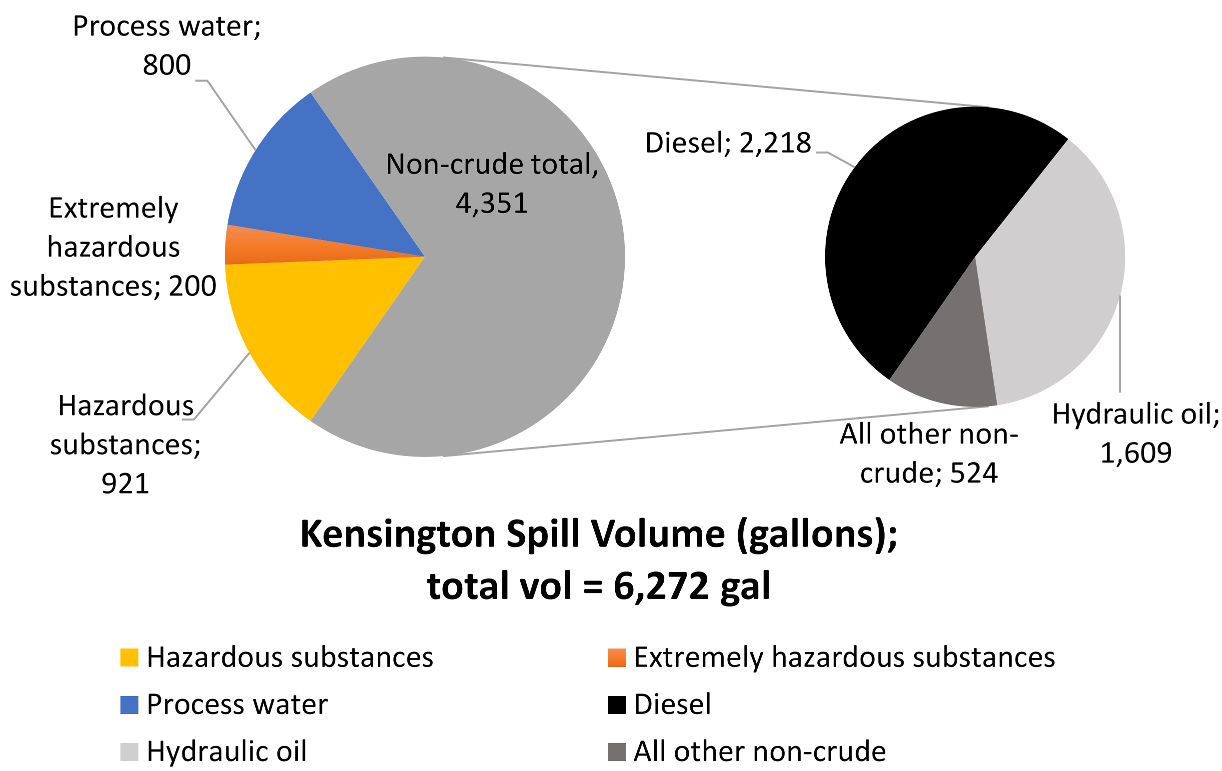

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Figure 4.4. Relative proportions of (a) number and (b) volume from different substance classes at Kensington Mine from 1995-2020 with non-crude oil spills further broken down to show the amounts due to diesel and hydraulic oil spills.

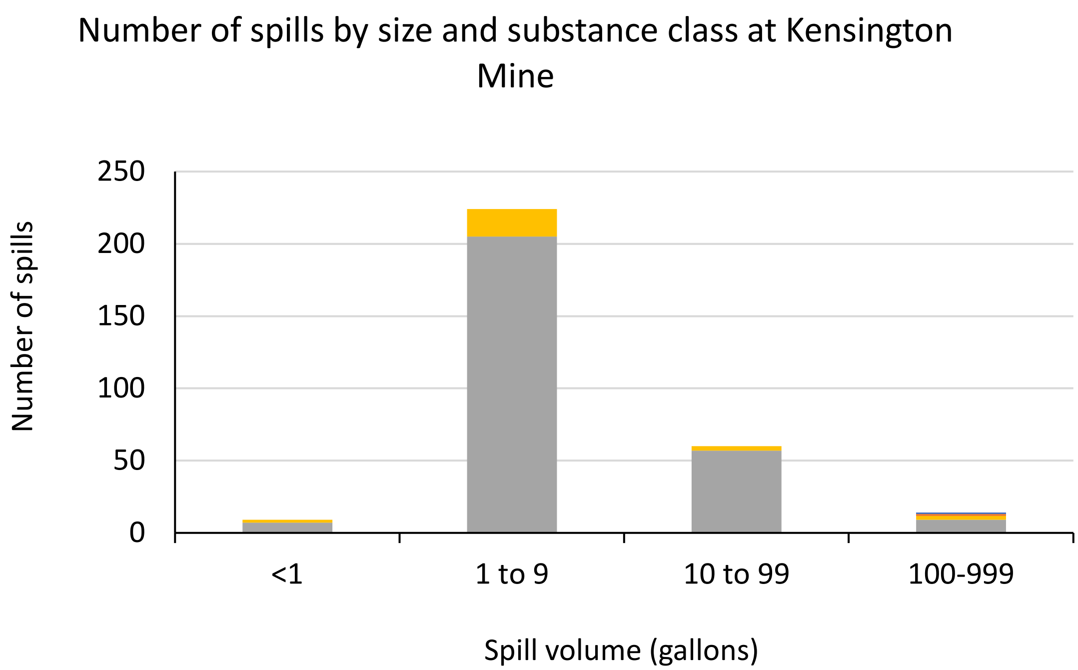
Hazardous and *extremely hazardous substances* represented 9.1% of the number of spill incidents and 17.9% of the volume spilled (Tables 4.13 and 4.14, Figures 4.5 and 4.6). They were most often caused by *human error* (12 spills), or *line failure* (6 spills) (Table 4.15). *Non-crude oil* spills were most commonly caused by *line failure* (108 spills), *equipment failure* (52 spills), and *leaks* (40 spills) (Table 4.15).

Table 4.13. Counts of Kensington Mine spills from July 1995-December 2020 by substance class and size category (ADEC 2021).

Substance class	Number of spills per size class (gallons)				Total	Percent
	Spill Size Class (gallons)					
	<1	1-9	10-99	100-999		
Ex Haz Sub				1	1	0.3
Haz Sub	2	19	3	3	27	8.8
Non-crude	7	205	57	9	278	90.6
Process water				1	1	0.3
Total	9	224	60	14	307	
Percent	2.9	73.0	19.5	4.6		

Table 4.14. Cumulative volume released through Kensington Mine spills from July 1995-December 2020 by substance class and size category (ADEC 2021).

Substance class	Cumulative volume spilled per size class (gallons)				Total	Percent
	Spill Size Class (gallons)					
	<1	1-9	10-99	100-999		
Ex Haz Sub				200	200	3.19
Haz Sub	1	75	120	725	921	14.68
Non-crude	1.7	725	1,328	2,296	4,351	69.37
Process water				800	800	12.76
Total	3	800	1,448	4,021	6,272	
Percent	0.05	12.76	23.09	64.11		



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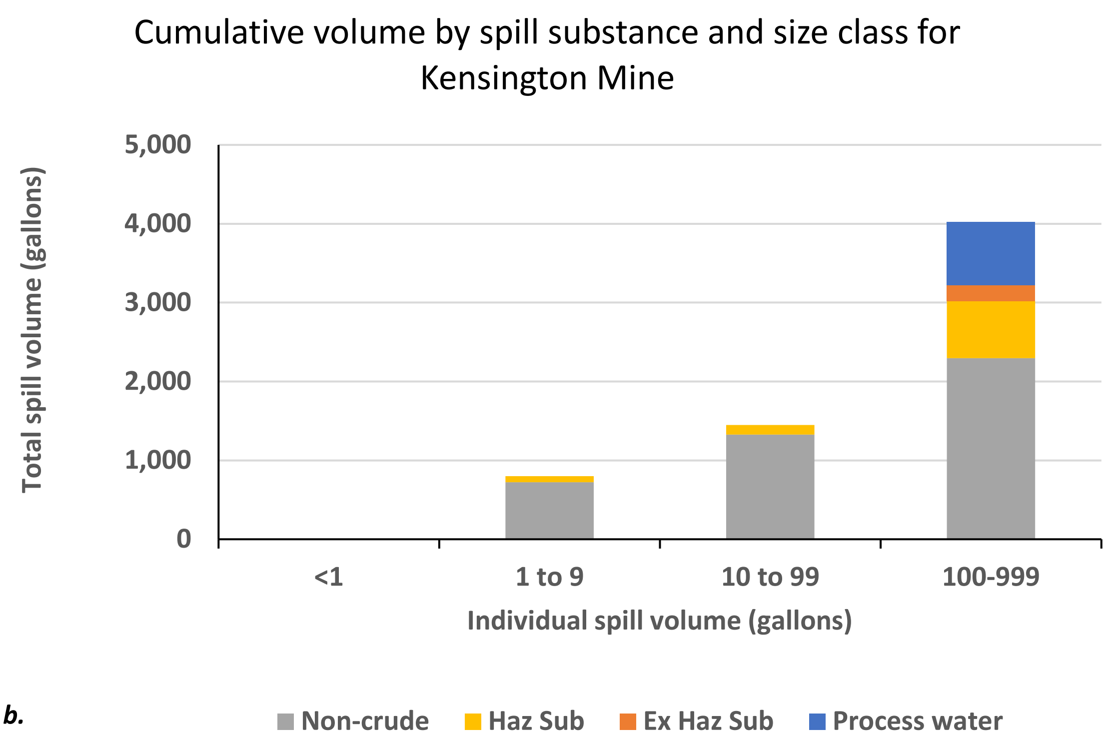

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Figure 4.5. Number of spill incidents (a) and cumulative gallons spilled (b) for non-crude oil, hazardous substances, extremely hazardous substances, and process water in different spill size classes for Kensington Mine from July 1995-December 2020 based on ADEC (2021).

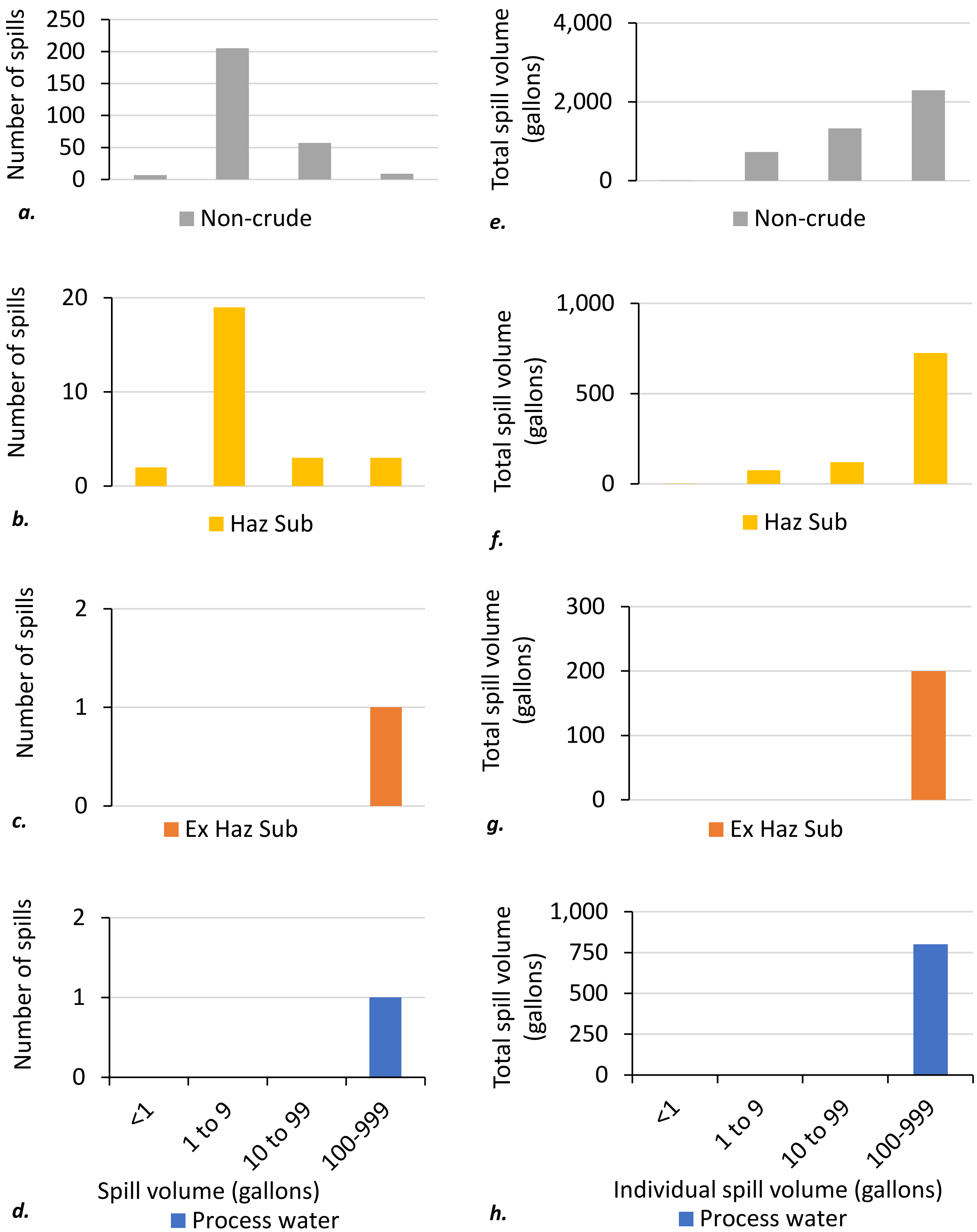


Figure 4.6. Number of spill incidents (a-d) and cumulative gallons spilled (e-h) for non-crude oil (a, e), hazardous substances (b, f), extremely hazardous substances (c, g) and process water (d, h) in different spill size classes for Kensington Mine from July 1995-December 2020 based on ADEC (2021). All subfigures share the same x-axes.

Table 4.15. Spills associated with Kensington Mine by cause sub-type and substance category. One spill with a quantity given in pounds is excluded.

Cause subtype	Extremely Hazardous Substances		Hazardous Substances		Non-crude oil		Process Water	
	n	volume range (gal)	*n*	volume range (gal)	*n*	volume range (gal)	*n*	volume range (gal)
Cargo not secured					4	2-20		
Collision/allision			1	325	1	1		
Crack			1	55	1	45		
Equipment failure			3	0.5-9	52	1-300	1	800
External factors					4	3-200		
Human error	1	200	11	0.5-300	17	0.5-100		
Intentional release					1	20		
Leak			1	1	40	0.015-600		
Line failure			6	1-5	108	0.25-250		
Overfill					13	1-120		
Puncture					2	2		
Rollover/capsize					2	1.5-5		
Seal failure					15	1-40		
Tank failure					6	1-35		
Valve failure					5	1-20		
Vehicle leak, all			2	1-1.5	5	1-7		
Other			1	100				
Unknown			1	1.5	2	5-9.5		
Total spills and volume range (gal)	1	200	27	0.5-325	278	0.015-600	1	800

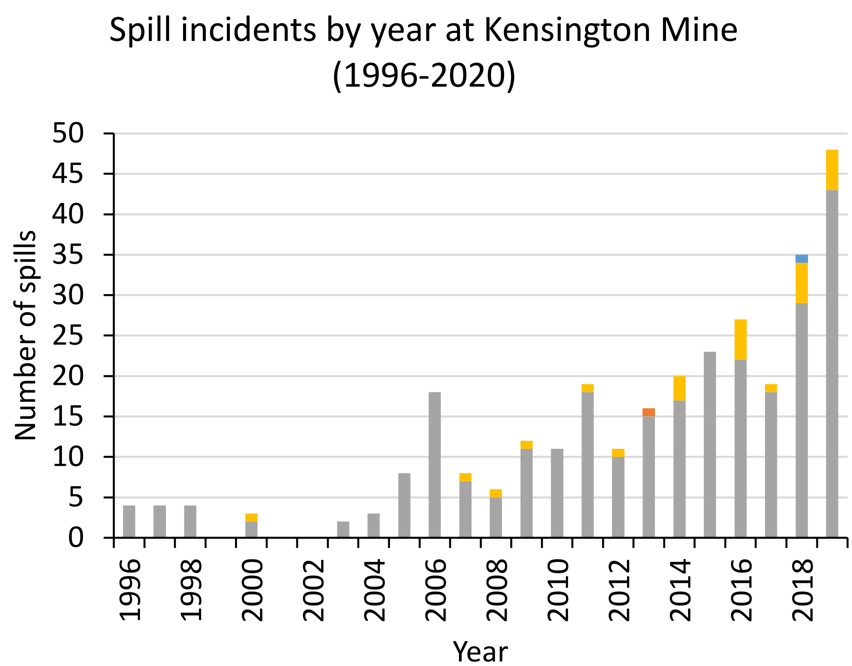
The spill record at Kensington pre-dates mine permitting in 2004 (Table 4.16). Spill frequency has increased over time (Table 4.16, Figure 4.7), especially in *non-crude oil,* with a lesser uptick in *hazardous substance* spills starting in 2017. The spill record by month shows a few more *non-crude oil* spills in spring (March and April) and autumn (October and November) than in summer (May-July) and winter (December-February) (Table 4.17, Figure 4.7).

Table 4.16. Spills per year by substance type at Kensington Mine from 1996-2020 based on ADEC (2021). One spill with a quantity given in pounds (4 lb of hydraulic oil in 2012) is included in the count of non-crude oil spills.

Year	Spills				Total
	Ex Haz Sub	Haz Sub	Non-crude	Process water	
1996		2	5		7
1997			4		4
1998			4		4
1999			4		4
2000					0
2001		1	2		3
2002					0
2003					0
2004			2		2
2005			3		3
2006			8		8
2007			18		18
2008		1	7		8
2009		1	5		6
2010		1	11		12
2011			11		11
2012		1	18		19
2013		1	10		11
2014	1		15		16
2015		3	17		20
2016			23		23
2017		5	22		27
2018		1	18		19
2019		5	29	1	35
2020		5	43		48
total	1	27	279	1	308
mean	0.04	1.08	11.16	0.04	14
sd	0.20	1.66	10.50	0.20	11.64

Table 4.17. Total spills per month by substance type at Kensington Mine from July 1995-December 2020 based on ADEC (2021). One spill with a quantity given in pounds (4 lb of hydraulic oil in December) is included in the count of non-crude oil spills.

Month	Spills				Total
	Ex Haz Sub	Haz Sub	Non-crude	Process water	
January		3	25		28
February		4	22		26
March		3	32		35
April		3	28		31
May			21		21
June		2	18		20
July		1	23		24
August			23	1	24
September		3	18		21
October		2	28		30
November	1	2	26		29
December		4	15		19
Total	1	27	279	1	308



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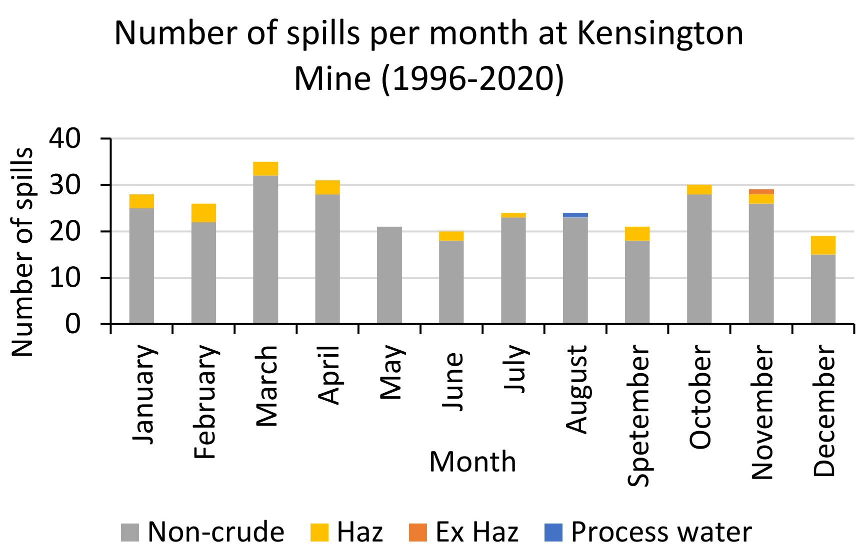

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Figure 4.7. Annual (a) and monthly (b) spill incidents at Kensington Mine based on ADEC records from 1996-2020 and broken down by substance type.

Of the 308 spills listed in ADEC (2021), at least 34 were related to transportation, as determined from a combinations of *facility type*, *source type*, and *cause subtype* (Table 4.18 and 4.19). Four transportation spills were caused by *collision/allision* and *rollover/capsize*. The largest truck accident spill was 325 gallons of an unidentified *hazardous substance* in January 2020.

Table 4.18. Transportation related spills from Kensington Mine from June 1995-December 2020.

Facility type	Source type	Cause subtype	*n*
Mining operation	Container, other	Cargo not secured	1
Mining operation	Drill	Cargo not secured	1
Mining operation	Drum(s)	Cargo not secured	1
Mining operation	Heavy equipment	Collision/allision	1
Mining operation	Heavy equipment	Rollover/capsize	1
Mining operation	Heavy equipment	Vehicle leak, all	4
Mining operation	Hydraulic system	Rollover/capsize	1
Mining operation	Hydraulic system	Vehicle leak, all	2
Mining operation	Other	Cargo not secured	1
Mining operation	Other	Collision/allision	1
Mining operation	Unknown	Vehicle leak, all	1
Other	[blank]	Vehicle leak, all	1
Vehicle	Hydraulic system	Various	5
Vehicle	Tank, other, mobile	Various	2
Vehicle	[blank]	Various	11
Total			34

Table 4.19. There were 34 recorded spill incidents at Kensington Mine from July 1995-2020 associated with transportation with quantities given in gallons (ADEC 2021).

		Volume (gallons)	
	n	Maximum release	Total
Hazardous substances			
Ethylene glycol	5	2	6.5
Other (potassium hydroxide)	1	325	325
Total	6		331.5
Non-crude oil			
Diesel	9	40	62
Engine lube oil	1	1	1
Engine lube/gear oil	2	7	8.5
Hydraulic oil	15	20	89*
Other	1	1	1
Total	28		161.5

* This total does not include one spill listed as 4 lb.

Sewage spills, environmental enforcement, and notices of violations

ADEC (2021) does not include sewage and grey water spills, but the annual reports from Kensington did. The 28 sewage and grey water spills from 2008 to 2019 had a combined volume of 2,836.5 gallons, with 81% of that volume coming from two spill incidents: a 950-gallon release of grey water at the Slate Cove lay down yard in May 2010 and a 900-gallon release of grey water on the Jualin access road between Spur Road and the port in January 2017 (Tables 4.11 and 4.20). Had sewage and grey water spills, as well as the other spills recorded in the annual reports, been included in the ADEC database, the number of spill incidents at Kensington would have been 346, and sewage/grey water would have represented 8% of the spill incidents.

Table 4.20. Kensington Mine sewage and grey water spills size distribution.

Spill size class (gallons)	*n*	%	Volume	%
<1	1	3.6%	0.5	0.0%
1 to 9	13	46.4%	46	1.6%
10 to 99	10	35.7%	490	17.3%
100 to 999	4	14.3%	2,300	81.1%
Total	28		2,836.5	

In 2019 the Kensington Mine generator pad was referred to ADEC's Contaminated Site Program due to "historical contamination from past spills", specifically heating oil and used oil (ADEC DSPR 2021b). Site characterization workplans, including sampling and fieldwork, and reports were approved for assessing and cleaning up the generator pad sites.

EPA ECHO (2021) has detailed facility reports for both the Kensington Mine Project and for the associated Jualin labor camp. In the past three years, the Kensington Mine itself has had federally reportable Clean Air Act violations in October 2019, August 2020, and August 2021. Warning letters related to the Clean Air Act were sent in December 2017 and September 2020.

Clean Water Act violations at Kensington Mine have been numerous and ongoing in the past three years. Single violations of the Clean Water Act at Kensington include effluent violations (numeric effluent violations and unauthorized discharges), management practice violations (best management practice deficiencies, failure to maintain records, and improper operation and maintenance), monitoring violations (failure to monitor for non-toxicity requirements, and improper analysis or lab error), and reporting violations (failure to submit required report and improper/incorrect reporting). Stormwater concentrations of total recoverable cadmium, copper, and zinc have exceeded benchmark limits, although these exceedances "are not violations, but rather indicators of potential problems at the site" which "require permittees to review their stormwater control measures and take corrective action" (EPA ECHO 2021). Total recoverable copper was in noncompliance in the third quarter of 2018 and total dissolved solids were in noncompliance in the third quarter of 2020. There have been five Notices of Violation for Clean Water Act issues between October 2019 and April 2021 and one Letter of Violation/Warning Letter in October 2017. Kensington Mine also "improperly releasing acid rock discharge without treatment in violation of the CWA and its Alaska Pollutant Discharge Elimination System (APDES) permit" (EPA ECHO 2019a).

In addition to the informal enforcement actions, Clean Water Act violations have resulted in $210,000 and $240,000 penalties in August 2019, and a $84,500 penalty for Emergency Planning and Community Right-to-Know Act violations in July 2019. The $210,000 penalty was because Kensington Mine "failed to develop a complete Stormwater Pollution Prevention Plan (SWPPP); failed to develop and implement procedures for non-petroleum-based leaks, spills, and other releases; failed to conduct required monitoring, assessments, and inspections; and failed to use proper sample handling and analysis procedures" and included a compliance action cost of $10,000 (EPA ECHO 2019c). The $240,000 penalty was assessed because Kensington Mine "discharged pollutants in excess of permit limits; conducted unauthorized discharges; improperly operated and maintained sampling equipment; and non-representative sampling" and included a compliance action cost of $1,980,000 (EPA ECHO 2019b). Finally, the $84,500 penalty was because Kensington Mine "failing to file Form R reports tothe (sic) Toxic Release Inventory (TRI) for nitrate compounds manufactured by the facility from 2013 to2017 (sic)" (EPA ECHO 2019d).

Finally, the Kensington Mine Jualin labor camp had monitoring and reporting violations in 2016, 2017, and 2019 (EPA ECHO 2021) and a November 2016 Safe Drinking Water Act sanitary survey found significant deficiencies in the distribution, management operation, and treatment categories.

How well were the recorded spills predicted?

Within the SEIS, the expected number of transportation spills of diesel from trucks and tailings slurry from a pipeline were estimated on an annual basis and for the 10-year expected project length originally proposed (Table 4.21). For both diesel and tailings, the expected number of spills was less than one, but no other spill probabilities were calculated, nor were the combined risks.

Table 4.21. Spills predicted in USFS (2004) Alternative D.

Substance	Transport method	Length (miles)	Years	Expected number of spills
Diesel	Truck	5	1	<0.0004
			10	<0.004
Tailings	Pipeline	3.5	1	0.003
			10	0.03

I applied the Harwood and Russell (1990) estimated spill rate per mile to a fuller picture of the hazardous materials that would have been transported by truck from 2006-2020, if the supply needs matched those described in the SEIS (Table 4.22). I found that on an annual basis, the risk I calculated is five times higher once hazardous materials other than diesel are included. Over the course of the project, my estimated number of spills was 7.5 times higher, which was the result of the more inclusive list of hazardous materials transported and that Kensington Mine did not stop operating after 10 years. The POA did not include any quantitative estimates of expected spills or their probabilities, although it was noted that the spill risk would be extended by 10 years (USFS 2021). The inclusion of trucking filtered tailings more than doubles the annual estimated number of spills. The $N = RT$ model with Harwood and Russell's (1990) spill rate per mile leads to a probability of 8.3% that there would be at least one spill from 2006 to 2030 from trucking accidents (Table 4.22).

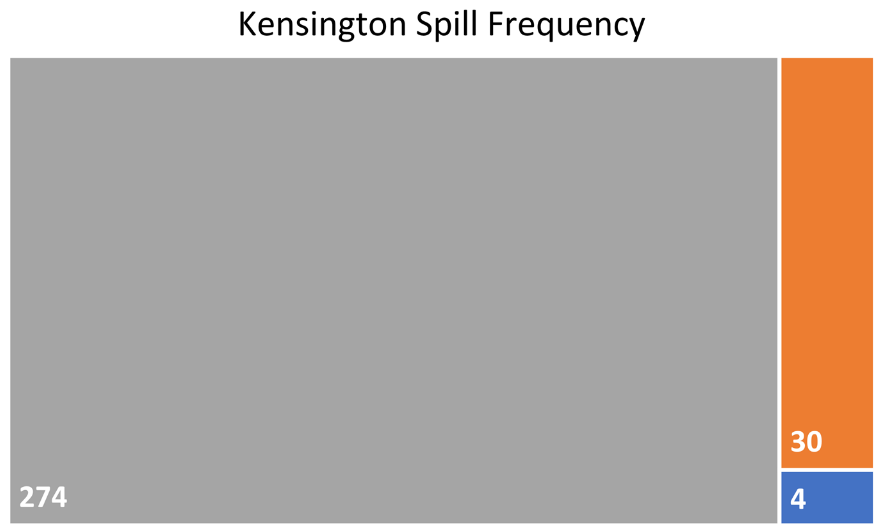
Table 4.22. Transportation spills predicted based on the N = RT model using Harwood and Russell (1990) spill rate per mile traveled for Alternative D (USFS 2004) and the POA (USFS 2021).

Scenario	Alternative D	POA	Alt D and POA
Years	2006-2020; 15 years inclusively	10 years	
Substances	Flotation concentrate Reagents and other materials Diesel Ammonium nitrate	Flotation concentrate Reagents and other materials Diesel Ammonium nitrate Filtered tailings	
Expected spills			
In one year	0.0023	0.0052	
For the scenario length	0.0347	0.0523	0.087
Probability of at least one spill	3.41%	5.10%	8.3%

In practice, ADEC (2021) shows there were four *collision/allision* and *rollover/capsize spills* at Kensington Mine from 2006-2020. Two of those spills occurred between 2006 and 2016, or within the initial project lifetime described in the SEIS (USFS 2004) and included one diesel spill (Table 4.23). The remaining two both occurred in 2020 (Table 4.23). These four spills were all of different substances and represented 11.7% of the 34 spills attributed to transportation at Kensington Mine (Table 4.18). The 34 transportation spills themselves represented 11.0% of the 308 spills in the ADEC (2021) database for Kensington. Thus, the *collision/allision* and *rollover/capsize* spills were 1.3% of the total spills (Figure 4.8).

Table 4.23. Observed collision/allision and rollover/capsize spills associated with Kensington Mine listed in ADEC (2021).

Date	Spill name	Substance	Amount (gallons)	Cause subclass
11/22/2006	Kensington Mill Pad forklift	Hydraulic Oil	5	Rollover/Capsize
2/29/2016	Coeur pumper truck diesel tank puncture	Diesel	1	Collision/Allision
1/26/2020	Coeur Kensington Potassium Hydroxide Release JNU	Other	325	Collision/Allision
7/20/2020	Kensington Engine Oil Mile .5 Access Rd	Engine Lube/Gear Oil	1.5	Rollover/Capsize



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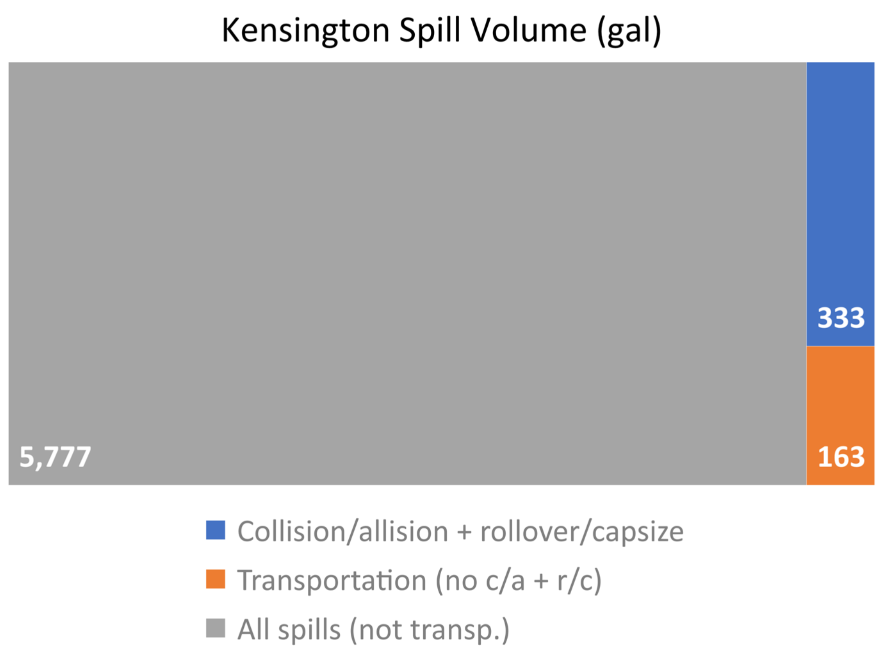

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Figure 4.8. A comparison of the relative (a) number and (b) cumulative volume of (collision/allision and rollover/capsize spills) compared to the remaining transportation spills and non-transportation spills at Kensington Mine from 1995-2020.

Kensington Mine Summary

Kensington Mine is an underground gold mine roughly 45 miles north-northwest of Juneau, Alaska, with infrastructure that includes mill facilities, a tunnel connecting Kensington Mine to Jualin Mine, permanent waste rock disposal facilities near the Kensington Mine and the Jualin Mine process area, and a tailings storage facility. Ore production was expected to be 2,000 tons per day (tpd) in the 2004 EIS (USFS 2004) and 3,000 tpd under the updated Plan of Operations (USFS 2021).

Kensington's processing facility is "a conventional milling gold froth flotation recovery circuit. The major components include crushing, grinding, gravity separation, flotation, thickening, and filtering" (USFS 2021).

A 12,000-foot tunnel connects Kensington Mine to Jualin Mine and is the primary access for workers and materials into the mine, as well as ore haulage between the mine and mill (USFS 2004). There are two roads from the coast to mine facilities: the 5.5-mile Jualin Road from the Slate Cove Marine Terminal and the 1.8-mile Comet Beach Road which connects Comet Beach to the Comet Portal (USFS 2021). There is a 3.5-mile buried tailings pipeline from the mill near the Jualin Mine portal to the tailings storage facility at Lower Slate Lake (USFS 2004). The amended plan of operations would have 37 daily trips carrying filtered tailings to the filtered tailings facility. (Assuming tailings are transported 365 days per year in 20-ton loads, this is 270,100 tons of filtered tailings per year.)

Reagents, blasting materials, and fuels are delivered to Slate Creek Cove and then transported by road to the mill, with ore concentrate making the reverse journey. Under the 2,000 tpd ore production scenario from the 2004 EIS (USFS 2004), 2,146-2,511 tons of chemicals and materials (excluding fuel and blasting agents) were to be used at Kensington Mine annually. When the ore production rate is increased to 3,000 tpd, the material and chemical needs are estimated as 2,854 tons per year.

The 2004 EIS estimated that 3,200,000 gallons of diesel would be used annually under Alternative D, requiring 492 truck trips with each truck hauling 6,500 gallons (USFS 2004). Under the amended plan of operations, those figures could increase to 4,800,000 gallons of diesel in 738 truckloads.

The total amount of hazardous materials transportation was estimated as 2,472 loads per year under the scenario described in the 2004 EIS and 17,213 loads per year under the amended plan of operations with expanded production and tailings haulage by truck.

Harwood and Russell's (1990) estimate of $R = 1.87 \times 10^{-7}$ spills per mile was used in the 2004 EIS to estimate the percent chance of diesel spills annually and over the expected project life for six Alternatives considered (USFS 2004). The road length, load size, and number of loads per year varied, but all Alternatives were expected to have a ≤0.5% chance of at least one diesel spill over the life of the project. Pipeline spill risks were also calculated. Once the hazardous materials to be transported (other than diesel) were included, the probability of at least one spill for Alternative D from 2006-2020 was 3.4% and the probability of at least one spill in the next 10 years under the amended plan of operations was 5.1% using the $N = RT$ model with the same value of R.

Based on data from ADEC (2021) there were four *collision/allision* and *rollover/capsize* spills associated with Kensington Mine through the end of 2020. There were an additional 30 spills associated with mine transportation from causes such as *vehicle leaks* and *cargo not being secured*, for a total of 34 transportation spills. Spills from accidents (*collision*/*allision* + *rollover*/*capsize*) were 11.8% of transportation spills.

Overall, ADEC (2021) listed 308 spills of 18 different hazardous materials at Kensington Mine, with a total of 6,272 gallons released. Most of the substances spilled were not mentioned in the permitting documents. The most frequently spilled substance was hydraulic oil (170 spills totaling 1,609 gallons). The greatest percentage (90.6%) of spill incidents involved *non-crude oil* products, mostly diesel fuel and hydraulic oil. *Non-crude oil* products were also 69.4% of the total volume released. Although 95.4% of the spills were <100 gallons, the remaining 4.6% of the spills (those ≥100 gallons) accounted for 64.1% of the volume released. The largest single spill incident was a release of 800 gallons of *process water* due to a coupler failing at slurry pond 1 on August 4, 2018.

Hazardous and *extremely hazardous substances* represented 9.1% of the number of spill incidents and 17.9% of the volume spilled. They were most often caused by *human error* (12 spills), or *line failure* (6 spills). *Non-crude oil* spills were most commonly caused by *line failure* (108 spills), *equipment failure* (52 spills), and *leaks* (40 spills). The number of reported spills per year has been increasing at Kensington Mine, especially for *non-crude oil*.

In addition to the spills reported to ADEC, Kensington Mine also had 28 sewage and grey water spills from 2008 to 2019, with a combined volume of 2,836.5 gallons. Eighty-one percent of that volume came from two spill incidents: a 950-gallon release of grey water at the Slate Cove lay down yard in May 2010 and a 900-gallon release of grey water on the Jualin access road between Spur Road and the port in January 2017.

Kensington Mine has published annual reports from 2006-2021 with lists of their hydrocarbon spills (2005-2007) and all hazardous materials spills (2008-2020). Two reports (Coeur Alaska, Inc. 2007, 2021) mentioned spills but did not include tables showing them. Kensington Mine's list of spills has many discrepancies when compared against the records in ADEC (2021). Many of those differences were Kensington Mine listing sewage and grey water spills that were not in ADEC (2021), but there were multiple instances of other types of spills being listed in one source and not the other in both directions.

CHAPTER 5
Greens Creek Mine

Location and description

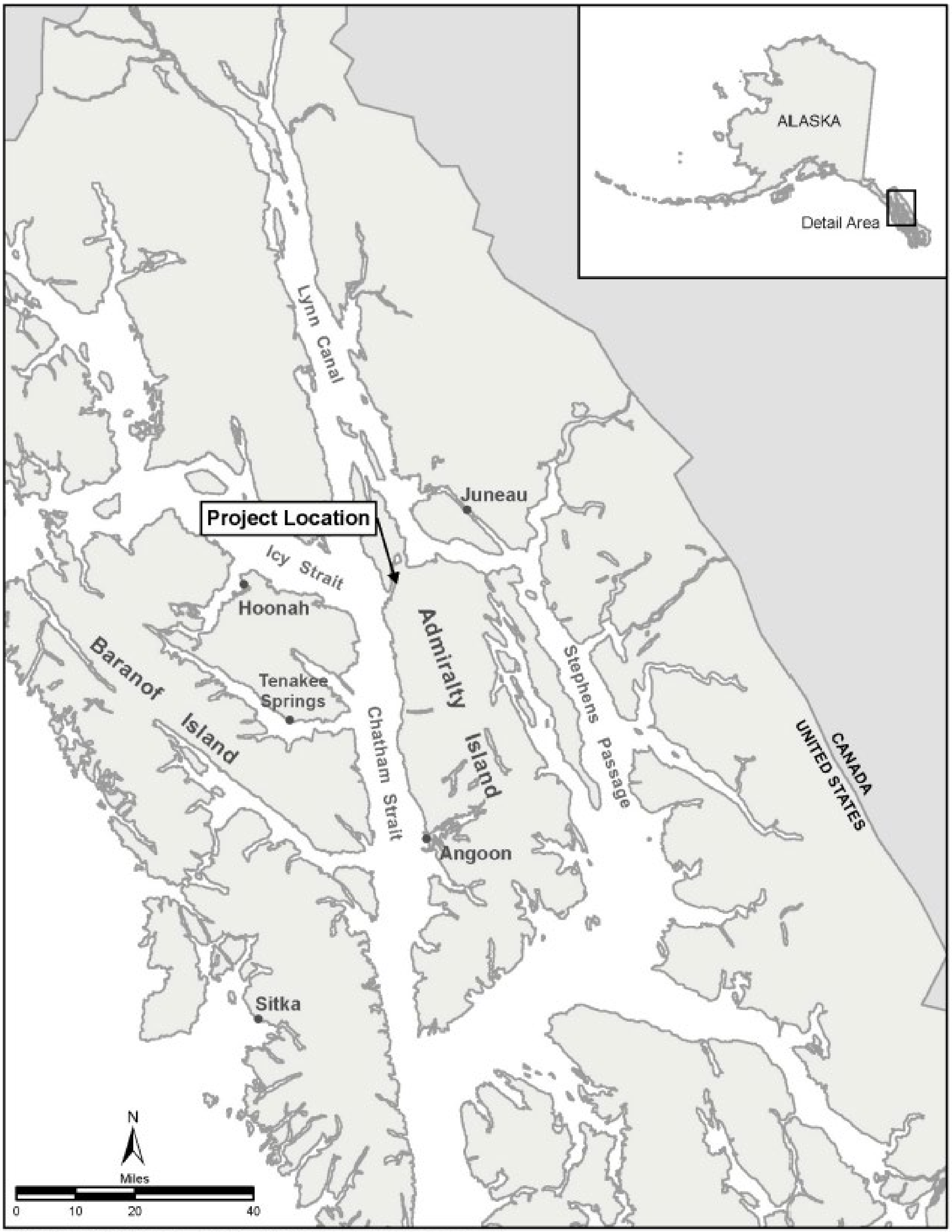
Greens Creek Mine is an underground mine that produces silver and gold, as well as lead and zinc concentrates. Greens Creek is located on Admiralty Island, about 18 miles southwest of Juneau (Figures 5.1, 5.2, and 5.3). The ore body was described as "small, but richly mineralized", and containing silver, gold, lead, zinc, and copper (USFS 1983). In the initial EIS the estimated life of the mine based on the ore reserves known at the time was 11 years and the life of operations was 15-17 years for planning purposes (USFS 1983), but Greens Creek Mine is still in production today.

The 2020 General Plan of Operations described the major mine infrastructure as including "the mill and underground mine area, Site 23 waste rock storage facility, Hawk Inlet Facility, the [tailings disposal facility] TDF, Young Bay dock, approximately 13 miles of connecting roadways, a power intertie connecting the Mine to the Juneau area power grid, and various pipelines and outfalls for wastewater and stormwater" (Hecla Greens Creek Mining Company 2020). The mill, backfill batch plant, powerhouse, water treatment plants, surface maintenance shop, main warehouse, administrative offices, and fuel storage tanks are grouped together at the 920 area, and additional office buildings, assay laboratory, and core-logging facilities are grouped together at the adjacent 860 area (Hecla Greens Creek Mining Company 2020). Core storage, concentrate storage, a deep-water port for cargo ships, freight barges and fuel barges, a warehouse, sanitary sewer and potable water treatment, fuel storage, and camp housing are all parts of the Hawk Inlet Facility (Hecla Greens Creek Mining Company 2020).

Greens Creek Mine has a complicated history of ownership and expansion, resulting in the production of multiple EISs and environmental assessments. They are summarized in the most recent Plan of Operations (Hecla Greens Creek Mining Company 2020), with a few important dates and milestones noted here. The first EIS for Greens Creek Mine was completed in 1983 (USFS 1983). Subsequent changes in mine ownership and plans required the production of an environmental assessment in 1988. Ore production began in 1989, and a second environmental assessment was prepared in 1992 for expansion of waste rock disposal. Ore production was halted from 1993-1996 due to low metal prices. After production resumed, a second EIS was completed in 2003 for an extension of the tailings disposal facility. A third EIS was produced in 2013 to modify the plan of operations and expand the tailings disposal facility to allow for 30-50 years of additional storage capacity. The resulting ROD from the Forest Service approved a 10-year extension of the tailings disposal facility.

By the numbers

The descriptions of Greens Mine have evolved over time. The numeric values for ore processing, reagent and fuel use, the transportation corridor, and waste and tailings generation from the original EIS (USFS 1983), the tailings disposal facility expansion FSEIS (USFS 2013a), and the most recent Plan of Operations (Hecla Greens Creek Mining Company 2020) are shown in Table 5.1.



Z:\Gdrive\Projects_2011\Greens_Creek\maps\Report\updated_format\grayscale\Fig_1_1-1_loc.mxd

Figure 5.1. USFS (2013) "Figure 1: Project Area and Vicinity Map".

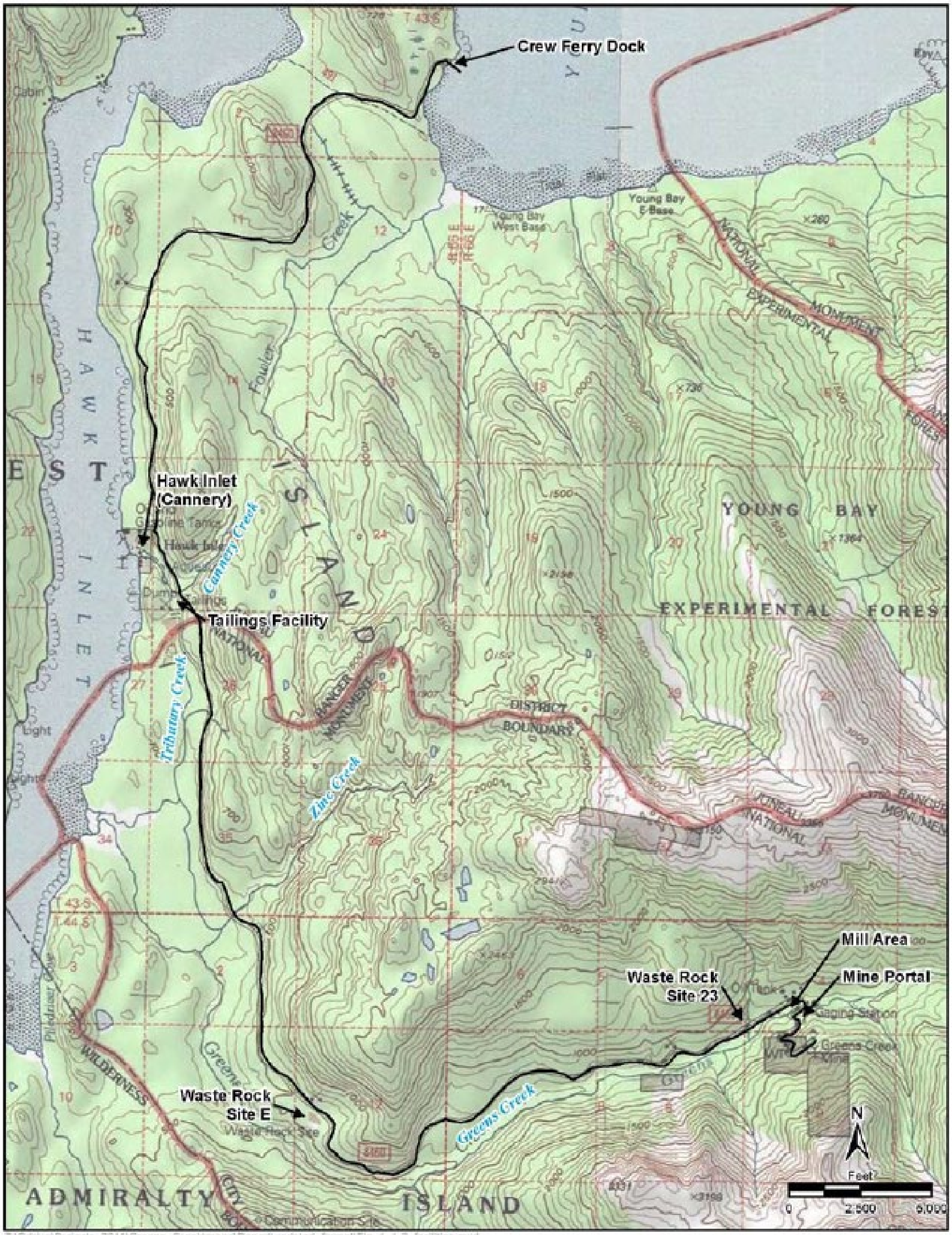


Figure 5.2. USFS (2013) "Figure 1.1-2: Greens Creek Project General Location of Existing Facilities".

Figure 5.3. Hecla Greens Creek Mining Company (2020) "Figure 1: Mine Site Location Map"

Table 5.1. Quantitative descriptions of ore production, reagent use, fuel use, the transportation corridor, and waste rock and tailings produced in permitting documents for Greens Creek Mine.

Value	Description	Reference
	Ore and ore concentrate	
800	tons per day of ore	USFS (1983)
160	tons of zinc concentrate produced per day	USFS (1983)
100	tons of lead concentrate produced per day	USFS (1983)
30 to 50	year mine operations	USFS (2013)
2,200	tons per day production rate	USFS (2013)
7 million	ounces of silver annually	USFS (2013)
40,000	ounces of gold annually	USFS (2013)
200,000	tons of zinc, lead, and bulk concentrates annually	USFS (2013)
>2,300	tons per day nominal production rate	Hecla Greens Creek Mining Company (2020), Appendix 6 (SPCC Plan)
	Reagents	
5.0	trips/day for material haulage (Alt 1)	USFS (1983)
	Waste rock, tailings and wastewater	
300	tons per day of waste rock	USFS (1983)
3.4 million	cubic yards capacity for the tailings pond	USFS (1983)
0.76 million	cubic yards fill	USFS (1983)
14.2 million	cubic yards additional tailings and waste rock in the expansion of the tailings disposal facility (TDF)	USFS (2013)
180,000	cubic yards tailings annually filtered and transported by haul truck to the TDF	USFS (2013)
2	tons of tailings = 1 cubic yard	USFS (2013)
2	tons of waste rock = 1 cubic yard	USFS (2013)

Table 5.1. (Continued.)

Value	Description	Reference
	Fuel and energy	
400,000	gallons stored at the cannery (a 40-day supply)	USFS (1983)
400,000	gallons stored at the mine service area (if mill is there)	USFS (1983)
150,000	gallons stored at the mine service area (if mill is at the tailings pond)	USFS (1983)
350,000	gallons stored at the mill (if mill is at tailings pond)	USFS (1983)
200,000	gallons fuel offloaded from a barge to a storage facility every 10 days	USFS (2013)
9,000	gallon tanker truck for diesel	Hecla Greens Creek Mining Company (2020)
<12	trucks/week for diesel if facility is self-generating electricity	Hecla Greens Creek Mining Company (2020)
4,000	gallons per month for lubricating oils and hydraulic oil	Hecla Greens Creek Mining Company (2020)
200,000	gallons diesel storage at Hawk Inlet	Hecla Greens Creek Mining Company (2020)
2 to 3	trucks/week for diesel usually	Hecla Greens Creek Mining Company (2020)
20,000	gallons per hour maximum pumping rate	Hecla Greens Creek Mining Company (2020)
45	seconds to cut-off in case of catastrophic line failure	Hecla Greens Creek Mining Company (2020)
250	gallons released in catastrophic fuel line rupture at 920 bulk storage facility	Hecla Greens Creek Mining Company (2020)

Table 5.1. (Continued.)

Value	Description	Reference
	Transportation	
35	ton truck or tram car to transport ore to a mill at a tailings pond	USFS (1983)
600	foot long dock at Hawk Inlet	USFS (1983)
≤5	shipments of supplies or concentrates in and out of Hawk Inlet each month	USFS (1983)
14.8	miles of roadway	USFS (1983)
7.5	mile slurry line	USFS (1983)
30	round trips/day (Alt 1)	USFS (1983)
5	trips/day for ore concentrate (Alt 1)	USFS (1983)
12	trips/day for crew buses (Alt 1)	USFS (1983)
2	trips/day for fuel (Alt 1)	USFS (1983)
5	trips/day for material haulage (Alt 1)	USFS (1983)
6	trips/day for miscellaneous inspection and administration (Alt 1)	USFS (1983)
8.1	miles between cannery shiploading area and mine service area	USFS (1983)
6	stream crossings between cannery shiploading area and mine service area	USFS (1983)
6.4	mile tailings slurry line from the mill to the tailings pond if the mill is located at the mine service area	USFS (1983)
15.6	mile transport of tailings by truck from the mill to the TDF (round trip)	USFS (2013)
20-40	trips/day for tailings	USFS (2013)
45	tons of tailings per truck	USFS (2013)
1,000	tons of tailings per day delivered to TDF by truck on average	USFS (2013)
16.0	miles, unpaved road length, Alt A, B, and mitigated B (roundtrip)	USFS (2013)
21.0	miles, unpaved road length, Alt C and D (roundtrip)	USFS (2013)
5.5	miles from the mill site to the tailings station	USFS (2013)
9.0	miles ore concentrate trucking proposed in 1984 GPO	USFS (2013)
8.5	miles from marine terminal at Hawk Inlet to the mine/mill site	Hecla Greens Creek Mining Company (2020)

Production and Process

Initially, it was thought that Greens Creek Mine would produce about 800 tons per day of ore and 300 tons per day of waste rock (USFS 1983). The 1983 EIS predicted that 160 tons of zinc concentrate and 100 tons of lead concentrate would be produced per day (USFS 1983), for a combined production of 94,900 tons per year. The 2013 EIS more than doubled that rate, and described the annual production of zinc, lead, and bulk concentrates as 200,000 tons per year (~550 tons daily). By 2013, ore was mined at a rate of ~2,200 tons per day (USAFS 2013).

As described in the initial EIS (USFS 1983):

> The project would use a selective flotation milling process to concentrate valuable minerals. The flotation process would consist of three major steps: size reduction, mineral concentration, and moisture reduction of the concentrate.
>
> Size reduction involves crushing ore from the mine in jaw and cone crushers similar to the types used in the production of road base material at a rock quarry. Ore would enter the crushing plant at a diameter of 12-inches or smaller and leave in the one-half inch size range. From the crushing plant, the ore would be conveyed to a grinding mill that would reduce the ore size further and produce a slurry.
>
> The ore slurry would then be transported in pipes or launders to flotation cells or tanks, where valuable minerals would be separated from waste materials in a froth flotation process. The ore minerals in this case would be sulfides of lead, zinc, silver, and uncombined gold. Waste would include various silicate, carbonate, and sulfide minerals. The valuable minerals adhere to air bubbles that rise to the surface of the tank and are removed. To make the process work efficiently it would be necessary to add air and various reagents to the tanks. This would allow the bubbling or frothing action to float different ore minerals selectively, so that metal concentrates could be produced. The concentrator would recover about 90 percent of various valuable minerals and would separate more than 90 percent of the waste rock from the concentrate.
>
> Following separation of the ore minerals from waste rock, the concentrate slurry would be piped to a thickener tank where the water content would be reduced. The thickened slurry would be filtered to remove most of the remaining water and the concentrate would be ready for shipment to an off-site smelter.

Transportation corridor

The first EIS stated that ore would be transported from the underground mine to the mill via a 35-ton truck or tram car (USFS 1983). Ore concentrate is transported from the mill to storage facilities at the Hawk Inlet Facility, which was built on the site of an old cannery. The initial EIS anticipated there being five shiploads of supplies and concentrates traveling in and out of Hawk Inlet monthly (USFS 1983). The ore concentrate is shipped to smelters (USFS 2013a). The road from the Hawk Inlet Facility, where supplies are brought in and ore concentrate is shipped out, to the mill site is 8.5 miles long (Hecla Greens Creek Mining Company 2020).

The mill location – whether at the mine service area or the tailings pond – was a determining factor in whether the tailings would be transported via a 7.5-mile pipeline to the tailings pond or discharged directly into it (USFS 1983). Of the six Alternatives presented in the DEIS, five of them, including the Forest Service Preferred Alternative, included the tailings pipeline (USFS 1983). The initial EIS (USFS 1983) approved a tailings slurry pipeline. However, when Amelsco Minerals Incorporated became the project director in 1986, they reviewed the mine plans and changed the tailings handling from a slurry pipeline to trucked tailings. The distance from the mill to the tailings disposal facility is ~7.8 miles. The 2013 EIS (USFS 2013a) described the tailings transportation as they were then:

> Currently tailings are transported from the mill to the TDF in 45-ton capacity covered tractor/trailer trucks. Approximately 20 to 40 round trips (15.6 miles for each round trip)from the mill to the TDF are made daily, delivering an average of 1,000 tons to the TDF.Round trip travel time for each truck is approximately one hour. Tailings transport isusually conducted during the day shift with two to four trucks in use at any given time.

The 2013 EIS described alternative locations for the tailings disposal, including shipping them off-site for disposal elsewhere (USFS 2013a). That possibility was not carried farther due to economic constraints as the costs would quadruple, making it prohibitively expensive, and because

> Shipping tailings off site would involve moving the tailings to the existing load-out facility, loading them onto a ship, transporting them to a different location, offloading them, and then placing them in a facility with a similar design to the existingTDF. This approach would not eliminate environmental impact since the existing tailings would remain in place and would create similar impacts in another location. The process would also increase the potential for spills to the marine environment as a result of the additional handling that would be necessary for transportation. (USFS 2013a)

Alternatives C and D of the 2013 EIS would have increased the distance from the mill to the tailings disposal facility to 21.2 miles roundtrip (USFS 2013a). Some of the tailings are used to backfill the mine, leaving 180,000 cubic yards per year of tailings to be delivered to the tailings disposal facility by truck (USFS 2013a).

List of hazardous materials to be transported

Ore concentrate

The 1983 EIS predicted that 160 tons of zinc concentrate and 100 tons of lead concentrate would be produced per day (USFS 1983), for a combined production of 94,900 tons per year. The 2013 EIS more than doubled that rate, and described the annual production of zinc, lead, and bulk concentrates as 200,000 tons per year (~550 tons daily).

Reagents, including blasting reagents and water treatment chemicals

The reagents list varied over time and exact amounts of chemicals have not been specified. The 1983 FEIS mentioned sodium cyanide, copper sulphate, and inorganic and organic salts as potential pollutants (USFS 1983) (Table 5.2). Sodium cyanide was described as the most significantly toxic chemical to be used (USFS 1983) but has not been mentioned in subsequent reagent lists (Table 5.2). Appendix G of the second EIS (USFS 2003) mentioned concentrated sulfuric acid, SIPX, MIBC, and lime, among other reagents (Table 5.2). The list of specified reagents has grown, with the most extensive list in Appendix 7 of the 2020 General Plan of Operations (Hecla Greens Creek Mining Company 2020).

Table 5.2. Reagents listed in permitting documents (USFS 1983, 2003) and General Plan of Operations (Hecla Greens Creek Mining Company 2020).

Reagent	USFS (1983)	USFS (2003), Appendix G	Hecla Greens Creek Mining Company (2020)		
			Table 2-1	Appendix 5	Appendix 7
Aerophine			x	x	x
Carbon dioxide			x	x	
Copper sulfate	x		x	x	x
Ferric chloride			x	x	x
Flocculents			x	x	x
Flotation reagents				x	
Fluxes					x
Goldenwest 774			x		
Hydrogen peroxide					x
Lime		x	x	x	x
MIBC		x	x	x	x
Muriatic acid					x
Perol 351		x			
Polyoxyparafins					x
SIPX		x	x	x	x
Sodium carbonate				x	
Sodium cyanide	x				
Sodium hydroxide		x			x
Sodium nitrate					x
Sodium sulfite				x	
Sulfuric acid (93%)		x		x	x
Unimax SD-200				x	
Urea					x
Water softening and anti-scalant agents					x
Zinc sulfate			x	x	x

Only two reagents had further descriptions of their uses or properties.

> MIBC: A frothing reagent used in the mill flotation process (USFS 2003)
>
> Sodium hydroxide: A common laboratory reagent that is strongly alkaline when in solution with water (USFS 2013a)

See Appendix A for details about the materials listed for and spilled at the mine.

The amount of blasting agents to be used was not specified. Therefore, I will use an estimate of 0.4 tons of ammonium nitrate per year for each ton of ore produced per day. Under the initial production level of 800 tons per day of ore (USFS 1983), 320 tons of ammonium nitrate would be needed annually.

If 2,200 to 2,300 tons of ore are produced daily (USFS 2013a and Hecla Green Creek Mining Company 2020, respectively), then 880 to 920 tons of ammonium nitrate would be used each year.

Diesel and other fuels

The initial EIS described a 400,000 gallon supply of diesel as enough for 40 days (USFS 1983), or a consumption rate of 10,000 gallons per day. By the time the second EIS was produced, the usage was 200,000 gallons every 10 days (USFS 2013a), or a consumption rate of 20,000 gallons per day. Under normal operating conditions, 2-3 tanker trucks carrying 9,000 gallons of diesel are required on a weekly basis, as well as 4,000 gallons per month of lubricating oils and hydraulic oil (Hecla Greens Creek Mining Company 2020). If the mine needs to generate its own power, 12 trucks per week of diesel are needed.

Tailings

The initial EIS (USFS 1983) approved a tailings slurry pipeline. However, when Amelsco Minerals Incorporated became the project director in 1986, they reviewed the mine plans and changed the tailings handling from a slurry pipeline to trucked tailings. This change was approved by the Forest Service after an EA in 1987-1988, and ore production began in 1989 (Hecla Greens Creek Mining Company 2020). On average, 1,000 tons of tailings are delivered from the mill to the TDF daily in 45-ton truckloads, with 20-40 trips per day (USFS 2013).

Load size, frequency and method

The picture of the evolving annual transportation at Greens Creek Mine had to be assembled piecemeal (Table 5.3). Load frequencies for ore concentrate, materials haulage, and fuel were specified in the 1983 EIS when the expected production rate was 800 tons per day of ore (USFS 1983). The 2013 EIS, which was focused on extending the tailings storage capacity, made note of the ore production rate, fuel delivery schedule, and tailings transport (USFS 2013). The most recent General Plan of Operations included an updated nominal ore production rate, as well as fuel usage values. Assuming that the load sizes for ore concentrate, mine materials, fuel, and tailings have remained constant and that ore concentrate and tailings production scale linearly with ore production, the number of trips for ore concentrate, mine supplies, and tailings transportation can be estimated (Table 5.3).

Table 5.3. Stated and inferred transportation quantities, load sizes, and load frequencies at Greens Creek Mine over time. Quantities stated directly in the references are in shaded cells.

	USFS 1983	USFS 2013a	Hecla Greens Creek Mining Company 2020
Ore production	800 tons/day	2,200 tons/day	2,300 tons/day
Truck capacity for ore	35 tons/truck	35 tons/truck	35 tons/truck
Ore concentrate production	94,900 tons/year	200,000 tons/year	209,090 tons/year
	260 tons/day	548 tons/day	573 tons/day
Truck capacity for ore concentrate	52 tons/truck	52 tons/truck	52 tons/truck
Trips for ore concentrate	5 trips/day	11 trips/day	11 trips/day
	1,825 trips/year	4,015 trips/year	4,015 trips/year
Trips for material haulage	5 trips/day	14 trips/day	14 trips/day
	1,825 trips/year	5,110 trips/year	5,110 trips/year
Fuel	18,000 gallons/day	200,000 gallons/10 days	22,500 gallons/week
Fuel truck capacity	9,000 gallons	9,000 gallons	9,000 gallons
Trips for fuel	2 trips/day	2 trips/day	2-3 trips/week usually; up to 12 trips/week
	730 trips/year	730 trips/year	130-600 trips/year
Tailings	360 tons/day hauled by truck to the TDF	324,000 tons/year hauled by truck to TDF 1,000 tons/day hauled by truck to the TDF	1,045 tons/day hauled by truck to the TRF
Tailings truck capacity	45 tons/truck	45 tons/truck	45 tons/truck
Trips for tailings	8 trips/day	20-40 trips/day	23 trips/day
	2,920 trips/year	7,300-14,600 trips/year	8,395 trips/year

Spill risks discussed in the permitting documents

The initial EIS for Greens Creek (USFS 1983) acknowledged the risks of spills of hazardous substances:

> Potential pollutants would include chemicals used in the milling process such as sodium cyanide, copper sulphate, and other inorganic and organic salts. Fuel, hydraulic fluid, cement, and other materials would be used and stored in the mine and mine service area. Although those materials would be carefully transported, stored, and used, the potential for spillage exists.

but stated that the chances of spills reaching streams and causing environmental damage was low. When the EIS for the tailings disposal facility expansion came out in 2013 (USFS 2013a), the spill risk of a chemical or mining product spill having an impact on aquatic resources under Alternative D (the chosen Alternative) was described as similar to Alternative A ("Low, due to [best management practices] and Spill Prevention, Control and Countermeasure Plan requirements"), except that the area of potential spills would expand to include Fowler Creek Drainage and would extend for 30-50 years, rather than to 2019. The Forest Supervisor selected Alternative D in his Record of Decision with the primary modification to "delete construction of a second tailings facility in the Fowler Creek watershed" and "authorize[d] the Greens Creek Mine to expand the existing tailings disposal facility by about 18 acres, further south into the Admiralty Island National Monument" (USFS 2013b). ADEC (2021) recorded 753 spills at Greens Creek Mine from 1995-2012. (See Table 5.5 in the *Spills reported by the mine* section.) The average annual number of spills prior to the 2013 EIS was 41.8 spills per year. Had that rate continued through 2013-2019, then 292.8 more spills would have been expected, and 1,255-2,091 more spills would have been expected in 30-50 years. In fact, ADEC (2021) lists an additional 662 spills from 2013-2019, for an average annual spill rate of 94.6 spills per year for those 7 years. If that rate were consistent over 30-50 years, 2,837-4,729 spills would be expected over the extended life of the project.

According to the Record of Decision (USFS 2013b), Section 3.5 describes the "Spill response and reporting procedure. Detailed Contingency Plan outlines spill response and reporting procedures in the event of a spill of a hazardous substance." The spill risks to marine waters and potential responses were actually addressed in Section 3.7 of the EIS (USFS 2013a):

> With continued operation for another 30 to 50 years, the chance of accidental spills of concentrate during loading or transport would continue. However, since the 1989 spill, no observed spills or leakage of concentrate to the marine environment have been documented. While the monitoring program has indicated some metals have remained elevated near the loading dock, there is no indication of a trend of increasing metals concentrations and such a trend is not anticipated to develop under Alternative B.
>
> Large fuel spills from offloading to the terminal or during transit of the fuel vessel is also a risk that would continue for the duration of operations (30–50 years). Typical fuel barge offloading to a 200,000-gallon storage facility occurs about every 10 days. The largest reported spill to marine waters at the site was 3,000 gallons and occurred in 1989 during an offloading. In the entire project area all other documented spills were less than 100 gallons per event. The

> Greens Creek Mine has a detailed Spill Prevention Control and Countermeasures Plan addressing procedures to be followed to prevent spillage of all hazardous liquids to water systems. While the risk of spills at the dock seems remote, effects of a spill near the dock could have substantial short-term adverse effects and some potential long-term effects. The effect would depend on weather, tides, size, location, and material involved in the spill. While there is substantial water exchange locally, Hawk Inlet is a confined bay and the confined nature of this area would aid in retaining much of a spill in the inlet where it could impact shoreline intertidal areas. Depending on the season and where a spill occurred, various resources could be affected. For example, during early spring pink and chum salmon rear in shallow shoreline areas. With the substantial salmon runs into several of the Hawk Inlet tributaries the number of early rearing fish potentially exposed to hydrocarbons could be high. But these fish may actively move away from toxic concentrations thereby reducing effects. There is a substantial intertidal community; especially at the head of the inlet where extensive shallow areas could be affected by a spill. Dissipation and evaporation of oil and fuel would limit effects over time. However, spill control plans and rapid response to spills would be the primary mitigation measures to avoid or minimize adverse spill effects to marine resources. The confined nature of Hawk Inlet aids cleanup and response actions compared to unsheltered waters, potentially retaining much of a spill within a smaller area and reducing effects outside of the inlet. HGCMC maintains marine spill response equipment onsite and fuel barge unloading is closely monitored by trained employees to ensure rapid response in the event of a spill. Additionally, HGCMC maintains an active membership in the Southeast Alaska Petroleum Resource Organization. This membership makes available substantial quantities and types of response equipment and personnel in the event of a petroleum spill as well as training and support.

In addition to potential harm to the marine environment, the 2013 EIS (USFS 2013a) notes that spills of diesel, reagents, ore concentrate, and tailings could potentially affect groundwater quality, and freshwater quality and resources. While many of these risks would cease with mine operations, water treatment of the tailings disposal facility effluent, and thus the hauling to water treatment chemicals, "would be required for at least 100 years, perhaps in perpetuity" (USFS 2013a).

Example calculations for transportation spills

An order of magnitude value of the *N* = *RT* model using the Harwood and Russell (1990) spill rate per mile can be estimated for the combined number of trips required for ore concentrate, reagents and supplies, fuel, and tailings that would be transported by truck (Table 5.4). For this exercise, I have used values of the number of annual trips required for each type of mine supply, product, or by-product based on annual ore production of 2,200 to 2,300 tons per day (Table 5.3). The reagents and supplies are trucked 8.5 miles from Hawk Inlet to the mill site, and the ore concentrate is trucked 8.5 miles from the mill site to Hawk Inlet. The tailings storage facility is 7.8 miles from the mill site. Based on the number of annual trips and the trip lengths, Greens Creek Mine trucks would log more than 145,000 miles per year with environmentally hazardous materials, and each year there would be a 2.7% chance of a spill related to a trucking accident. If the mine had operated at 2,200 to 2,300 tons of ore produced each year for the 28 years it has been in operation, then more than 4,000,000 truck miles have been traveled. With that level of exposure, the Harwood and Russell (1990) spill rate suggests that 0.76 spills from vehicle accidents should have occurred since 1989, and a 53.4% chance of at least one spill related to a truck accident.

Table 5.4. Example calculations of transportation spill risks in number of spills per year and probability of at least one spill.

	Ore concentrate	Reagents and supplies	Fuel	Tailings	Combined
Annual amount	200,000 tons			365,000 tons	
Load size	52 tons		9,000 gallons	45 tons	
Loads per year	4,015	5,110	300	8,400	
Miles per trip	8.5	8.5	8.5	7.8	
Miles per year	34,127	43,435	2,550	65,520	145,632
Spill risk per mile	1.87×10^{-7}	1.87×10^{-7}	1.87×10^{-7}	1.87×10^{-7}	1.87×10^{-7}
Expected spills per year	0.0064	0.0081	0.0005	0.0123	0.0272
P(≥1 spill per year) (%)	0.64%	0.81%	0.05%	1.22%	2.69%
Project years to 2020	Operating 1989-1992 (4 years, inclusively) and 1997-2020 (24 years, inclusively), for a total of 28 years				
Miles since production began to 2020	955,570	1,216,180	71,400	1,834,560	4,077,710
Spill risk per mile	1.87×10^{-7}	1.87×10^{-7}	1.87×10^{-7}	1.87×10^{-7}	1.87×10^{-7}
Expected spills over the project to 2020	0.18	0.23	0.01	0.34	0.76
P(≥1 spill over the project to 2020) (%)	16.36%	20.34%	1.33%	29.04%	53.35%

EPA responses to project proposal

The EPA letter in response to the 2003 Draft EIS made no mention of spills or reagents (EPA 2003a). The EPA's response to the 2012 DEIS regarding the tailings disposal facility expansion included that "The EPA has a particular interest in the water quality issues, especially the need for long-term water quality treatment at the Greens Creek Mine" (EPA 2012), and, while the EPA was "pleased to note that the DEIS addresses a number of our concerns, clarifying the need for and commitment to long term water treatment and adaptive management..., EPA still believes that there is inadequate information regarding financial assurance and environmental analysis. The EPA also has concerns regarding long term environmental impacts to wetlands and Monument values" (EPA 2012). In particular, and related specifically to geochemical modeling but also more broadly applicable, the EPA (2012) stated:

> In addition, we also believe that the modeling predictions used in the analysis are limited and lack sufficient detail to support long term planning. Without knowledge of the model and assumptions, reviewers and the decision maker cannot understand the environmental risks, ensure that adequate mitigation is required, and support selecting an alternative that meets the purpose and need while minimizing impacts...The USFS should disclose the probability that predictions are accurate and identify any uncertainties or gaps. The level of confidence in predicted outcomes should be provided so that reasonable decisions about management, monitoring, and mitigation will be made. Disclosure of the uncertainty and sensitivity analysis is a key component in interpreting predictions. We recommend considering the EPA's guidance [USEPA. 2009. Guidance on the Development, Evaluation, and Applications of Environmental Models. https:/ /ecf.oknd.uscourts.gov/cgi-bin/DisplayPDF.pl?dm id-852412&dm seg-17] as a resource on sufficient level of detail when discussing environmental modeling.

Overall, the draft EIS for the tailings disposal facility expansion was rated Category 3: Inadequate, which meant that:

> EPA does not believe that the draft EIS adequately assesses potentially significant environmental impacts of the action, or the EPA reviewer has identified new, reasonably available alternatives that are outside of the spectrum of alternatives analyzed in the draft EIS, which should be analyzed in order to reduce the potentially significant environmental impacts. EPA believes that the identified additional information, data, analyses, or discussions are of such a magnitude that they should have full public review at a draft stage. EPA does not believe that the draft EIS is adequate for the purposes of the National Environmental Policy Act and or Section 309 review, and thus should be formally revised and made available for public comment in a supplemental or revised draft EIS. On the basis of the potential significant impacts involved, this proposal could be a candidate for referral to the CEQ. (EPA 2012)

For more about EPA's ratings of EISs, see Section 6.2 of Lubetkin (2020).

Spills reported by the mine

The most recent General Plan of Operations (Hecla Greens Creek Mining Company 2020) included detailed lists of spills. The first was Attachment B to Appendix 5, which was a history of spills and leaks from 2013-2020 (Table 5.5). The spill date, location, material, and quantity (as small as 0.03 gallons) were listed for each spill, as were brief descriptions of 58 incidents, how they were cleaned up, and any corrective actions taken. Materials spilled included non-crude oil, hazardous substances, process water, treated water, storm water, and run-off. Attachment K of Appendix 9b was the oil spill history of Greens Creek Mine from 1989 to 2019. It included 139 spills, 17 of which were from prior to the ADEC (2021) spill record that began in July 1995 (Table 5.5). The spill date, material, quantity (down to < 1 gallon), and location were listed for the spills, as well as the equipment they were associated with, a brief incident description, whether the spill reached ground or concrete, and whether it was contained. Nearly all the spills listed in Attachment K were of non-crude oil, such as diesel fuel and hydraulic oil, but there were also five glycol spills included (two each in 2008 and 2009 and one in 2018).

I compared the ADEC (2021) spill records for Greens Creek Mine against both Appendix 5 Attachment B and Appendix 9 Attachment K, as well as the two attachments against one another (Tables 5.5 and 5.6). There is little temporal overlap between Appendix 5 and Appendix 9b, and the largest number of spills reported in a single year for either attachment is 12. In contrast to the 139 spills from 1989-2020 given in Appendix 9b (five of which were not oil spills), there were 1,399 *non-crude oil* spills listed in ADEC (2021) for Greens Creek from July 1995-December 2020 (Table 5.5). While 32 of the 58 spills listed in Appendix 5 were also listed in Appendix 9b and ADEC (2021), there were 26 spills that were not listed in Appendix 9b and/or ADEC (2021).

Table 5.5. Summary from Greens Creek spill logs. Shaded rows indicate years when operations were suspended due to low metal prices (Hecla Greens Creek Mining Company 2020).

Year	GPO Appendix 05 Attachment B History of Spills and Leaks	Appendix 9b Attachment K Oil Spill History	ADEC (2021)	
			Non-crude oil	All substance classes
1989	-	1	-	-
1990	-	2	-	-
1991	-	3	-	-
1992	-	4	-	-
1993	-	0	-	-
1994	-	2	-	-
1995	-	10	2	2
1996	-	7	7	7
1997	-	6	5	7
1998	-	1	0	1
1999	-	9	8	10
2000	-	12	14	17
2001	-	11	32	32
2002	-	3	20	23
2003	-	2	16	16
2004	-	4	54	61
2005	-	3	44	49
2006	-	2	19	22
2007	-	0	18	24
2008	-	5	57	64
2009	-	9	247	260
2010	-	4	48	56
2011	-	1	46	53
2012	-	3	45	49
2013	7	4	30	35
2014	11	6	31	35
2015	6	4	26	29
2016	7	6	44	45
2017	8	7	214	218
2018	7	4	158	166
2019	9	4	124	134
2020	3	-	90	94
Total	58	139	1,399	1,515

Table 5.6. Comparison of spill records listed in A: GPO Appendix 05 Attachment B History of Spills and Leaks, B: Appendix 9b Attachment K Oil Spill History, and C: ADEC from Greens Creek Mine from 2013-2020.

Year	Spill listings that match across			Spills only listed in A	Spills in A (Total)
	A, B, and C	A and B, but not C	A and C, but not B		
2013	3	1	2	1	7
2014	6	0	0	5	11
2015	3	1	0	2	6
2016	5	1	0	1	7
2017	7	0	0	1	8
2018	3	1	1	2	7
2019	5	0	2	2	9
2020	0	0	1	2	3
Total	32	4	6	16	58

There were 20 spills that were listed in Appendix 5 that were not listed in ADEC (2021), four of which were listed in Appendix 9b Attachment K (Table 5.6). There were 26 spills in Appendix 9b since June 1995 that were not listed in ADEC (2021), including four which were included in Appendix 5. Overall, the ADEC (2021) record from June 1995-December 2020 is missing 42 spills that are in the Greens Creek Mine records.

Appendix 5 included six spills between June 2013 and April 2020 of at least 5,000 gallons that were not part of ADEC (2021). Spills of treated process water (estimated at 2,000,000 to 9,000,000 gallons), treated water (5,400,000 gallons), and treated wastewater (600,000 gallons) are the three largest examples (Table 5.7). Seventeen of the oil spills in Appendix 9b that were not in ADEC (2021) were from prior to July 1995 (Table 5.8), the largest of which was a 3,300-gallon diesel release due to a valve failure in April 1989. The oil products spilled onto cement, ground, and water, and only some were listed as having been contained. Even when spills are included in multiple lists, the details, such as spill volume, can differ (Table 5.9).

Table 5.7. Spills in GPO Appendix 05 Attachment B but not in Appendix 9b Attachment K and/or ADEC. Spills shown in shaded rows only appear in Appendix 5.

Date	Location	Spilled material	Quantity spilled		Equipment	Listed in Att. K or ADEC?
4/7/2013	Port facility	Diesel	250	gal	lube truck	Att. K
6/2/2013	920 mill complex	Process water	100	gal	tails filter press	ADEC
6/13/2013	Hawk Inlet	Treated process water	2,000,000 to 9,000,000	gal	AVR	neither
12/10/2013	920 Mill complex	Zinc sulfate	1,200	lb	super sack	ADEC
4/16/2014	DB02	Process water	50-100	gal	HDPE pipe	neither
5/31/2014	920	Process water	50	gal	HDPE pipe	neither
6/19/2014	WTP Pond 7	Process water		gal	10" pipeline	neither
7/8/2014	Forest	Treated water	5,400,000	gal	AVR	neither
9/10/2014	DB02	Storm water	100	gal	920 Ditch	neither
1/1/2015	Underground	Hydraulic fluid	50	gal	LR46	Att. K
8/24/2015	WTP Pond 7	Treated water	17,500	gal		neither
9/28/2015	1350 Adit	Mine drainage	Unknown	gal	N/A	neither
4/10/2016	1.2 B-road	Water	300	gal	8" pipeline	neither
7/1/2016	Tailings	Hydraulic oil	45	gal	MT13 KT 17	Att. K
4/23/2017	3.4 B- road	Storm water/process water	166	gal	8" pipeline	neither
1/3/2018	C-Pond	Storm water	16,350	gal	C-Pond	neither
1/3/2018	Woods	Treated process water	5,000	gal	AVR	neither
6/18/2018	Tailings	Hydraulic oil	60	gal	MT 23	Att. K
11/15/2018	Underground	Concrete accelerant	200	gal	675 shotcrete plant	ADEC
2/1/2019	Tailings	Treated water	50	gal	AVR	neither
6/4/2019	920	Glycol	125	gal	pipeline	neither
7/6/2019	920	Hydraulic oil	35	gal	HT59	ADEC
8/8/2019	Hawk Inlet	Lubricant spray	0.001	gal	Barge	ADEC
2/21/2020	Hawk Inlet	Glycol	170	gal	Pipeline	ADEC
3/22/2020	Tailings	Runoff	600	gal	Ditch	neither
4/29/2020	5.1 mile B-road	Treated waste water	600,000	gal	10" pipeline	neither

Table 5.8. Spills in Appendix 9b Attachment K Oil Spill History that are not in ADEC (2021). Shaded rows were also shown in Appendix 5.

Date	Spilled material	quantity (gal)	Location	Equipment	Incident	Spilled onto	Contained?
4/1/1989	diesel fuel	3,300	Generator day tank	solenoid valve	valve failure during auto refill, <50 gal to water	ground/water	no
10/24/1990	diesel fuel	<1			faulty D-ring released fuel	ground	no
11/26/1990	diesel fuel	1	920 area	haul truck	truck struck power pole	ground	no
1/3/1991	hydraulic oil	60	920-storage	forklift	punched hole in full barrel	ground	no
1/21/1991	hydraulic oil	60	Hawk Inlet	ship loader	blown seal released hydraulic oil	gravel	no
9/11/1991	hydraulic oil	<10	Hawk Inlet	fuel system	line leak, sheen on water	ground/water	no
1/20/1992	hydraulic oil	60		hydraulic system	seal failure, 5 gal to water	ground/water	no
9/28/1992	diesel fuel	8	1350 area	55-gallon drum	overfilled drum/tank	ground	no
9/30/1992	hydraulic oil	40	920 area – concrete apron	hydraulic system	hydraulic line failure	ground	no
10/31/1992	hydraulic oil	20		hydraulic system	hydraulic line failure	ground	no
2/24/1994	hydraulic oil	7		hydraulic system	hydraulic line failure	ground	no
3/14/1994	diesel fuel	50	Hawk Inlet core shed	heater day tank	tank shifted	ground	no
1/21/1995	diesel fuel	>50 (est)	920-power house	DG-03 generator engine	fire; diesel spray onto exhaust	concrete	no
1/30/1995	hydraulic oil	20	B-road	haul trailer	hydraulic line failure	ground	no
2/8/1995	diesel fuel	<5	920 area	front-end loader	fuel link leak	ground	no

Table 5.8. (Continued.)

Date	Spilled material	quantity (gal)	Location	Equipment	Incident	Spilled onto	Contained?
3/16/1995	diesel fuel	15	920 area	ambulance	fuel line crack	concrete	no
5/15/1995	hydraulic oil	40		hydraulic line	hydraulic line burst	ground	no
10/25/1995	hydraulic oil	5		hydraulic hose	hydraulic hose burst	ground	no
12/2/1995	diesel fuel	10	920 area	fuel pump	nozzle failed to fully shut off	concrete	yes
12/18/1995	diesel fuel	<10	Hawk Inlet	fuel haulage trailer	dry-lock hose fitting leak	concrete	yes
12/31/1996	diesel fuel	<10	920 area	fuel pump	fuel refill valve left slightly open	concrete	yes
1/20/1997	hydraulic oil	100-150	920-surface top	lube tank hose valve	tank valve not fully closed	concrete	yes
3/25/1998	hydraulic oil	150	920-UG shop	hydraulic fluids system	line maintenance began without tank isolation	concrete	yes
5/5/1999	hydraulic oil	15	920 area	surface haul truck	hydraulic filter broken	concrete	yes
8/24/1999	used oil	30	Hawk Inlet warehouse	used oil tank	overfill holding tank during transfer	ground	no
8/28/1999	hydraulic oil	50		hydraulic system	blown hydraulic hose	ground	yes
2/24/2000	diesel fuel	20-40			tank overfilled	concrete	yes
6/19/2000	hydraulic oil	20		hydraulic system	blown hydraulic line	ground	no
7/12/2000	40-weight oil	80	920-surface shop	lubricating oil holding tank	valve left partially open following transfer	concrete	yes
7/26/2000	diesel fuel	40	tailings area	surface fuel truck	pressure gauge failure during delivery	ground	yes

Table 5.8. (Continued.)

Date	Spilled material	quantity (gal)	Location	Equipment	Incident	Spilled onto	Contained?
5/6/2001	glycol	70	920 power house	DG-05 GenSet	catastrophic engine failure		yes
8/24/2001	oil	45	mill compressor room	AC-21 air compressor	loose pipe flange fitting		yes
2/20/2008	glycol	50	mill regrind building	glycol heater	FEL fork rack struck heater feed pipes	concrete	yes
2/27/2008	jet fuel	25-50	Hawk Inlet helicopter pad	helicopter fuel tank	valve left partially open at last use	ground	no
5/3/2009	hydraulic oil	30	mill	filter press	flange blew off end of hydraulic ram	concrete	yes
5/21/2009	hydraulic oil	60	underground	haul truck	ruptured hydraulic hose	concrete and rock	yes
6/28/2009	hydraulic oil	75	underground	valve	valve fitting worked loose	cement	yes
8/5/2009	DS200	15	mill	drum	drum spilled	concrete	yes
4/11/2010	hydraulic oil	20	surface shop	tank	overfilled tank	concrete	yes
4/7/2013	diesel	250	port facility	lube truck	the transfer line rupture, while the truck was idling	gravel	no
1/1/2015	hydraulic oil	50	underground	LR-46	pump failure resulted in leak	gravel	yes
7/1/2016	hydraulic oil	45	tailings	KT-19	failure of a hydraulic line while dumping tails	tailings	no
6/25/2018	hydraulic oil	60	tailings	MT-23	broken filter housing	tailings	no

Table 5.9. Spills listed in multiple places with inconsistent volumes. The larger volumes are in shaded cells.

		Volume (gallons)	
Date	Substance	Appendix 9b Attachment K Oil spill history	ADEC Volume
5/27/1997	water/used oil	500 (est)	5 (used oil, all types)
11/19/1997	diesel fuel	50-55	30
7/21/1999	diesel fuel	300	200
10/18/2000	hydraulic oil	80	100
10/24/2000	hydraulic oil	20	15
1/17/2001	hydraulic oil	10	20
5/6/2001	lube oil	100	50
6/5/2003	aviation fuel	40	25
6/29/2004	diesel fuel	2	4
9/30/2006	diesel fuel	480	960
6/21/2010	hydraulic oil	20	10
11/3/2011	Jet A fuel	30	10
2/4/2019	hydraulic oil	30	35
2/6/2019	hydraulic oil	20	4 hydraulic oil spill incidents listed on that date with volumes of 3, 8, 8, and 20 gallons
3/23/2019	hydraulic oil	0.03	0.1

Appendix K (Hecla Greens Creek Mining Company 2020), portions of which are shown in Table 5.8, lists 139 spills. Almost 60% of the spills (80 out of 139, or 57.6%) were not contained. There were 25 spills from 2001-2006 for which the media the spilled material contacted was not listed. At least 38 releases spilled onto concrete, at least 40 spills were onto the ground, at least 11 onto gravel, and the remainder onto a mix of packed dirt, frozen ground/snow, waste rock, tailings, and ore, among others.

USFS (2013), p. 3-98

> Two events may have effected metals concentrations at two of the sampling sites, S-4 and S-5 (Figure 3.5-4). Debris from a fire in 1974 at the old cannery affected metals concentrations at sites S-4 and S-5, which were selected to monitor metals near the concentrate loading dock. A concentrate spill occurred from the shiploader site in 1989 at the shiploader facility near Site S-5. In 1995, a suction dredge was used to remove sediments in the area of the spill. Based on sampling results, a rapid increase in metals concentrations occurred after the spill and sample values have been highly variable but remain elevated in the immediate vicinity of the shiploader relative to metals concentration in other inlet sampling sites.

The shiploading spill occurred on May 16, 1989, when 9,080.884 tons of bulk concentrate and 2,340.354 tons of zinc concentrate were being loaded and “dribbled” from a chute onto a tarp (Kennecott Greens Creek Mining Company 1990). Rough estimates were that one-third of the dribbled material reached the water and two-thirds fell on land. The spill size was estimated as 95-100 pounds of lead sulfide and 900-1,000 pounds total of concentrate. According to correspondence from Kennecott Greens Creek Mining Company, this was deemed not be a reportable spill based on a preliminary sampling report.

Spill record from ADEC

I sorted the more than 12,000 spills in the Southeast Alaska subarea (ADEC 2021) by responsible party. There were 1,515 spills attributed to Greens Creek Mining from July 1995-December 2020 (Appendix B3). ADEC (2007) listed two spills of ≥1,000 gallons, both of which were included among eight such spills in ADEC (2021) (Table 5.10).

Most of the spills in ADEC (2021) were listed by volume rather than by weight (Tables 5.11 and 5.12). The most common type of spill was hydraulic oil, with 1,039 spills releasing 7,196 gallons (Figure 5.4). The largest single spill listed in ADEC (2021) was a 72,000-gallon process water spill from December 2004. Overall, more than 2,000 gallons of *hazardous substances* were spilled in 90 incidents, and more than 19,000 gallons of *non-crude oil* were spilled in just less than 1,400 incidents (Table 5.11). There were nearly 14,000 pounds of *hazardous substances*, including arsenic, lead, zinc and zinc concentrate, tailings, and copper sulfate, spilled in 15 incidents (Table 5.12).

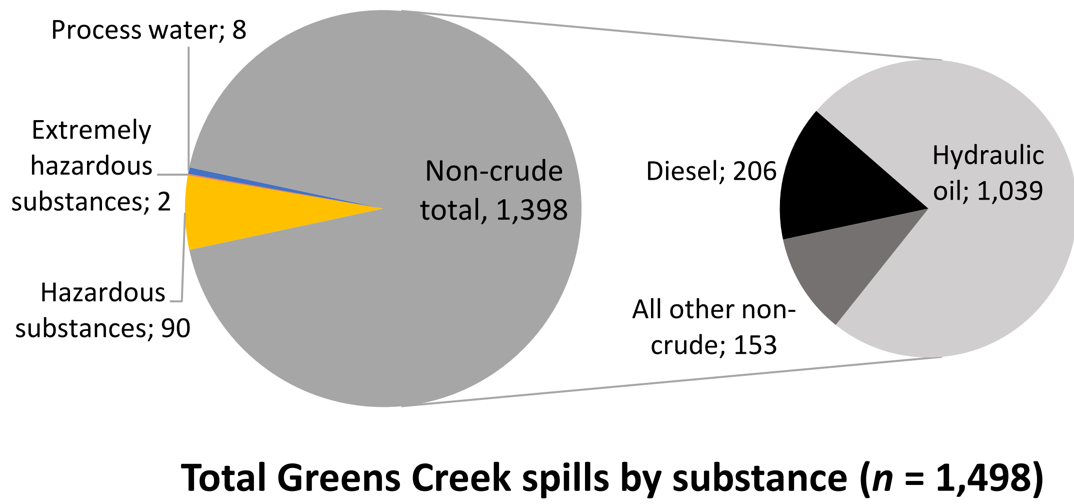
Table 5.10. There were 8 recorded spills of at least 1,000 gallons from July 1995-December 2020 at the Greens Creek Mine (ADEC 2021). Shaded rows indicate spills listed in ADEC (2007).

Date	Spill Name	Product	Gallons
12/24/2004	Greens Creek monthly report	Process Water	72,000
4/23/2011	Greens Creek Processed Water Spill	Process Water	7,000
9/25/2005	Greens Creek monthly report	Process Water	6,750
6/30/2004	Zinc Creek Drill Mud	Process Water	2,400
4/12/2012	Greens Creek Diesel Overfill	Diesel	2,000
6/27/2006	Greens Creek containment spill	Diesel	1,500
6/27/2006	Greens Creek containment spill	Used Oil (all types)	1,500
6/24/2006	Tributary Creek Process water	Process Water	1,000

Table 5.11. There were 1,499 recorded spill incidents at Greens Creek Mine from July 1995-2020 with quantities given in gallons (ADEC 2021). Total values for each substance subtype have been rounded to the gallon. Substances in shaded rows were not discussed in references describing the Greens Creek project.

		Volume (gallons)	
	n	Range	Total
Extremely hazardous substances			
Hydrogen peroxide	2	300-350	650
Hazardous substances			
Corrosion inhibitor	1	0.1	0.1
Ethylene glycol	43	0.063-305	1,165
Glycol, other	37	0.125-300	492
Other*	9	0.25-250	381
Total	90		2,038
Non-crude oil			
Aviation fuel	6	4-25	57
Creosote	1	0.125	0.125
Diesel	206	0.013-2,000	8,020
Engine lube oil	43	0.01-620	1,441
Engine lube/gear oil	9	0.1-40	60
Gasoline	3	1	3
Grease	5	0.063-10	24
Hydraulic oil	1,039	0.01-350	7,196
Kerosene	2	9-40	49
Other	16	0.03-100	235
Synthetic oil	1	2	2
Transmission oil	47	0.125-45	207
Used oil (all types)	20	0.033-1,500	1,800
Total	1,398		19,095
Process water			
Process Water	7	100-72,000	89,350
Source water	1	200	200
Total	8		89,550
Unknown	1	0.03	0.03

* Other hazardous substances listed in the spill names include “tailings fell off dozer”, “dry floc”, “methyl amyl spill”, “aerophine container puncture”, HCl, copper sulfate, and concrete admixture.



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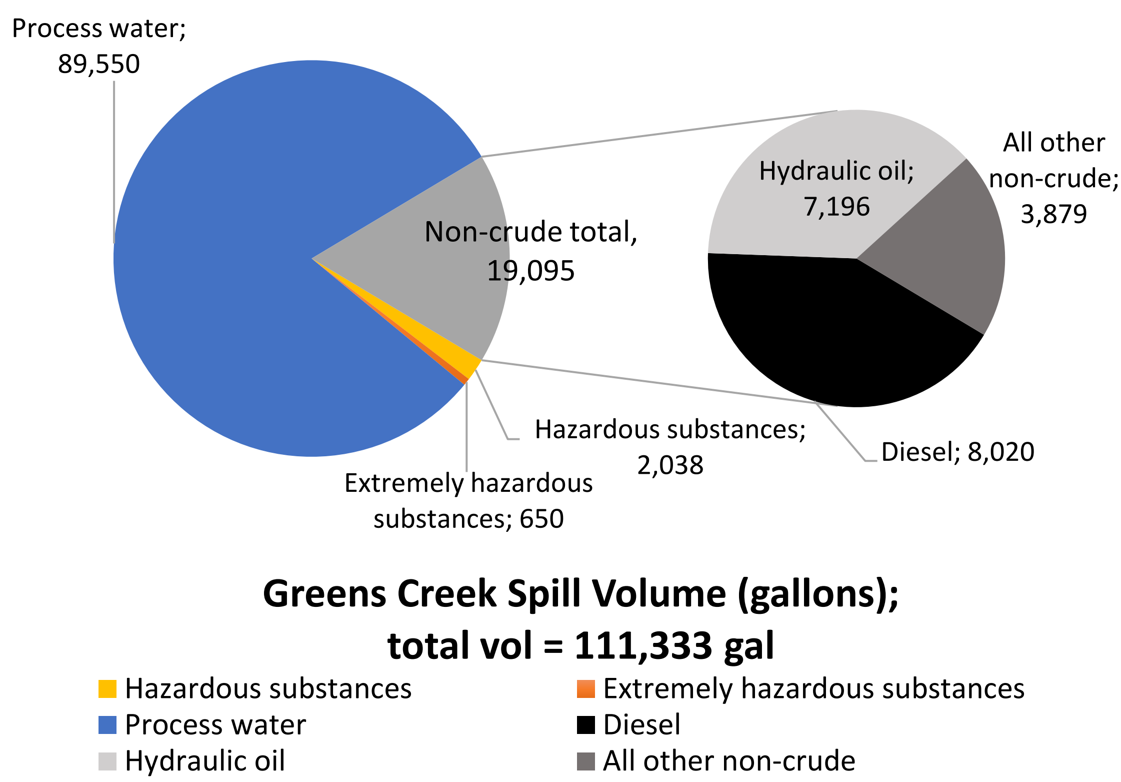


b.

Figure 5.4. Relative proportions of (a) number and (b) volume from different substance classes at Greens Creek Mine from 1995-2020 with non-crude oil spills further broken down to show the amounts due to diesel and hydraulic oil spills.

Table 5.12. There were 16 recorded spill incidents at Greens Creek Mine from July 1995-2020 with quantities given in pounds (ADEC 2021). Total values for each substance subtype have been rounded to the pound.

		Quantity (pounds)	
	n	Range	Total
Hazardous substances			
Arsenic	1	29	29
Lead	6	4-3,500	4,030
Other*	4	10-250	285
Zinc	1	1,200	1,200
Zinc concentrate	3	15-8,000	8,255
Total	15		13,799
Non-crude oil			
Other	1	100	100

* These were described in the spill names as a chemical spill, "loading shut", dry tailings, and copper sulfate.

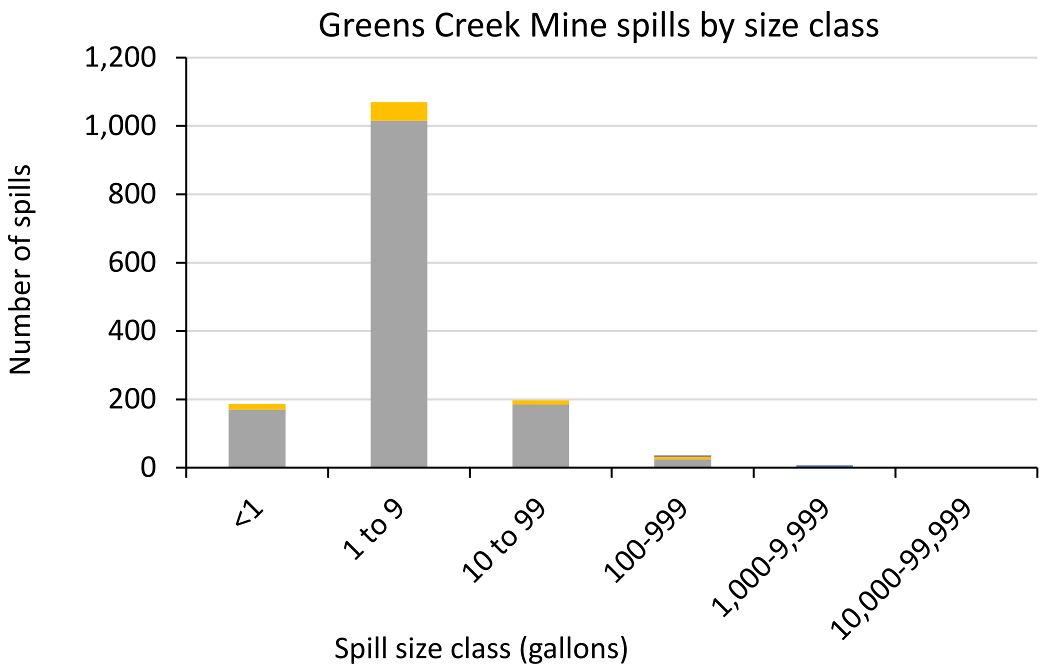
The spills of less than 1,000 gallons accounted for 99.4% of the incidents, but the remaining 0.6% of the spills represented 84.6% of the volume released (Tables 5.13 and 5.14, Figures 5.5 and 5.6). While there were relatively few *process water* spills, they accounted for the more than 80% of the spill volume in ADEC (2021) (Table 5.14, Figures 5.5 and 5.6). (Recall that the ADEC (2021) spill database did not include the largest spills listed in Appendix 5 of the most recent General Plan of Operations (Hecla Greens Creek Mining Company 2020), so the cumulative volume of process water spilled is underrepresented by millions of gallons here.) For the smaller number of spill quantities listed by weight, three spills of ≥1,000 pounds represented 18.8% of the number of incidents and 91.4% of the material spilled (Tables 5.15 and 5.16). Nearly all the spills listed by weight were of *hazardous substances*.

Table 5.13. Counts of Greens Creek Mine spills with quantities given in gallons from July 1995-December 2020 by substance class and size category (ADEC 2021). There was also one 0.03-gallon spill of an unknown substance.

Substance class	Number of spills per size class							
	Spill Size Class (gallons)							
	<1	1-9	10-99	100-999	1,000-9,999	10,000-99,999	Total	Percent
Ex Haz Sub				2			2	0.1%
Haz Sub	17	55	12	6			90	6.0%
Non-crude	170	1,015	185	25	3		1,398	93.3%
Process water				3	4	1	8	0.5%
Total	187	1,070	197	36	7	1	1,498	
Percent	12.5%	71.4%	13.2%	2.4%	0.5%	0.1%		

Table 5.14. Cumulative volume released through Greens Creek Mine spills from July 1995-December 2020 by substance class and size category (ADEC 2021). There was also one 0.03-gallon spill of an unknown substance.

Substance class	Cumulative volume spilled per size class (gallons)							
	Spill Size Class (gallons)						Total	Percent
	<1	1-9	10-99	100-999	1,000-9,999	10,000-99,999		
Ex Haz Sub				650			650	0.58%
Haz Sub	5	188	345	1,500			2,038	1.83%
Non-crude	45	3,631	4,399	6,020	5,000		19,095	17.15%
Process water				400	17,150	72,000	89,550	80.43%
Total	50	3,819	4,744	8,570	22,150	72,000	111,333	
Percent	0.04%	3.43%	4.26%	7.70%	19.90%	64.67%		



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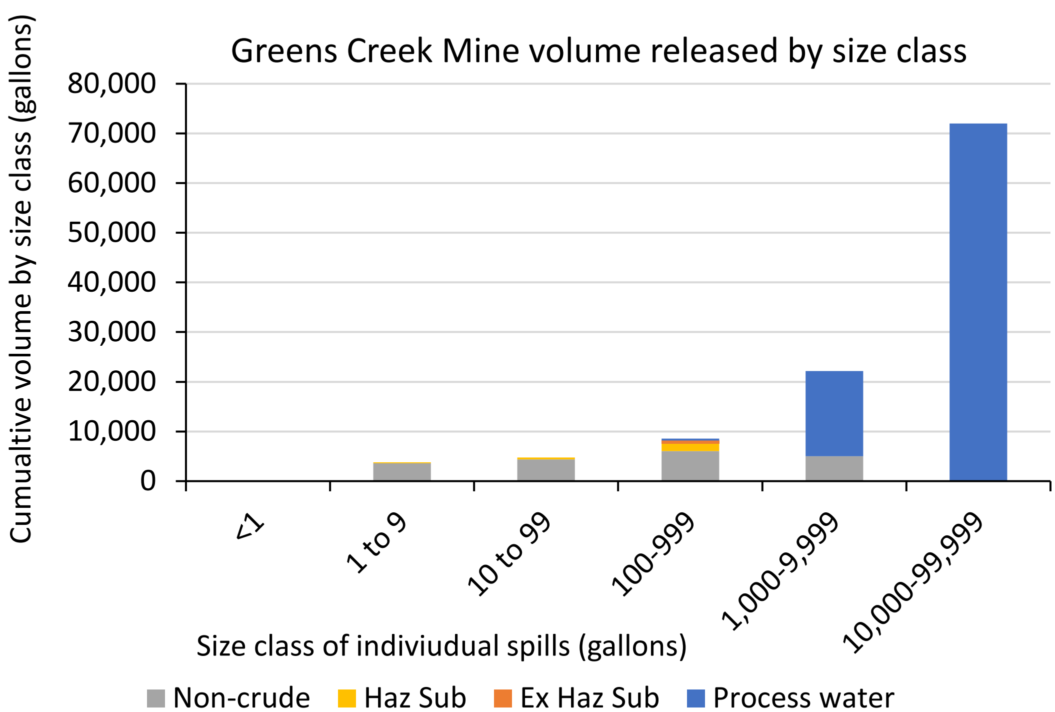


b.

Figure 5.5. Number of spill incidents (a) and cumulative gallons spilled (b) for non-crude oil, hazardous substances, extremely hazardous substances, and process water in different spill size classes for Greens Creek Mine from July 1995-December 2020 based on ADEC (2021).

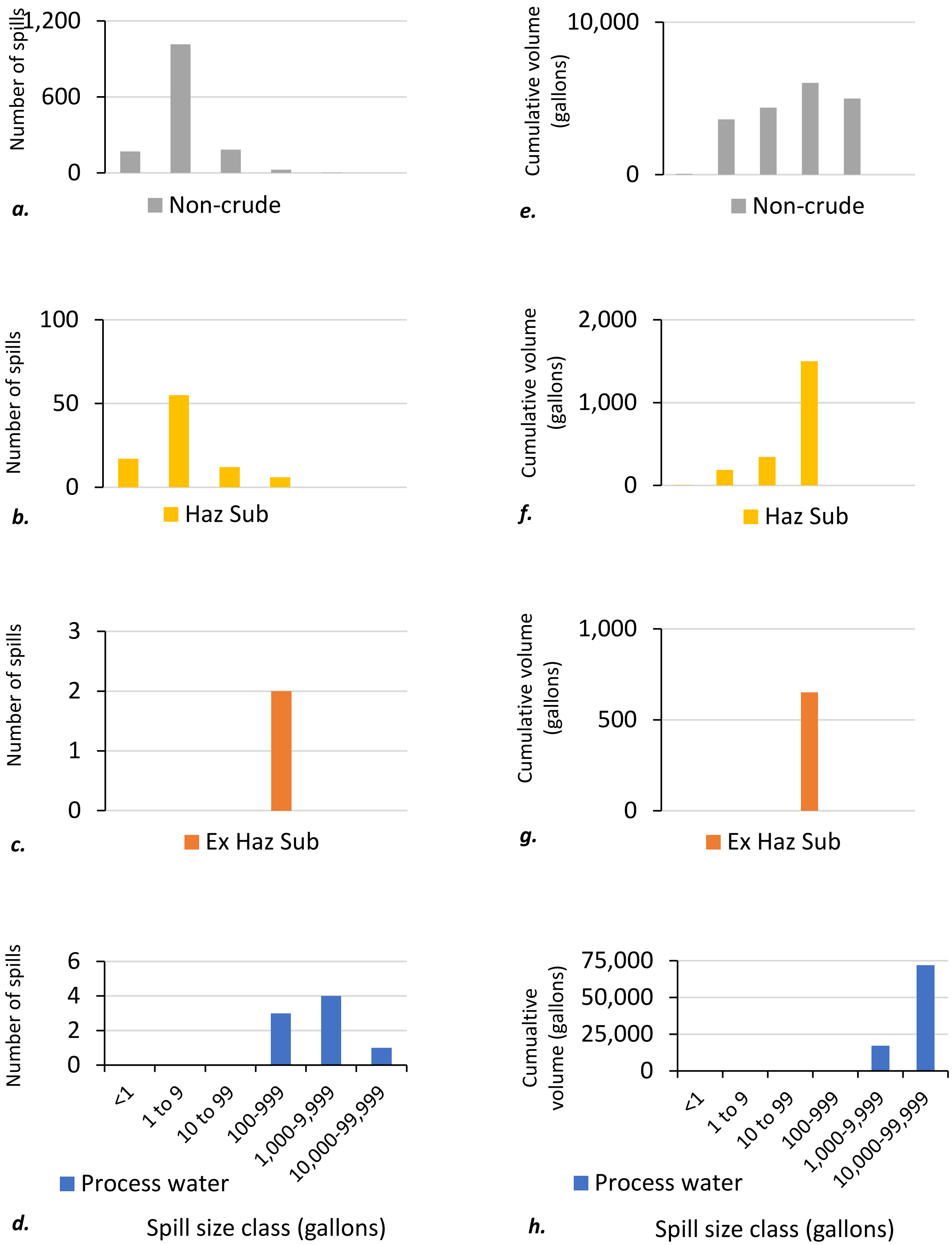


Figure 5.6. Number of spill incidents (a-d) and cumulative gallons spilled (e-h) for non-crude oil (a, e), hazardous substances (b, f), extremely hazardous substances (c, g) and process water (d, h) in different spill size classes for Greens Creek Mine from July 1995-December 2020 based on ADEC (2021). All subfigures have the same x-axes.

Table 5.15. Counts of Greens Creek Mine spills with quantities given in pounds from July 1995-December 2020 by substance class and size category (ADEC 2021).

Substance class	Number of spills per size class						
	Spill Size Class (pounds)					Total	Percent
	<1	1-9	10-99	100-999	1,000-9,999		
Haz Sub		1	7	4	3	15	93.8%
Non-crude				1		1	6.3%
Total		1	7	5	3	16	
Percent		6.3%	43.8%	31.3%	18.8%		

Table 5.16. Cumulative weight released through Greens Creek Mine spills from July 1995-December 2020 by substance class and size category (ADEC 2021).

Substance class	Cumulative volume spilled per size class (gallons)						
	Spill Size Class (pounds)					Total	Percent
	<1	1-9	10-99	100-999	1,000-9,999		
Haz Sub		4	125	970	12,700	13,799	99.3%
Non-crude				100		100	0.7%
Total		4	125	1,070	12,700	13,899	
Percent		0.03%	0.90%	7.70%	91.37%		

On average, there have been 60.3 spills each year at Greens Creek Mine from 1996-2020, including when the mine's operations were suspended (Table 5.17). Most of the annual variability is from the number of *non-crude oil* spills over time (Table 5.17, Figure 5.7). The year with the most spill incidents was 2009, when there were 260 recorded spills. There was a sizable jump in the number of spills in 2017, and, although the number of incidents has decreased since then, it was still higher in 2020 than in all but four of the previous 25 years (Table 5.17, Figure 5.7). Spills are slightly more frequent in spring and less common in winter than they are in summer and autumn (Table 5.18, Figure 5.7).

Table 5.17. Spills per year by substance type at Greens Creek Mine from July 1995-December 2020 based on ADEC (2021). There was also one spill in the unknown substance type (0.03 gallons in December 2014). Shaded rows indicate years with suspended operations.

Year	Spills				
	Ex Haz Sub	Haz Sub	Non-crude	Process water	Total
1995			2		2
1996			7		7
1997		2	5		7
1998		1			1
1999	1	1	8		10
2000		3	14		17
2001		5	32		37
2002		3	20		23
2003			16		16
2004		5	54	2	61
2005		4	44	1	49
2006		2	19	1	22
2007		6	18		24
2008	1	5	57	1	64
2009		13	247		260
2010		8	48		56
2011		6	46	1	53
2012		4	45		49
2013		4	30	1	35
2014		4	31		35
2015		3	26		29
2016		1	44		45
2017		4	214		218
2018		7	158	1	166
2019		10	124		134
2020		4	90		94
total	2	105	1,399	8	1,514
mean*	0.08	4.2	55.88	0.32	60.28
sd*	0.28	3.04	64.19	0.56	66.42

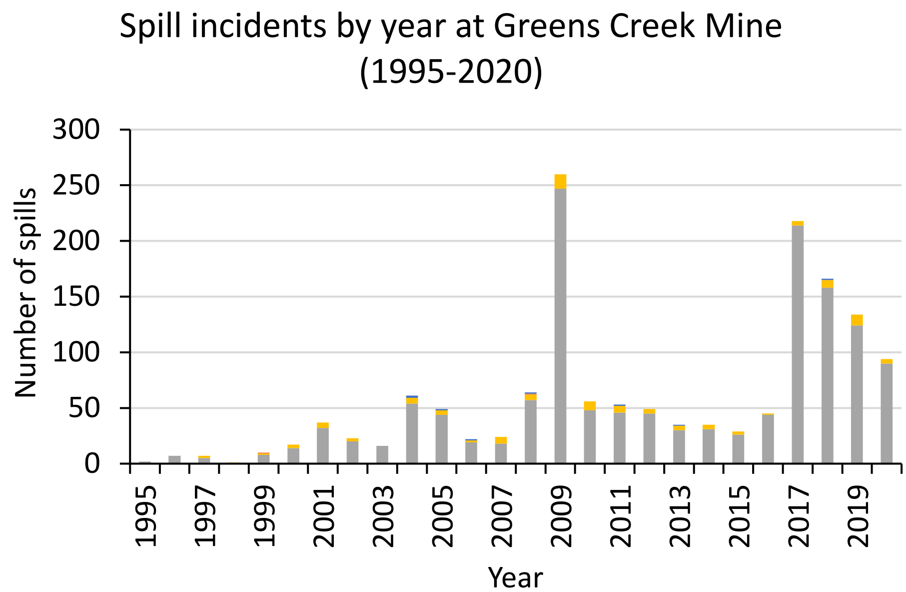
* for years with complete data (1996-2020)

Table 5.18. Total spills per month by substance type at Greens Creek Mine from July 1995-December 2020 based on ADEC (2021).

Spills	Spills					
Month	Ex Haz Sub	Haz Sub	Non-crude	Process water	Unknown	Total
January		12	82			94
February	2	7	119			128
March		4	175			179
April		10	155	1		166
May		9	159	1		169
June		6	136	3		145
July		10	108			118
August		12	103			115
September		8	103	1		112
October		12	104			116
November		8	79	1		88
December		7	76	1	1	85
Total	2	105	1,399	8	1	1,515

Hazardous substance spills were most commonly caused by *line failure* (28 spills) and *equipment failure* (26 spills) (Table 5.19). Those two causes were also the most common reasons for *non-crude oil* spills (accounting for 529 and 430 spills, respectively), followed by *human error* (70 spills), *vehicle leaks* (67 spills), *overfilling* (61 spills), and *leaks* (60 spills) (Table 5.19).

Based on a combination of *facility type*, *source type*, and *cause subtype*, I estimate there were at least 123 spills related to transportation (Table 5.20). Those spills included seven *collision/allision* incidents and three *rollover/capsize* incidents. Nearly 2,400 gallons of *extremely hazardous substances*, *hazardous substances*, and *non-crude oil* have been spilled in relation to transportation at Greens Creek Mine (Table 5.21). Most of those spills incidents and volume are associated with releases of *non-crude oil* products, especially hydraulic oil.



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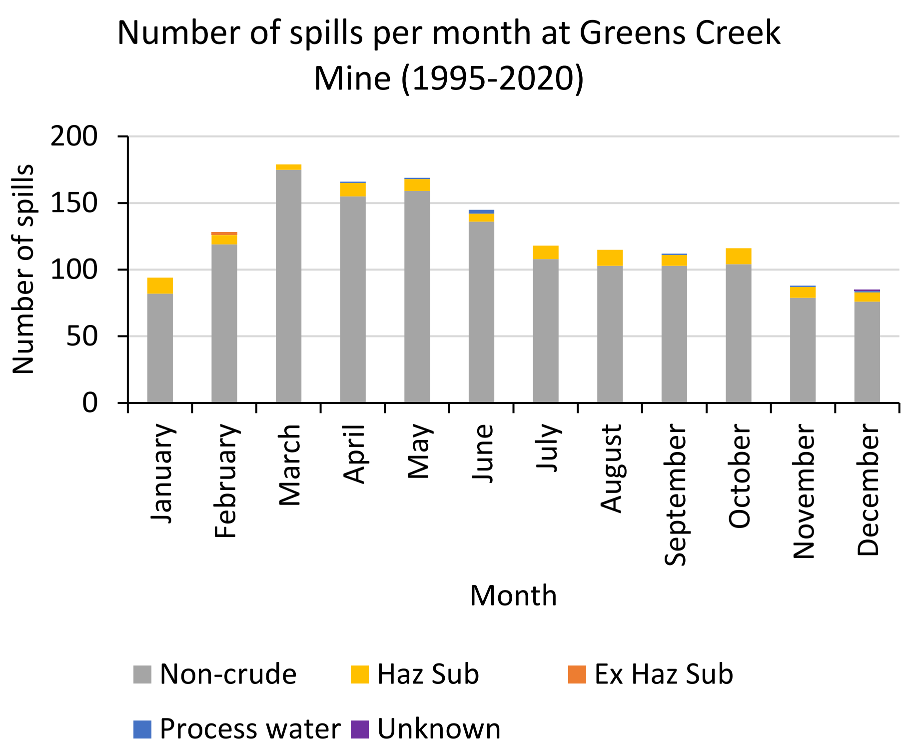


b.

Figure 5.7. Greens Creek Mine a. spills by year and b. average spills per month from July 1995-December 2020 based on records from ADEC (2021).

Table 5.19. Spills with quantities given in gallons associated with Greens Creek Mine by cause sub-type and substance category. Sixteen spills with quantities given in pounds are excluded*. One unknown spill from an unknown cause (0.03 gallons in December 2014).

Cause subtype	Extremely Hazardous Substances		Hazardous Substances		Non-crude oil		Process Water	
	n	volume range (gal)	*n*	volume range (gal)	*n*	volume range (gal)	*n*	volume range (gal)
Cargo not secured			2	0.1-7	4	0.2-150		
Collision/allision			2	2-5	5	2-50		
Containment overflow					4	1-6	1	100
Corrosion			1	10	4	1.5-120		
Crack					10	0.125-20	1	100
Equipment failure			26	0.2-170	430	0.013-250	1	72,000
External factors					2	7-10		
Gauge/site glass failure					1	200		
Human error			5	0.25-305	70	0.1-1,500	3	200-7,000
Leak			5	0.5-75	60	0.06-170		
Line failure			28	0.063-200	529	0.06-250		
Overfill			1	25	61	0.2-2,000		
Puncture			1	0.063	5	0.01-10		
Rollover/capsize			1	5	2	5-6		
Sabotage/vandalism			1	50				
Seal failure			1	0.313	56	0.125-350		
Support structure failure					2	1-8		
Tank failure					2	1-20		
Tank support structure failure					1	1		
Valve failure			3	5-275	13	0.063-960	2	1,000-6,750
Vehicle leak, all			4	2-2.5	67	0.1-50		
Other	2	300-350	5	0.1-40	40	0.063-200		
Unknown			4	0.125-250	30	0.01-50		
Total spills and volume range (gal)	2	300-350	90	0.063-305	1,398	0.01-2,000	8	100-72,000

* The causes were corrosion (1), equipment failure (1), human error (6), line failure (3), puncture (1), other (2), and unknown (1) for spills of hazardous substances ranging from 4-8,000 pounds, and a spill of 100 pounds of non-crude oil caused by "other".

Table 5.20. Transportation related spills from Greens Creek Mine from June 1995-December 2020.

Facility type	Source type	Cause subtype	*n*
Harbor/port/marina	Heavy equipment	Line failure	1
Mining operation	Container, other	Cargo not secured	3
Mining operation	Container, other	Collision/allision	1
Mining operation	Heavy equipment	Cargo not secured	2
Mining operation	Heavy equipment	Collision/allision	3
Mining operation	Heavy equipment	Rollover/capsize	3
Mining operation	Heavy equipment	Vehicle leak, all	36
Mining operation	Hydraulic system	Vehicle leak, all	28
Mining operation	Tank, other, aboveground	Collision/allision	1
Mining operation	Tank, other, mobile	Vehicle leak, all	4
Mining operation	Trailer	Equipment failure	1
Mining operation	[blank]	Cargo nor secured	1
Mining operation	Oher	Vehicle leak, all	3
Vehicle	Heavy equipment	Seal failure	1
Vehicle	Hydraulic system	Various	3
Vehicle	Other	Various	4
Vehicle	Pipe or line	Equipment failure	1
Vehicle	Tank, other	Leak	1
Vehicle	Tank, other, mobile	Various	2
Vehicle	[blank]	Various	22
Vessel		Various	2
Total			123

Table 5.21. Substances released from transportation spills associated with Greens Creek Mine based on ADEC (2021).

	n	Volume (gallons)	
		Range	Total
Extremely hazardous substances			
Hydrogen peroxide	1	350	350
Hazardous substances			
Corrosion inhibitor	1	0.1	0.1
Ethylene glycol	2	2-5	7
Glycol, other	6	2-7	21
Other*	1	50	50
Total	10		78.1
Non-crude oil			
Diesel	14	0.25-250	372.25
Engine lube oil	5	0.5-50	63.5
Engine lube/gear oil	2	1	2
Gasoline	1	1	1
Hydraulic oil	81	0.1-200	1,251.4
Other	3	3-100	109
Transmission oil	5	0.5-10	18.5
Used oil (all types)	1	150	150
Total	12		1,967.65

Environmental enforcement and Notices of Violation

EPA shows that the Greens Creek Mine has had a violation of the Clean Air Act May 2021, a violation of the Clean Water Act identified in February 2020, and was in significant noncompliance with the Resource Conservation and Recovery Act (RCRA) in August 2019 (EPA ECHO 2021b). Since 2018, Greens Creek Mine has had federally reportable violations of the Clean Air Act for particulate matter (<10 μm), total hazardous air pollutants, volatile organic compounds, carbon monoxide, carbon dioxide equivalents, nitrogen oxides, and visible emissions. Greens Creek has had permit schedule violations related to the Clean Water Act since the first quarter of 2019, as well as deficient best management practices, failure to maintain records, improper operation and maintenance, and effluent violations, among others. Greens Creek has been in significant noncompliance with RCRA from the first quarter of 2020 to the current quarter. In addition, Greens Creek has also had Safe Drinking Water Act violations of the Lead and Copper Rule, the Stage 1 and Stage 2 Disinfectants and Disinfection Byproducts rules, and the Surface Water Treatment Rule. No formal enforcement actions have taken place in the last five years, but informal enforcement has included two Notices of Violation (one each in 2017 and 2018), a Letter of Violation/Warning Letter in 2020, all of which were related to the Clean Water Act, and four warning letters between June 2017 and May 2021 pertaining to the Clean Air Act.

These most recent issues follow a 1994 action resulting in a 1997 penalty of $300,000 for copper, zinc, and pH pollution, which also incurred an estimated compliance cost of $8,000,000 (EPA ECHO 1997b), and a smaller $12,900 penalty for discharging drilling mud and four gallons of diesel into Zinc Creek in June 2004 (EPA 2006, *Juneau Empire* 2006).

A 2009 environmental audit listed 45 major findings at Greens Creek Mine. Eight of those were related to spills and releases and were at the significance level defined as “Environmental Systems: Has potential to cause an environmental effect or result in non-compliance or is non-compliant with permit requirements, policies or standards OR Management and Permits: Contradictory or ambiguous management and permit requirements OR Cost to Operation: Items between $1 million and $5 million” (SRK Consulting 2009). A decade later, a 2019 audit (HDR 2019):

> found that concrete curbing that is used for the secondary containment of reagents used in the milling process is in need of repair. The concrete curbing has deteriorated in some places such that in the event of a reagent spill, containment would be questionable. At one location the curbing was removed so that what appeared to be a heater could be installed under an area where Mill reagents are stored … The Audit Team recommends that the containment curbing for Mill reagents be assessed and repaired as necessary so that 110 percent containment is achieved.

Greens Creek Mine also received a Notice of Violation letter in February 2018 detailing nine violations relating construction and modification of dams without permits and diversion of water without authorization or certifications of approval at Ponds 7 and 10 and Sand Pit Dam (Alaska Department of Natural Resources 2018).

Most recently,

> On August 20-21, 2019 the Environmental Protection Agency (EPA) conducted a Resource Conservation and Recovery Act (RCRA) inspection of the Greens Creek Mine Port facility. During the inspection concentrate material was observed around the perimeter of the Concentrate Storage Building. It was confirmed that concentrate was escaping the structure through small gaps in the building's corrugated metal siding and initial sample results indicated the material exceeded DEC cleanup levels for both lead and zinc. Prior to October 28, 2019 some of the concentrate had been recovered and reprocessed at the mill facility. There are plans to conduct repairs to the building to prevent future releases and to excavate approximately 2-3 feet around the perimeter of the building, to a depth of 12-18 inches, and perform confirmation sampling. The DEC Contaminated Sites Program will oversee this cleanup in order to coordinate RCRA requirements with EPA. (ADEC DSPR 2021a)

The remainder of the site report described the ensuing actions (ADEC DSPR 2021a), summarized here. After using shovels to retrieve approximately 1.5 cubic yards of spilled concentrate and as little of the surrounding soil as possible in October 2019, a Vac-Truck was used to remove another 1.5 cubic yards of materials around the concentrate storage building in April 2020. A three-phase plan for cleaning up the concentrate and impacted soils was proposed in October 2019, but implementing phases 2 and 3 was delayed by the Covid-19 pandemic. By August 2020 the concentrate storage building had been sealed to prevent the loss of any further concentrate from the building, and the impacted soil was excavated around the storage building in September and October 2020, with laboratory testing for lead and zinc concentrations. In February 2021, 55.5 cubic yards (~62 tons) of contaminated soils were removed from around the building to be disposed of off-site. Further testing of the soil in April 2021 found residual contamination, and another 1-2 cubic yards of soil were removed in May 2021.

How well were the recorded spills predicted?

Using an order of magnitude estimate with the $N = RT$ model and Harwood and Russell (1990) spill rate yielded an estimate that 0.76 spills would occur at Greens Creek Mine due to transportation accidents (Table 5.22). In practice, there were 10 spills caused by *collision/allision* and *rollover/capsize* since 1995, which were just a subset of at least 123 transportation-related spills. Spills caused by *collision/allision* and *rollover/capsize* represented only 8% of the transportation spills, which were in turn only 8% of the spills listed in ADEC (2021) (Figure 5.8). The $N = RT$ model-based estimate was more than an order of magnitude too low for a subset of a subset of spills that accounted for 0.66% of the spill incidents at Greens Creek Mine since it began operations.

Table 5.22. Spills expected and observed at Greens Creek Mine through 2020.

Description of spills expected and observed at Greens Creek Mine	Value
Expected number using Harwood and Russell (1990) spill/mile rate with estimated miles per trip and number of trips (Table)	0.76
Observed transportation spills with cause subtypes collision/allision and rollover/capsize spills from ADEC (2021)	10
Observed transportation spills (all causes) from ADEC (2021)	123
Observed spills from ADEC (2021)	1,515
Observed spills from ADEC (2021), and Hecla Greens Creek Mining Company Appendices 5 and 9b	1,557

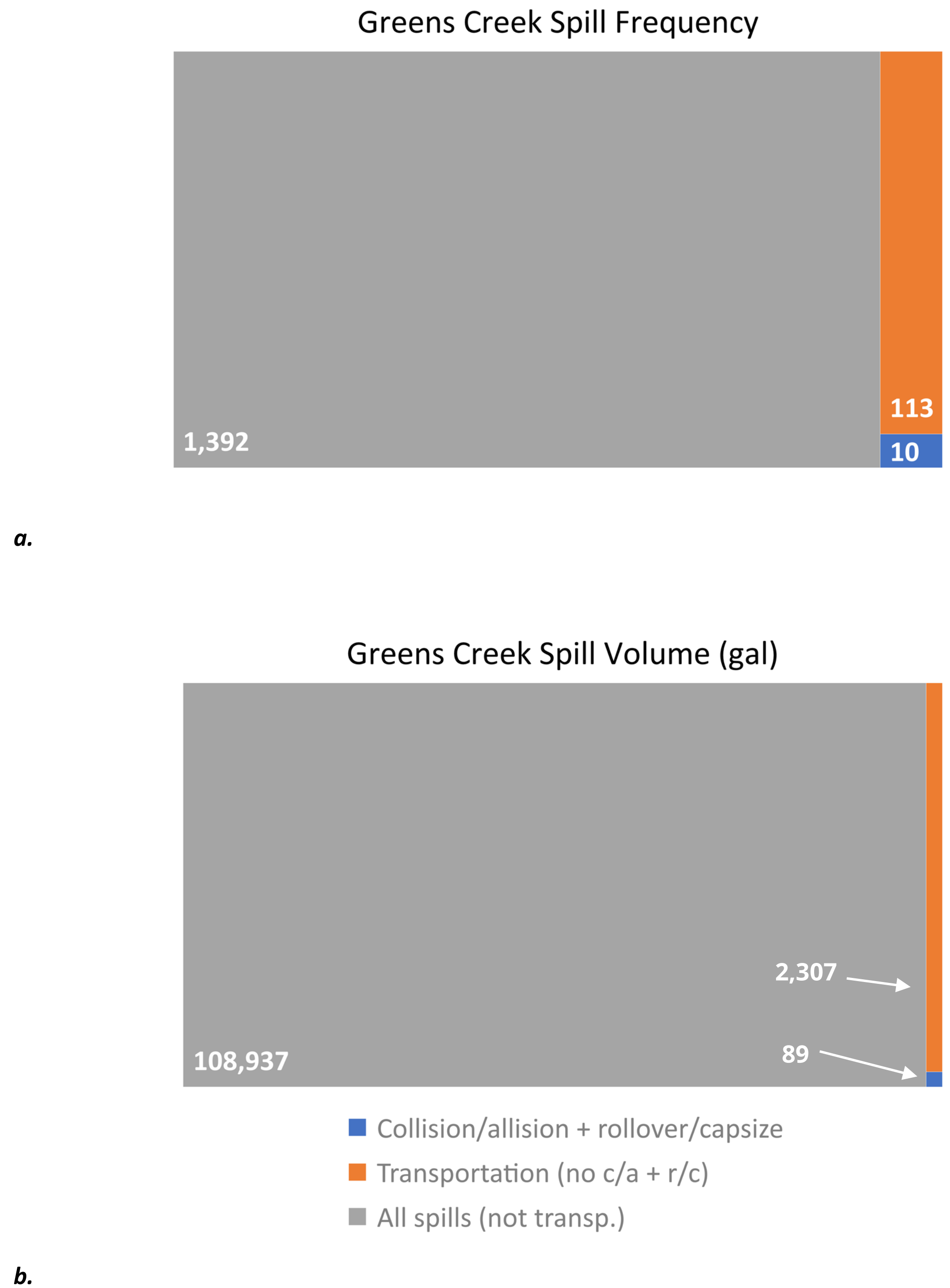


Figure 5.8. A comparison of the relative (a) number and (b) cumulative volume of (collision/allision and rollover/capsize spills) compared to the remaining transportation spills and non-transportation spills at Greens Creek Mine from 1995-2020.

Greens Creek Mine Summary

Greens Creek Mine is an underground mine located on Admiralty Island, about 18 miles southwest of Juneau, that produces silver and gold, as well as lead and zinc concentrates. At the time of the initial EIS the estimated life of the mine based on the known ore reserves was 11 years and the life of operations was 15-17 years for planning purposes (USFS 1983), but Greens Creek Mine still in production today.

Initially, it was thought that Greens Creek Mine would produce about 800 tons per day of ore and 300 tons per day of waste rock (USFS 1983). The 1983 EIS predicted that 160 tons of zinc concentrate and 100 tons of lead concentrate would be produced per day (USFS 1983), for a combined production of 94,900 tons per year. The 2013 EIS more than doubled that rate, and described the annual production of zinc, lead, and bulk concentrates as 200,000 tons per year (~550 tons daily). By 2013, ore was mined at a rate of ~2,200 tons per day (USFS 2013a).

The major mine infrastructure includes "the mill and underground mine area, Site 23 waste rock storage facility, Hawk Inlet Facility, the [tailings disposal facility] TDF, Young Bay dock, approximately 13 miles of connecting roadways, a power intertie connecting the Mine to the Juneau area power grid, and various pipelines and outfalls for wastewater and stormwater" (Hecla Greens Creek Mining Company 2020). Ore is crushed and made into a slurry that goes through a flotation process to concentrate minerals, and filtered ore concentrate is shipped to an off-site smelter.

The road from the Hawk Inlet Facility, where supplies are brought in and ore concentrate is shipped out, to the mill site is 8.5 miles long (Hecla Greens Creek Mining Company 2020). Reagents in use at Greens Creek Mine include sodium cyanide, copper sulphate, and inorganic and organic salts (USFS 1983), as well as concentrated sulfuric acid, SIPX, MIBC, and lime (USFS 2003), but annual usage quantities were not given for the reagents, blasting agents, or fuel. Neither the EIS nor the later supplemental EIS (USFS 1983, 2013) included estimates of expected spill frequencies.

Based on an estimated number of annual truckloads for ore concentrate, mine supplies, and tailings with the $N = RT$ model using the Harwood and Russell (1990) value of R, 0.76 spills from transportation accidents would have been expected at Greens Creek Mine from 1989-2020 for a 53.4% chance of at least one spill over that time. According ADEC (2021) there were seven *collision/allision* incidents and three *rollover/capsize* incidents at Greens Creek Mine from 1995-2020. There were an additional 113 spills related to transportation from other causes, such as *vehicle leaks*, *cargo not secured*, and various forms of *equipment failure,* for a total of 123 spills related to transportation at Greens Creek Mine from 1995-2020. Accidents (*collision/allision* + *rollover/capsize* incidents) made up 8.1% of transportation spills.

The full ADEC (2021) record of spills for Greens Creek Mine listed 1,515 incidents from 1995-2020. Transportation spills from all causes comprised 8.1% of that list, and transportation accident-related spills were 0.66% of the total. The most common type of spill was hydraulic oil, with 1,039 spills releasing 7,196 gallons. The largest single spill listed in ADEC (2021) was a 72,000-gallon *process water* spill from December 2004. Overall, more than 2,000 gallons of *hazardous substances* were spilled in 90 incidents, and more than 19,000 gallons of *non-crude oil* were spilled in just less than 1,400 incidents.

There were nearly 14,000 pounds of *hazardous substances*, including arsenic, lead, zinc and zinc concentrate, tailings, and copper sulfate, spilled in 15 incidents.

ADEC (2021) lists eight spills of ≥1,000 gallons at Greens Creek Mine. The spills of <1,000 gallons accounted for 99.4% of the incidents, but the remaining 0.6% of the spills represented 84.6% of the volume released. These records do not include some spills listed in spill logs from Greens Creek's most recent Plan of Operations (Hecla Greens Creek Mining Company 2020), which also showed a 2,000,000 to 9,000,000-gallon spill of treated process water in June 2013 among 42 spills listed in Greens Creek Mine records but not ADEC (2021).

CHAPTER 6
Fort Knox/True North Mines

Location and description

Fort Knox Mine is a conventional open-pit gold mine 26 miles northeast of Fairbanks, Alaska (Figure 6.1). Fort Knox did not go through an EIS process but had a less comprehensive environmental assessment (EA) (CH2M Hill 1993). Fort Knox's initial major components were the mine site, the development rock and overburden stockpiles, the mill site, the tailings impoundment, and the water and power supplies (CH2M Hill 1993) (Figure 6.2). After permitting in 1994, Fort Knox's construction began in 1995, and gold has been produced there since 1996 (SRK 2019). True North is a satellite deposit 12.5 miles away from Fort Knox, with the ore mined at True North hauled to Fort Knox for processing (Figures 6.3 and 6.4). True North Mine was suggested as a project in 2000, with amendments to the project description and transportation plan in 2001 (Fairbanks Gold Mining, Inc. 2000, 2001). The first ore from True North was processed at Fort Knox in March 2001 (Fairbanks Gold Mining, Inc. 2001), and True North Mine was closed in 2012 (SRK Consulting 2012). The Walter Creek Valley Heap Leach Facility (WCVHLF) at Fort Knox was authorized in 2007, with ore placement and leaching beginning in 2009 (SRK Consulting 2019). The Barnes Creek Heap Leach Facility was under construction 2019 and slated to be operational in 2020 (SRK Consulting 2019). It was anticipated that the WCVHLF would be in use until 2021, especially in light of the expansion of Fort Knox to Phase 7, which added 63.9 million tons of mining production (Kinross 2009). Heap leaching is now anticipated though 2024, including a period of residual leaching (SRK Consulting 2019). (SRK Consulting (2012) anticipated the heap leach would be in operation until 2026.) As of 2015, "Kinross' Fort Knox property includes the Fort Knox open pit mine, mill, tailings storage facility, heap leach facility, the Gil project, and the True North open pit mine (which is under post-closure monitoring)" (Sims 2015).

Fort Knox and True North by the numbers

The expected ore production and associated needs for reagents, blasting agents, and fuel are shown in Table 6.1. Fort Knox has an operating capacity of 35,000 to 50,000 tons of ore per day to produce approximately 300,000 ounces of gold each year. The initial project life was estimated as 16 years for Fort Knox and the amended mine life predicted for True North was 3-4 years (Fairbanks Gold Mining, Inc. 2001).

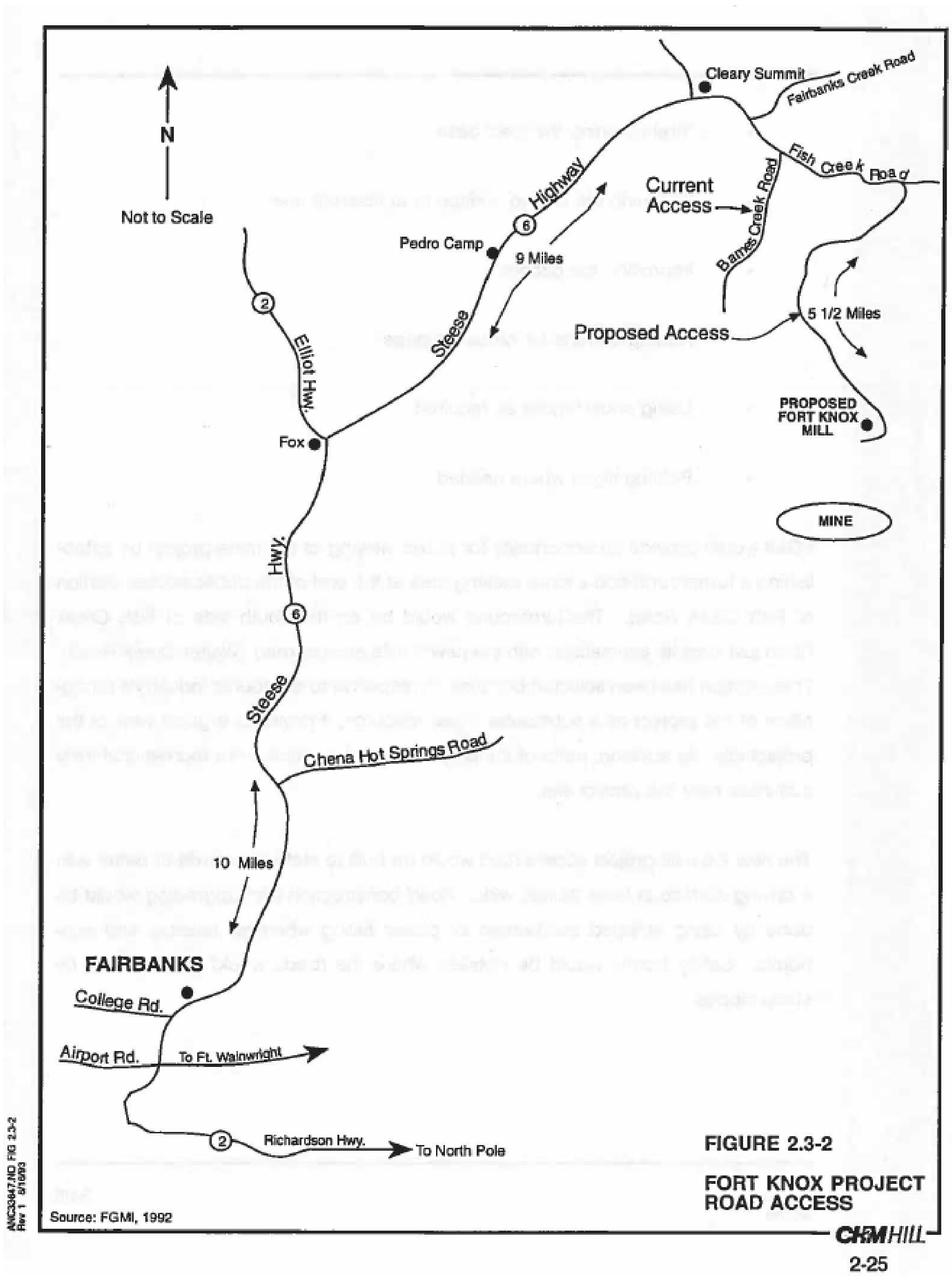


Figure 6.1. CH2M Hill (1993) Figure 2.3-2 Fort Knox Project Road access.

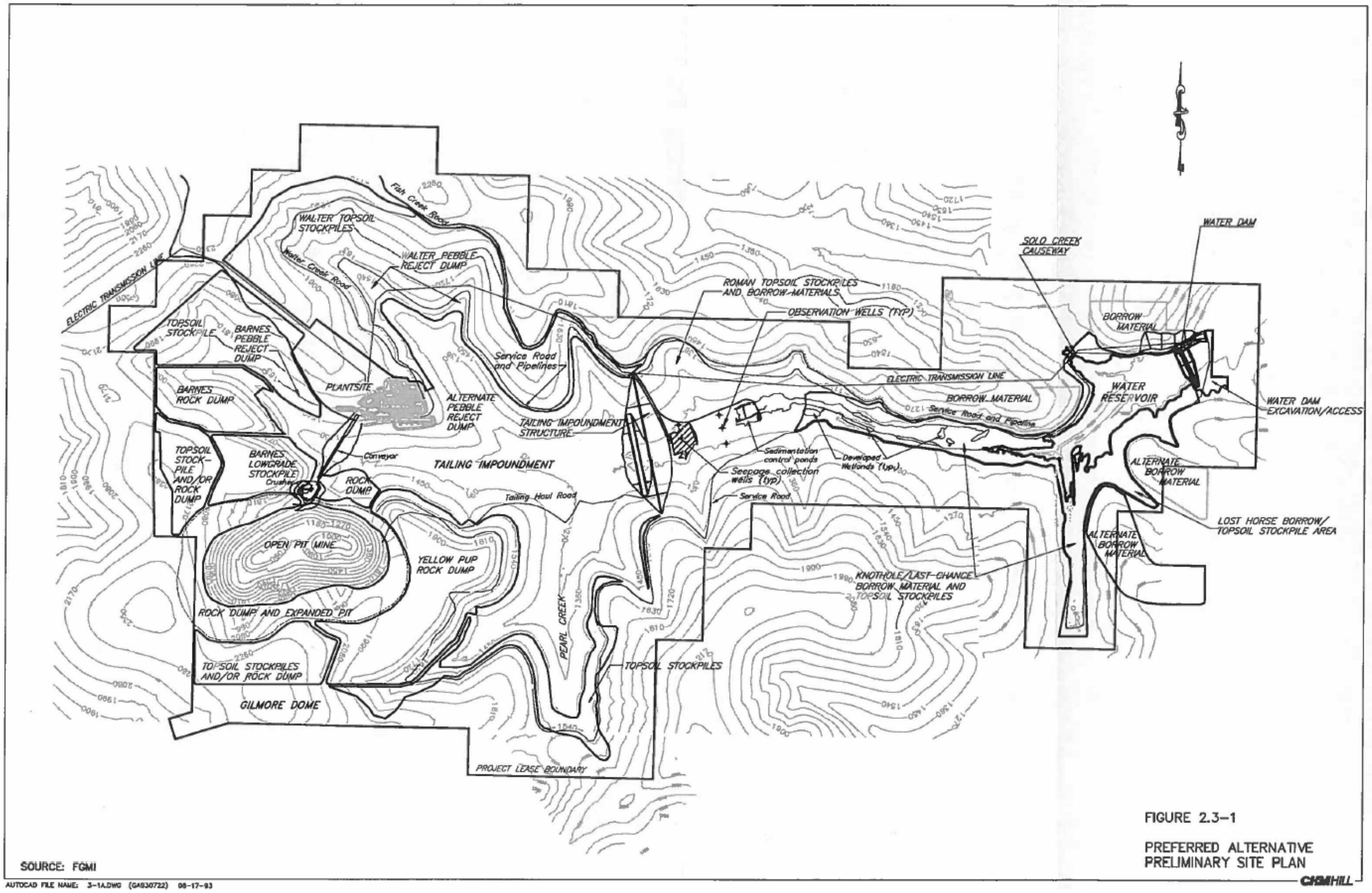


Figure 6.2. CH2M Hill (1993) Figure 2.3-1 Preferred Alternative Preliminary Site Plan

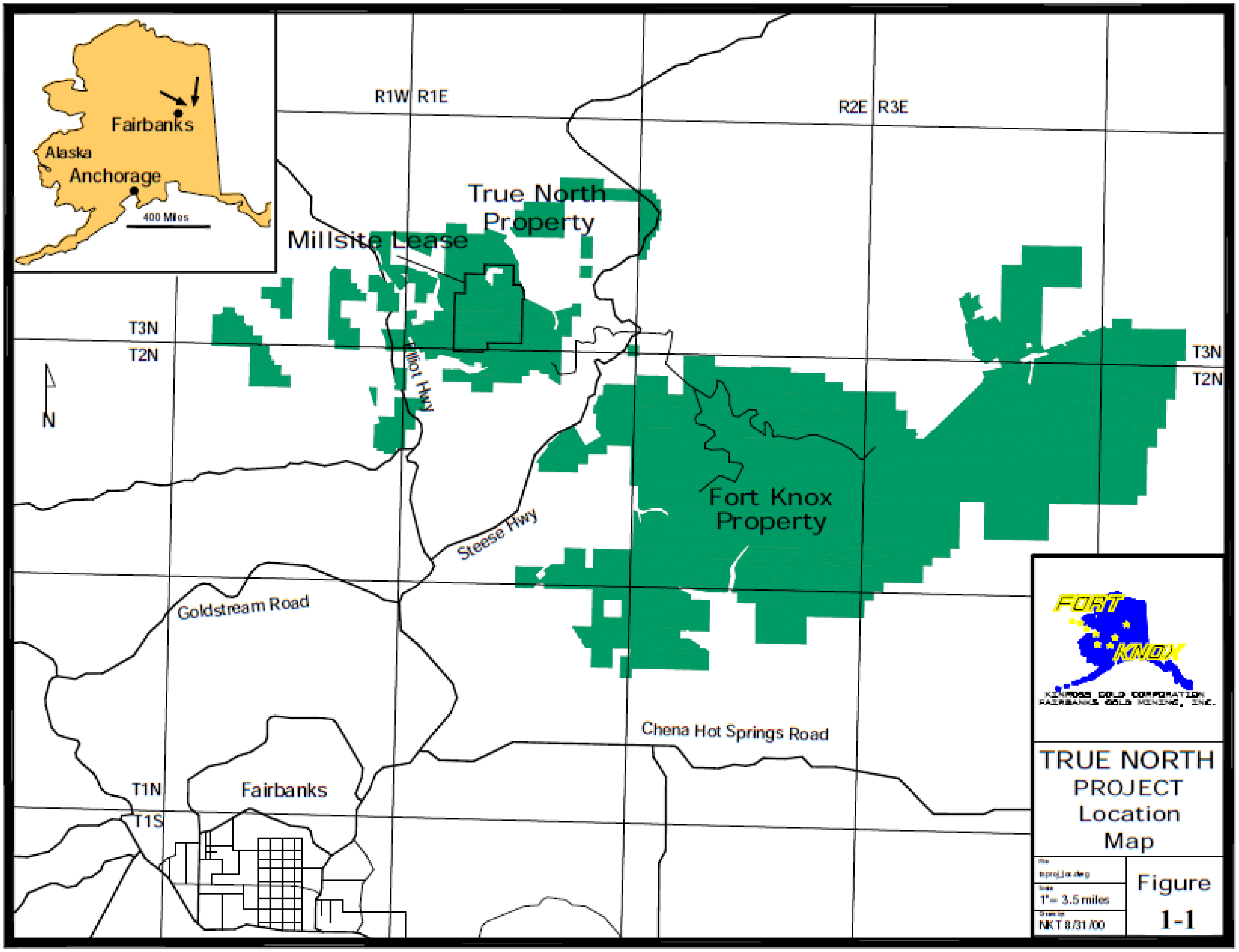


Figure 6.3. FGMI (2000) Figure 1-1: True North Project Location Map.

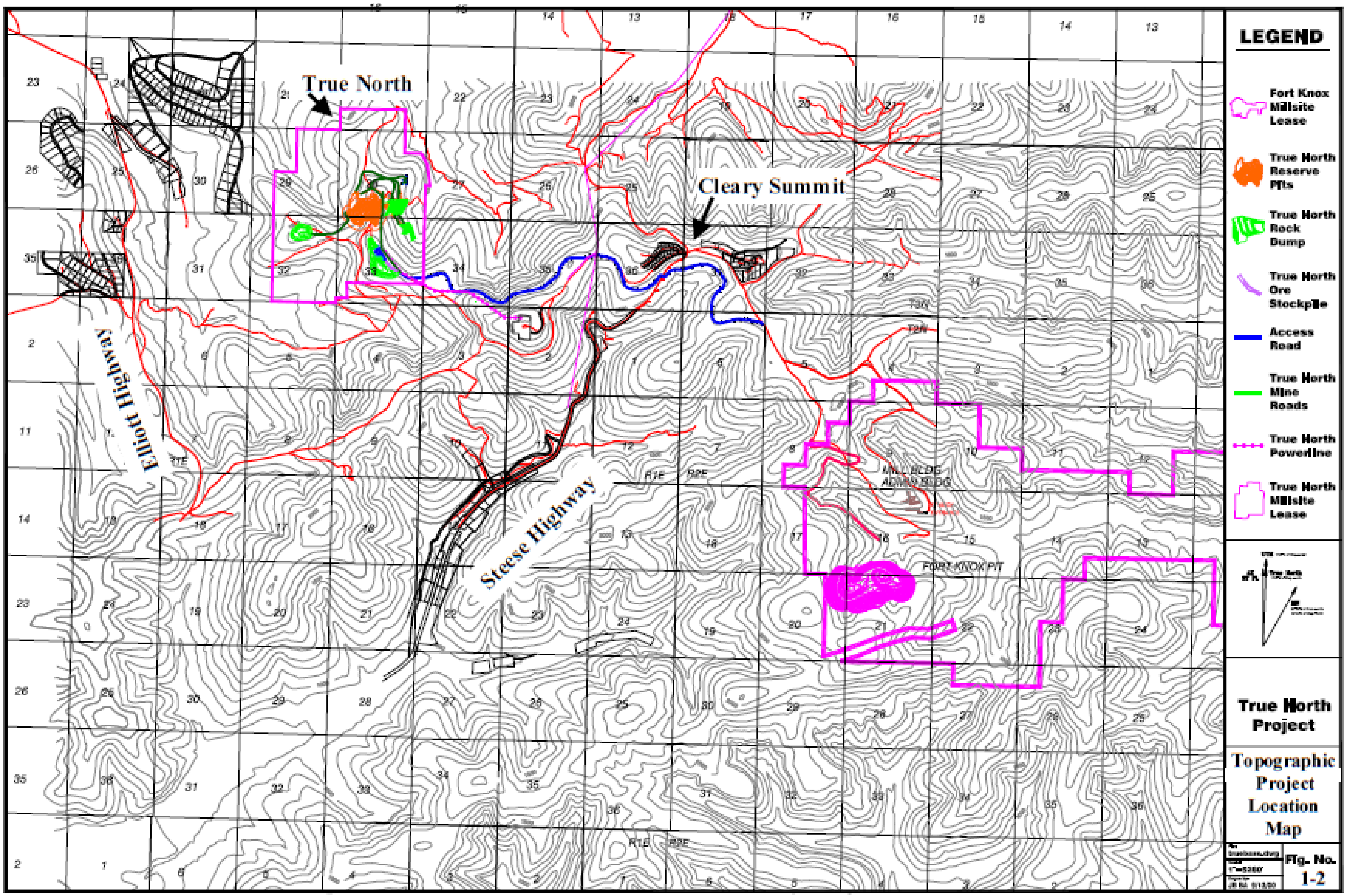


Figure 6.4. FGMI (2000) Figure 1-2: True North Project Topographic Project Location Map.

Table 6.1. Numerical values for ore production, reagents, fuel use, transportation, and waste rock and tailings generation at Fort Knox and True North Mines from various sources.

Amount	Description	Reference(s)
	Ore and production	
35,000 to 50,000	tons of ore per day would be processed	CH2M Hill (1993), p. 1-1, CH2M Hill (1993), p. 2-27
300,000	ounces of gold per year produced at Fort Knox	CH2M Hill (1993), p. 1-1
≥16	year project life at Fort Knox	CH2M Hill (1993), p. 2-2
200 million	ton ore deposit at Fort Knox	CH2M Hill (1993), pp. S-1, 2
~3.5 million	tons/yr ore production rate at True North	Fairbanks Gold Mining, Inc. (2000)
10,000	tons of ore/day at True North	Fairbanks Gold Mining, Inc. (2000)
20,000	tons per day development rock at True North	Fairbanks Gold Mining, Inc. (2000)
30,000	tons per day at True North	Fairbanks Gold Mining, Inc. (2000)
7.2 million	tons ore at True North	Fairbanks Gold Mining, Inc. (2000)
0.063	oz gold/ton of ore at True North	Fairbanks Gold Mining, Inc. (2000)
180,000	ounces gold annually at True North	Fairbanks Gold Mining, Inc. (2000)
~459,000	ounces proven gold reserve at True North	Fairbanks Gold Mining, Inc. (2000)
100-170	truck loads to the mill per day (mining rates vary seasonally) from True North to Fort Knox	Fairbanks Gold Mining, Inc. (2000)
2.5 million	ounces gold produced at Fort Knox by 2004	Golder Associates, Inc. (2004), pp. 5-6
370,000	ounces per year average gold production to 2004 at Fort Knox	Golder Associates, Inc. (2004), pp. 5-6
95 million	tons ore at Fort Knox by 2004	Golder Associates, Inc. (2004), pp. 5-6
14.2 million	tons ore per year average to 2004 at Fort Knox	Golder Associates, Inc. (2004), pp. 5-6
30,000	tons per mined day at True North from 2001-2004	Golder Associates, Inc. (2004), pp. 5-6
10,000	tons per day ore shipped from True North to Forth Knox	Golder Associates, Inc. (2004), pp. 5-6
54.529 million	tons of material mined from the Fort Knox pit in 2008	Kinross Gold Company (2009), p. 6
149,395	tons per day (average production rate in 2008)	Kinross Gold Company (2009), p. 6
14.7 million	tons of projected mill throughput in 2009	Kinross Gold Company (2009), p. 21
1,767	tons per hour feed rate for the mill	Kinross Gold Company (2009), p. 21

Table 6.1. (Continued.)

Amount	Description	Reference(s)
	Ore, ore concentrate	
0.0233	gold grade (ounces per ton)	Kinross Gold Company (2009), p. 21
82.37	recovery percent	Kinross Gold Company (2009), p. 21
282,315	ounces of gold produced	Kinross Gold Company (2009), p. 21
63.9 million	tons mining production in Phase 7	Kinross Gold Company (2009), p. 7
	Reagents	
200	tons blasting agents stored in two 100-ton capacity silos at Fort Knox, containing approximately a 10-day supply.	CH2M Hill (1993), pp. 2-61, 62
100	tons bulk ammonium nitrate storage (combined across two silos) at True North	Fairbanks Gold Mining, Inc. (2000)
0.226	lbs cyanide used per ton ore processed until 2002	Golder Associates, Inc. (2004), pp. 26-28
0.153	lbs cyanide used per ton ore processed 2003 and later	Golder Associates, Inc. (2004), pp. 26-28
0.556	lbs aluminum bisulfite used per ton ore processed until	Golder Associates, Inc. (2004), pp. 26-28
0.144	lbs aluminum bisulfite used per ton ore processed 2003 and later	Golder Associates, Inc. (2004), pp. 26-28
0.13	lbs copper sulfate used per ton ore processed until 2002	Golder Associates, Inc. (2004), pp. 26-28
0.042	lbs copper sulfate used per ton ore processed 2003 and later	Golder Associates, Inc. (2004), pp. 26-28
42,000	tons per day nominal milling rate for reagent use calculations	Golder Associates, Inc. (2004), pp. 26-28
0.1-0.2	pounds lead nitrate used per ton of leach feed	Kinross Gold Company (2009), p. 10
20,000	gallons per minute barren cyanide solution application rate at the Walter Creek Valley Heap Leach Facility (WCVHLF)	SRK Consulting (2019), pp. 3-2 to 3-3
0.0024	gallons per minute per square foot (at the WCVHLF)	SRK Consulting (2019), pp. 3-2 to 3-3
16,000-24,000	gallons per minute barren cyanide solution application rate at the Barnes Creek Heap Leach Facility (BCHLF)	SRK Consulting (2019), pp. 3-2 to 3-3
<0.005	gallons per minute per square foot (at the BCHLF)	SRK Consulting (2019), pp. 3-2 to 3-3

Table 6.1. (Continued.)

Amount	Description	Reference(s)
	Fuel and energy	
35	MW	CH2M Hill (1993), p. 2-2
80,000	gallons diesel storage	CH2M Hill (1993), p. 2-3
20,000	gallons heating oil storage	CH2M Hill (1993), p. 2-3
20,000	gallons waste oil storage	CH2M Hill (1993), p. 2-3
5,000	gallons unleaded gasoline storage	CH2M Hill (1993), p. 2-3
2,000	gallons propane storage	CH2M Hill (1993), p. 2-3
4,000	gallons diesel storage at True North	Fairbanks Gold Mining, Inc. (2000)
10,000	gallons heating oil storage at True North	Fairbanks Gold Mining, Inc. (2000)
10,000	gallons waste oil storage at True North	Fairbanks Gold Mining, Inc. (2000)
4,000	gallons unleaded gasoline storage at True North	Fairbanks Gold Mining, Inc. (2000)
20,000	gallons 2-diesel storage at True North	Fairbanks Gold Mining, Inc. (2000)
	Transportation corridor	
120 to 150	ton dump trucks for ore removal	CH2M Hill (1993), p. 2-27
12	trucks per day bringing reagents and other supplies to the during operations	CH2M Hill (1993), p. 4-66
60	ton capacity highway trucks for hauling ore	Fairbanks Gold Mining, Inc. (2000)
12.5	miles from True North to Fort Knox	Fairbanks Gold Mining, Inc. (2000)
26	miles from Fairbanks to Fort Knox	Golder Associates, Inc. (2004), pp. 5-6

Table 6.1. (Continued.)

Amount	Description	Reference(s)
	Waste rock, tailings, and wastewater	
35,000 to 100,000	tons per day development (waste) rock	CH2M Hill (1993), p. 2-2
200 million	dry tons tailings deposited in a zero-discharge tailing impoundment	CH2M Hill (1993), p. 2-3
75	pounds per cubic foot dry tailings density	CH2M Hill (1993), p. 2-3
70,000 to 120,000	tons of material including overburden, development (non-mineralized) rock, and ore removed per day	CH2M Hill (1993), p. 2-27
1,177	acre impoundment for tailings	CH2M Hill (1993), pp. S-1, 2
15.5 million	tons of waste at True North	Fairbanks Gold Mining, Inc. (2000)
39,500	tons per day of slurried tailings are processed and deposited in the TSF	SRK Consulting (2019), pp. 3-2 to 3-3
1,147	acre TSF	SRK Consulting (2019), pp. 3-2 to 3-3
304.6	Mt of tailings have been placed in the facility by 12/30/2017	SRK Consulting (2019), pp. 3-2 to 3-3

Ore production

The initial project environmental assessment was planned around a ~200 million ton ore deposit (CH2M Hill 1993). Ore production ranged from 10.80 to 15.51 million tons in the years 1997–2008 (Kinross Gold Company 2009) (Table 6.2). Based on the total of 477,740,000 tons mined at Fort Knox, the average mining rate at Fort Knox was 56,908 tons per day from 1996-2008. True North Mine had an average of 30,000 tons mined per day, with 10,000 tons of ore shipped to Fort Knox daily for processing (Golder Associates Inc. 2004). True North Mine produced between 1.26 and 3.37 million tons in the years 2001–2004 (Kinross Gold Company2009) (Table 6.2). Since the 1997, the average milling rate has been above 36,000 tons per day, with a nominal milling rate of 36,287 tons per day (Sims 2015). The amount of ore mined and the amount of ore processed per year are not in exact agreement (Tables 6.2 and 6.3). The total tons of ore processed per year increased once the heap leach facility was added in 2009, and the amount of gold produced per year averaged 352,571 ounces per year from 1997 to 2014 (Figure 6.5).

Table 6.2. Reproduction of the information in "Table 1: Fort Knox Annual Mining Rates", "Table 2: True North Annual Mining Rates", "Table 3: Fort Knox Annual Milling Rates", and "Table 9: Planned Mining Tons for Calendar Year 2009" from Kinross (2009). All mining and milling values are in million tons.

Year	Fort Knox Annual Mining Rates					True North Annual Mining Rates				Milling Rates
	Ore	Transition Grade Ore	Leach Grade Ore	Waste	Total	Ore	Low Grade Ore	Waste	Total	
1996	0.96	0.36	0	15.36	16.68					0.77
1997	12.57	4.88	0	14.93	32.38					12.16
1998	13.83	5.27	0	14.19	33.29					13.74
1999	14.10	4.09	0	12.16	30.35					13.82
2000	15.51	2.20	0	17.89	35.61					14.99
2001	12.09	1.24	0	12.62	25.96	2.38	0.81	5.26	8.45	15.66
2002	11.73	0.86	0	12.00	24.58	3.37	1.08	7.01	11.45	15.26
2003	11.08	2.09	0	17.43	30.60	2.85	0	9.86	12.71	15.08
2004	10.80	6.80	0	24.09	41.68	1.26	0	2.51	3.76	14.59
2005	13.23	5.86	0	44.16	63.25	0	0	0	0	14.38
2006	12.39	3.68	0	35.00	51.06	0	0	0	0	14.84
2007	11.71	10.31	0	23.92	45.98	0	0	0	0	14.02
2008	12.78	3.82	13.3	16.40	46.32	0	0	0	0	15.11
Total	152.77	51.46	13.3	260.15	477.74	9.85	1.89	24.64	36.38	174.42
Pro-jected	Mill grade	Low grade	Leach stock-pile	Waste	Total					Mill through-put
2009	13.51	4.50	13.30	20.67	51.98					14.7

Table 6.3. Reproduction of Sims (2015) "Table 6-1: Fort Knox Production Summary".

Year	Total tonnes processed (000's)	CIP tonnes processed (000's)	Grade (g/t)[1]	Heap Leach tonnes loaded (000's)[2]	Gold produced (oz)
1997	9,979	9,979	1.17	-	320,758
1998	12,466	12,466	0.99	-	365,452
1999	12,536	12,536	0.95	-	351,120
2000	13,606	13,606	0.94	-	362,959
2001	14,209	14,209	1.05	-	411,221
2002	13,843	13,843	1.09	-	410,519
2003	13,685	13,685	1.07	-	391,831
2004	13,239	13,239	0.94	-	338,334
2005	13,050	13,050	0.90	-	329,320
2006	13,462	13,462	0.90	-	333,383
2007	12,722	12,722	0.96	-	338,459
2008	13,769	13,706	0.88	-	329,105
2009	16,224	12,830	0.69	3,393	263,260
2010	25,735	13,206	0.79	12,528	349,729
2011	31,078	13,503	0.56	17,575	289,794
2012	43,153	13,204	0.69	29,950	359,948
2013	42,419	12,668	0.82	29,751	421,641
2014	39,386	13,538	0.66	25,848	379,453
	355,582			119,045	6,346,286

[1] Amount represents CIP mill grade only

[2] Heap leach process was added in 2009

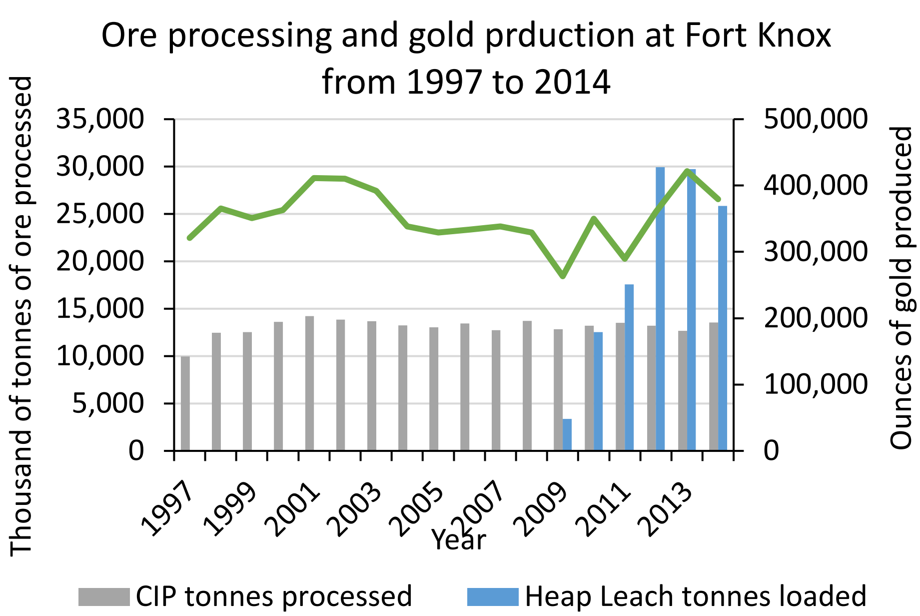


Figure 6.5. Fort Knox ore processing and gold production from 1997-2014 based on Sims (2015).

Process

The mill at Fort Knox mine was expected to process between 35,000 and 50,000 tons of ore per day (CH2M Hill 1993, Kinross Gold Company 2009). Before the introduction of the heap leach facility, the steps for processing the ore were crushing, grinding, gravity concentration, cyanide leaching, gold recovery, cyanide detoxification, and discharge of tailings (CH2M Hill 1993). The ore was initially described as being crushed near the pit to minus 10 inches (CH2M Hill 1993) but later as down to minus 6 inches (Kinross 2009) before transport to the mill. Processing of the ore depends on the grade and the mineral content. The combination of the higher and lower grade ore will require "a nominal mining rate of 61 Mt/a … to provide the 13 Mt/a of mill feed and 17 Mt/a of leach material. Approximately 155 Mt of waste is envisaged to be mined over the remaining five years of operation" (Sims 2015).

For higher grade ore, the mill at Fort Knox uses the conventional processes of crushing and finely grinding the ore in ball mills, followed by gravity concentration and agitated cyanide leaching, and finally a carbon-in-pulp (CIP) circuit for gold adsorption on carbon and carbon stripping. The CIP circuit typically processes approximately 36,000 tons of higher grade ore per day (Sims 2015). A thickener was added to the process circuit at Fort Knox in 2002 (Golder Associates Inc. 2004). The thickener is a wide cylindrical vessel that allows for separation of thickened tailings from the bottom and process water from the top.

Lower grade ore is processed in a "run-of-mine valley-fill cyanide heap leaching operation where gold is recovered using two parallel carbon-in-column (CIC) circuits" (Sims 2015). Sims (2015) continued:

> Run-of-mine ore from the pit and existing stockpiles is dumped with the addition of lime…In the heap leach operation, irrigation of the heap with cyanide solution extracts gold from the ore into solution. The solution is captured within the 416 ML heap reservoir, and is pumped at a fixed rate to the mill to be processed in two parallel carbon-in-column (CIC) circuits with a combined capacity of 61,000 L/m (16,000 gpm). Gold is extracted to activated carbon and periodically stripped and refined to gold bars.

For the heap leach process, both gold recovery and cyanide consumption were related to the amount of solution applied to the ore (irrigation rate) and the leaching time (Sims 2015). At the WCVHLF, barren cyanide solution is applied at a rate of 20,000 gallons per minute (and 0.0024 gallons per minute per square foot of leached area) through drip emitters (SRK Consulting 2019). The gold-bearing solution is then collected in the storage pond for gold recovery.

According to the environmental assessment, "Pilot testing has shown that the Fort Knox ore deposit and the development rock do not contain substantial sulfides, and thus, have very low potential for acid mine drainage" (CH2M Hill 1993). The ore from True North had a more extensive suite of reagents than the ore from Fort Knox to compensate for its higher sulfide content (Sims 2015).

Characterization of transportation corridor

As described in the Five-Year Environmental Audit (Golder Associates Inc. 2004):

> Access [to Fort Knox Mine] is via the Steese Highway for approximately ten miles to the town of Fox and then northeast on Alaska Highway 2 for approximately ten miles to Cleary Summit. Near the top of Cleary Summit travel southeast on the Twin Creek Road and Fish Creek Road for approximately six miles to the site. Access to the True North Mine is via the same route exiting the Steese Highway in the same location and traveling to west on the Twin Creek Road for approximately six miles.

The original True North Project Description (Fairbanks Gold Mining Inc. 2000) stated:

> The True North Project is within the Chatanika River watershed on the northwest flank of Pedro Dome approximately 25 miles northeast of Fairbanks… Historic access to the True North Project is accessed via the Steese Highway to Cleary Summit, then 6.5 miles via a gravel road skirting the south side of Pedro Dome. The new access/haul road (approximately 0.5 miles south of Cleary Summit) follows a new road alignment along the north side of Pedro Dome.

and

> The main access/haul road will be constructed from the southeast corner of the True North Millsite Lease boundary along the north side of Pedro Dome… At a 6% grade and will use approximately 2,500 feet of the existing Pedro Dome road/True North road. The road then leaves the existing Pedro Dome/True North road on the west side of the ridgeline immediately southwest of the Cleary Summit Subdivision on the Pedro Dome side of the Steese Highway to create a new intersection approximately 2,400-feet southwest of the existing intersection on a straight section of the highway. The amended description for True North (Fairbanks Gold Mining Inc 2001) noted that Ore transportation in the initial presentations included 9 ore haulage trucks with a Steese Highway crossing. Through the permit process, FGMI added the Steese Highway Bridge to eliminate the concerns about the Steese Highway crossing and the number of times that trucks would cross the highway. Further, FGMI accepted the State's noise limits on the ore haulage trucks. In the amended plan, the ore haulage on day shift will be with the 9 ore haulage trucks supplemented, if necessary, with additional trucks to maintain the average 10,000 tons per day and/or to adjust to increased mine efficiencies. The average 10,000 tons per day would also be increased if ore haulage efficiencies were achieved, for example if the trucks could safely haul more tons per load. This amendment remains the same for all other items including noise limits and only 9 ore haulage trucks at night.

List of hazardous materials to be transported

Reagents

At least a dozen reagents are listed for use at Fort Knox (Table 6.4). Although there are brief descriptions of the uses for each chemical and some description of their forms and containers for the reagents mentioned in the environmental assessment (CH2M Hill 1993), the quantities required and load sizes were not described, and neither were any environmental or health hazards. (See Appendix A for extracts from material safety data sheets.)

Table 6.4. Reagents listed in the environmental assessment (CH2M Hill 1993) and other documents (Golder Associates, Inc. 2004, Kinross 2009) for use at Fort Knox Mine.

Reagent	Use	Transport details	Reference
Lime	controlling the pH of the slurry during grinding, leaching, and cyanide detoxification	received as unslaked (not mixed with water) calcium oxide in bulk via 20-ton tank trucks	CH2M Hill 1993
Sodium cyanide	used to dissolve gold	received as dry briquets in either 3,000-pound heavy-duty steel flow bins, or in bulk, transported in tanker trucks	CH2M Hill 1993
Activated carbon	used to capture dissolved gold from the slurry in the CIL tanks	received in 1,000-pound bulk bags	CH2M Hill 1993
Sodium hydroxide	used to raise the pH in the carbon-stripping circuit, and to neutralize the pH after acid washing the carbon	received as pellets, packaged in steel drums with a capacity of 500 pounds each (p. 2-40) received in liquid form (p. 4-45)	CH2M Hill 1993
Hydrochloric acid	be used to remove scale from the carbon after the carbon stripping circuit	delivered by bulk tanker and would be stored in a 10,000-gallon tank; alternatively, hydrochloric acid would be received in 55-gallon drums	CH2M Hill 1993
Flocculant	be used to accelerate settling in the thickening process prior to leaching	delivered to the site in bags	CH2M Hill 1993

Table 6.4. (Continued.)

Reagent	Use	Transport details	Reference
Sulfur dioxide	used in the cyanide-detoxification circuit to oxidize the cyanide	delivered to the site as a liquid in pressurized cylinders or in tank trucks	CH2M Hill 1993
Copper sulfate	used as a catalyst in the cyanide detoxification process	received in 100-pound bags or 1,000-pound bulk bags	CH2M Hill 1993
Fluxes*	assay lab and refinery	received in 50- to 400-pound bags or drums	CH2M Hill 1993
Water-softening and anti-sealant agents	used in the mill facility to treat mill process water and prevent scaling in pipes	received in drums or in bulk	CH2M Hill 1993
Ammonium nitrate		bagged	CH2M Hill 1993
Ammonium nitrate/fuel oil [ANFO]	blasting		CH2M Hill 1993
Ammonium bisulfite (ABS)	cyanide detoxification		Golder Associates, Inc. 2004
Lead nitrate	leach circuit		Kinross Gold Company 2009

* Anhydrous borax, sodium nitrate, soda ash, and graded silica sand

The introduction of the thickener to the ore processing in 2002 reduced the need for cyanide, ammonium bisulfate, and copper sulfate (Golder Associates, Inc. 2004). Annual use values were not given directly for any reagents (Table 6.5).

Table 6.5. Reproduction of "Table 7: Reagent Consumption" (Golder Associates 2004, pp. 26-28). Reagent use is based on a nominal milling rate of 42,000 tons per day.

Reagent consumed	Average year to date 2002 prior to thickener (lb/ton)	Average year to date 2003 after thickener (lb/ton)	Mass of reagent reduced per day (lb)
Cyanide	0.226	0.153	3,066
ABS	0.556	0.144	17,304
Copper sulfate	0.130	0.042	3,696

We can infer annual use for sodium cyanide, ammonium bisulfite, and copper sulfate from the values in Table 6.5 by multiplying the pounds of reagent used per ton of ore by the daily ore milling rate of 42,000 tons per day, converting from pounds to tons, and from use per day to use per year (Table 6.6).

Table 6.6. Conversion of reagent use at Fort Knox from lb/ton of ore to tons used annually assuming an ore milling rate of 42,000 tons per day.

Reagent consumed	Average Year up to 2002			Average Year 2003 and later		
	lb reagent per ton ore	tons reagent per day	tons reagent per year	lb reagent per ton ore	tons reagent per day	tons reagent per year
Cyanide	0.226	4.75	1,732.29	0.153	3.213	1,172.75
ABS	0.556	11.68	4,261.74	0.144	3.024	1,103.76
Copper sulfate	0.130	2.73	996.45	0.042	0.882	321.93

I will estimate the annual usage for the remaining reagents used at both mines by comparing the tons per day (tpd) for Fort Knox with the tpd from Pogo, which also processes gold-containing ore and produces doré gold bars. The overlapping reagents are lime, flocculant, sodium hydroxide, and activated carbon. (These are rough estimates and will not be able to account for any differences in ore composition or process in the two locations.) For reference, Pogo Mine had an expected production rate of 2,500 to 3,500 tpd and gold production of 375,000-500,000 ounces per year (EPA 2003b). Fort Knox's ore production rates are described as more than an order of magnitude higher, at 35,000 to 50,000 tons per day, but the concomitant gold production is lower at 300,000 ounces per year (CH2M Hill 1993). Some reagent use may scale more directly to the ore production rate and some may be more proportional to the gold production rate. As an exercise, I computed the possible reagent uses at Fort Knox scaled both to gold production in ounces per year (Table 6.7) and to ore production in tons per day (Table 6.8). If the reagent use is based on the amount of ore to process, the reagent quantities required are about 17 times higher than if they are based on the amount of gold produced.

Table 6.7. Reagent use at Fort Knox estimated based on reagent use at Pogo Mine as a reference for tons of reagent per ounce of gold produced.

Commodity	Reagent use at Pogo Mine				Estimated reagent use at Fort Knox for 300,000 oz gold/year	
	tons of reagent used per year		tons reagent per year/oz gold produced per year			
	375,000 oz gold per year	500,000 oz gold per year	375,000 oz gold per year	500,000 oz gold per year	tons reagent per year/oz gold produced per year	tons reagent per year
Lime	1,000	1,500	0.0027	0.003	0.003	900
Flocculant	55	77	0.000147	0.000154	0.00015	45
Sodium hydroxide	30	45	0.00008	0.00009	0.000085	25.5
Activated carbon	5	10	0.000013	0.000020	0.000017	5.1

Table 6.8. Reagent use at Fort Knox estimated based on reagent use at Pogo Mine as a reference for tons of reagent per tons of ore processed.

Commodity	Reagent use at Pogo Mine				Estimated reagent use at Fort Knox for 36,000 tons ore per day	
	tons of reagent used per year		tons reagent per year/tons ore per day			
	2,500 tons ore per day	3,500 tons ore per day	2,500 tons ore per day	3,500 tons ore per day	tons reagent per year/tons ore per day	tons reagent per year
Lime	1,000	1,500	0.4	0.429	0.414	14,914.3
Flocculant	55	77	0.022	0.022	0.022	792.0
Sodium hydroxide	30	45	0.012	0.013	0.012	447.4
Activated carbon	5	10	0.002	0.003	0.002	87.4

Sims (2015) provides a check on how realistically reagent use could have been predicted based on the data given in the Fort Knox/True North Mine EAs that were then scaled based on usage at Pogo. More than 27,000 tons of supplies were used at Fort Knox in 2014 (Sims 2015) (Table 6.9). The heap leach used fewer tons of activated carbon, antiscalant, caustic, and hydrochloric acid than the mill did, but used 1.7 times more cyanide and 2.5 times more lime (Table 6.9).

Table 6.9. Reproduction of Sims (2015) "Table 17-2: Fort Knox 2014 Processing Material Consumption". Shaded cells were not part of the original document. Reagents shown in bold were also listed in CH2M Hill (1993) and/or Golder Associates Inc (2004).

Consumables	kg	lb	tons
SAG, 5.25"Balls	3,821,537	8,425,037	4,212.52
Ball Mill, 3"Balls	2,548,562	5,618,610	2,809.31
Molycop, 5.25" Balls	5,067	11,171	5.59
Molycop, 3" Balls	2,934,509	6,469,477	3,234.74
Corrosion Inhibitor	4,638	10,224	5.11
Mill Lime	**3,340,562**	**7,364,670**	**3,682.34**
Heap Leach Lime	**8,464,378**	**18,660,737**	**9,330.37**
Cyanide	**623,512**	**1,374,607**	**687.30**
Heap Leach Cyanide	**1,040,201**	**2,293,249**	**1,146.62**
Heap Leach Liquid Scale Inhibitor	41,639	91,799	45.90
Mill Antiscalant	7,393	16,298	8.15
Heap Leach Antiscalant	6,365	14,033	7.02
Mill Carbon	**195,975**	**432,051**	**216.03**
Heap Leach Carbon	**63,019**	**138,933**	**69.47**
Mill Caustic	456,266	1,005,893	502.95
Heap Leach Caustic	389,206	858,051	429.03
Mill HCL	231,402	510,153	255.08
Heap Leach HCl	198,557	437,743	218.87
Flocculant	**220,038**	**485,100**	**242.55**
SBS	51,257	113,002	56.50
Copper Sulfate	**9,979**	**22,000**	**11.00**
Total	24,654,062	54,352,838	27,176.42

There was only partial overlap in the supplies listed in Sims (2015) and those mentioned in other documents about Fort Knox, including the original environmental assessment describing the milling and refining process (CH2M Hill 1993) (Tables 6.4 and 6.9). Only five reagents that were mentioned in the original environmental assessment (CH2M Hill 1993) or the 2004 Five-Year Environmental Audit (Golder Associates Inc. 2004) and the technical report from at least a decade later (Sims 2015) have explicitly stated or inferable annual use quantities (Table 6.10). Not only is there little consistency among the reagents listed from document to document, but the amounts of estimated reagents required each year also vary widely (Table 6.10). The most recent value for cyanide annual use is higher than the amount used pre-thickener, but the copper sulfate used per year is only 3.4% of what was specified post-thickener and 1.1% of that called for pre-thickener. It appears that the most recent annual lime use scales more directly with ore production than with gold output, flocculants are used at an intermediate rate, and activated carbon use is higher than either estimate (Table 6.10).

Table 6.10. Estimated annual use of reagents explicitly stated and inferred for Fort Knox/True North Mines.

Reagent	Estimated use in tons per year		
	Golder Associates (2004) for pre-thickener use	Golder Associates (2004) for post-thickener use	Sims (2015)
Cyanide	1,732.29	1,172.75	1,833.92
Copper sulfate	996.45	321.93	11
	Use estimated by gold production	Use estimate by ore production	Sims (2015)
Lime	900	14,914.3	13,012.71
Flocculant	45	792.0	242.55
Activated carbon	5.1	87.4	285.5

Blasting agents

Fort Knox Mine uses conventional drilling and blasting techniques to break up the ore (CH2M Hill 1993), as True North did, as well (Fairbanks Gold Mining Inc. 2000). The environmental assessment (CH2M Hill 1993) specified:

> All explosives handling and storage would comply with applicable state and federal regulations. Two separate, locked storage magazines for caps, detonating cord, primers, and boosters would be a short distance off a side road in a safe location. Storage for certain specialty blasting agents (bagged ammonium nitrate or ammonium nitrate/fuel oil [ANFO] and water-resistant products) would be located along the same road, but closer to the mine. The storage facility would consist of one or more small trailers constructed to provide storage and security. Bulk storage of ammonium nitrate or ANFO would be located north of the pit off the main mine access road. The blasting agents would be stored in two 100-ton capacity silos containing approximately a 10-day supply.

When the True North Mine was proposed, the project description (Fairbanks Gold Mining, Inc. 2000) stated:

> Bulk ammonium nitrate will be stored in two silos containing a combined total of approximately 100-tons.

We can infer annual blasting agent use from the fact that two 100-ton capacity silos contain a 10-day supply for Fort Knox. If 200 tons of blasting agents are used in 10 days, then the average annual use is 20 tons per day or 7,300 tons per year. Using an estimate of 800 gallons of diesel for each ton of blasting agent (ammonium nitrate), the amount of diesel needed annually would be:

> 800 gallons diesel/ton ammonium nitrate per year x 7,300 tons ammonium nitrate per year = 5,840,000 gallons of diesel per year

The estimate of ammonium nitrate storage at True North was approximately 100 tons (Fairbanks Gold Mining, Inc. 2000). If this is again a 10-day supply, then True North's ammonium nitrate and diesel needs were half that of Fort Knox's. (As a check on this, recall that the mining rate at Fort Knox was roughly 57,000 tons per day and the average mining rate at True North was 30,000 tons of ore per day.)

Fuel

According to CH2M Hill (1993):

> Fuel would be delivered to the site by truck, as needed, from various Alaska suppliers. Fuel supply piping would be aboveground where practical. All piping, whether above ground or buried, would be designed to provide proper leak detection and collection systems. Final piping locations would be determined during basic and final engineering design phases.
>
> Diesel fuel for the mine fleet would be stored in two 40,000-gallon or equivalent smaller storage tanks, … The tanks and dispensing station would be designed to contain at least 110 percent of the volume of the largest tank. Diesel fuel would be pumped or would flow by gravity, with appropriate automatic shutoff devices, into various vehicles as required. All major mine equipment would be refueled at their locations by a fuel truck. Light vehicles such as pickup trucks would be refueled at one location near the fuel tanks. Storage for approximately 20,000 gallons of heating fuel, 20,000 gallons of waste oil, and 5,000 gallons of unleaded gasoline also would be provided in the fuel storage facility. Approximately 2,000 gallons of propane would be stored in a separate secure area for use in the refinery and the assay lab, as well as for general maintenance purposes throughout the mine. Six 10,000-gallon bulk tanks would be at the west end of the shop and warehouse complex … Two tanks would contain waste oil and the remaining four tanks would contain either 30-weight oil, 10-weight oil, hydraulic fluid, or ethylene glycol.

True North fuel storage was proposed as 20,000 gallons of diesel, 10,000 gallons of heating oil, and 10,000 gallons of waste oil stored near the shop, and 4,000 gallons each of unleaded fuel and diesel dispensing near the shop (Fairbanks Gold Mining, Inc. 2000).

Load size

No load sizes were specified. I will use the load sizes from Pogo Mine as a proxy (Table 6.11).

Table 6.11. Reproduction of "Table 4.3-15 Commodity Transport Frequency" for Pogo Mine (EPA 2003b).

Commodity	Quantity per Truck	Annual Number of Trucks
Fuel	8,000 gallons	100
Cement	27 tons	520
Lime	20 tons	50
Cyanide	20 tons	50
Sodium metabisulfite	20 tons	50
Sulfuric acid	20 tons	25

Load frequency

A good approximation of the load frequencies for the various reagents and other hazardous materials is not possible without more specific information in the environmental assessment (CH2M Hill 1993) about the quantities in which each reagent would be used and the load sizes transporting them. The only indication of load frequency was from CH2M Hill (1993):

> During operation, perhaps a dozen trucks per day would bring reagents and other supplies to the site on a regular basis…

If the 12 loads per day bringing "reagents and other supplies" include diesel, other fuels, and blasting agents, then there could be 4,380 trips per year importing materials to the mine by road until 2003. Based on the estimated quantities used per year and load sizes for the eight materials for which at least partial data were available or inferable, I found that there would be >1,492 loads/year of hazardous materials up to 2002 and >1,272.5 loads/year of hazardous materials from 2003 onward (Table 6.12). These estimates do not include loads carrying sodium hydroxide, hydrochloric acid, sulfur dioxide, fluxes, or lead nitrate. They are based on information from the environmental assessment (CH2M Hill 1993) and the reagent use comparison from Golder Associates Inc. (2004) to reflect most closely the estimations that would have been available prior to mine operations, instead of with nearly 20 years of retrospective data.

Table 6.12. Estimates of annual usage rates, loads sizes, and trips per year for reagents at Fort Knox Mine.

Commodity	Amount used per year		Amount per load	Loads per year	
Lime	900 tons		20 tons	45	
Activated carbon	5 tons		20 tons	0.25	
Sodium hydroxide	no data		20 tons	no data	
Hydrochloric acid	no data		20 tons	no data	
Flocculant	45 tons		20 tons	2.25	
Sulfur dioxide	no data		20 tons	no data	
Fluxes*	no data		20 tons	no data	
Water-softening and anti-sealant agents	no data		20 tons	no data	
Ammonium nitrate (blasting supplies)	7,300 tons		20 tons	365	
Lead nitrate	no data		20 tons	no data	
Diesel	5,840,000 gallons		8,000 gallons	730	
	Up to 2002	2003 and later		Up to 2002	2003 and later
Sodium cyanide	1,732 tons	1,173 tons	20 tons	86.6	58.7
Copper sulfate	4,262 tons	1,104 tons	20 tons	213.1	55.2
Ammonium bisulfite (ABS)	996 tons	322 tons	20 tons	49.8	16.1
Total				>1,492.0	>1,272.5

At Pogo Mine, 42-45% of the truck trips bringing supplies to the mine were transporting hazardous materials (Table 3.6). If the 43% of the 4,380 loads initially coming into Fort Knox were of hazardous materials, that would be 1,883.4 trips per year through 2002. As crude as the estimates in Table 6.12 are, they may account for 80% of the hazardous materials loads, with the remaining reagents' unspecified aggregate amounts accounting for approximately one more trip per day. For the purposes of later calculations, I will use an estimate of 1,880 trips/year carrying hazardous materials to Fort Knox from 1996-2002 and an estimate of 1,600 trips/year carrying hazardous materials to Fort Knox from 2003-2020. (Note: The 1,600 trips estimate is rounded down from 1,272 trips/year of commodities with estimated annual usage + ~365 trips/year of reagents with no specified amounts = 1,637 trips/year.)

As a check on this estimate with the benefit of later, more detailed reagent use data (Sims 2015), the number of trips with hazardous materials can be updated. Ignoring the grinding materials, there were approximately 17,000 tons of chemical reagents used at Fort Knox in 2014 (Table 6.12), not including blasting agents and fuel. If reagents were brought to the mine in 50-ton loads, that would require 340 loads per year. If the reagents were trucked in 20-ton loads, 850 truckloads per year would be needed. For the purposes of a rough estimate, if there were 500 loads of reagents, 370 loads of diesel, and 730 loads of ammonium nitrate annually, that would a total of 1,600 trips per year.

The loads of hazardous materials being brought to Fort Knox are only one portion of the potentially hazardous traffic. As noted in the environmental assessment (CH2M Hill 1993), "Materials not designated for disposal on the site would be sorted and shipped to Fairbanks for recycling or disposal. All waste material either listed as or meeting the characteristics of hazardous waste would be shipped off the site and disposed of according to applicable state and federal regulations." There was no estimate of the amount of hazardous waste materials that would be generated and then transported away from Fort Knox. There were also no estimates associated with the delivery of blasting agents to True North.

Spill risks discussed on the permitting documents

The environmental assessment (CH2M Hill 1993) cited the regulations in in 40 CFR, Section 1508.27 to define significance in terms of environmental impacts (bold emphasis added):

> Significance**.** To determine whether expected impacts would be significant, the CEO regulations in 40 CFR, Section 1508.27, were used. Following is the excerpt from the regulations containing the definition of the term "significantly":
>
> a) *Context.* This means that the significance of an action must be analyzed in several contexts such as society as a whole (human, national), the affected region, the affected interests, and the locality. Significance varies with the setting of the proposed action. For instance, in the case of a site-specific action, significance would usually depend upon the effects in the locale rather than in the world as a whole. Both short- and long-term effects are relevant.
>
> b) *Intensity.* This refers to the severity of impact. Responsible officials must bear in mind that more than one agency may make decisions about partial aspects of a major action. The following should be considered in evaluating intensity:
>
> (1) Impacts that may be both beneficial and adverse. A significant effect may exist even if the Federal agency believes that on balance the effect will be beneficial.
>
> (2) The degree to which the proposed action affects public health or safety.
>
> (3) Unique characteristics of the geographic area such as proximity to historic or cultural resources, park lands. prime farmlands. wetlands, wild and scenic rivers, or ecologically critical areas.
>
> (4) The degree to which the effects on the quality of the human environment are likely to be highly controversial.
>
> (5) The degree to which the possible effects on the human environment are highly uncertain or involve unique or unknown risks.
>
> (6) The degree to which the action may establish a precedent for Mure actions with significant effects or represents a decision in principle about a Mure consideration.

> **(7) Whether the action is related to other actions with individually insignificant but cumulatively significant impacts. Significance exists if it is reasonable to anticipate a cumulatively significant impact on the environment. Significance cannot be avoided by terming an action temporary or by breaking it down into small component parts.**
>
> (8) The degree to which the action may adversely affect districts, sites, highways, structures, or objects listed in or eligible for listing in the National Register of Historic Places or may cause loss or destruction of substantial scientific, cultural, or historical resources .
>
> (9) The degree to which the action may adversely affect an endangered or threatened species or its habitat that has been determined to be critical under the Endangered Species Act of 1973.
>
> (10) Whether the action threatens a violation of Federal, State, or local law or requirements imposed for the protection of the environment.

For the purposes of considering the impacts of accidental releases of hazardous materials at Fort Knox (and other mines), the seventh point under intensity (bolded above) is especially relevant. While any individual spill, particularly a small one, may seem insignificant, the cumulative effects may be significant, especially when combined across multiple spill sources (transportation, storage, etc.) and substances (hydraulic oil, ethylene glycol, etc.).

Within the environmental assessment (CH2M Hill 1993), the possibility of accidental releases was acknowledged in the context of medical training and response:

> FGMI would provide training opportunities for certification of employees in mine rescue and advanced technical training for hazardous material incidents, and as medical first responders, emergency medical technicians, and hazardous material incident first responders.

There were no prospective estimates of the number of spills that might be associated with Fort Knox Mine, either at the mine and milling site or along the transportation corridor. A 2004 environmental audit included inspection of hazardous material storage and handling (Golder Associates Inc. 2004). The 2012 audit did not mention hazardous materials among its eight areas of focus (SRK Consulting 2012). The 2019 environmental audit scope did not originally include spill reporting in its RFP, but that issue was part of an expanded scope of work (SRK Consulting 2019):

> **Spill Prevention and Response (SPAR)**
> The SPAR has a thankless but critical job of overseeing spill prevention and response throughout a large state with an extreme climate. Much of the reporting and response is likely based on reports with minimal and incomplete background from which they have to make their regulatory decisions. Ms. Ashley Adamczek, Environmental Program Specialist, was knowledgeable about the Fort Knox Mine and the spill history. She noted that the Division of SPAR has to work within the existing permits and authorizations.

SRK Recommendation: Continue to work with FGMI to resolve the ongoing issue regarding the October 2015 containment diesel spill. In the approved Reclamation and Closure Plan, FGMI plans an onsite assessment and mitigation of areas with potential contamination is part of the final closure procedures. With the location of the mill and process components upgradient of the TSF (approved solid waste facility), extensive site investigations during operations would only serve to complicate current operations and potential be disruptive if buried electrical or water lines were to be compromised.

Example quantitative spill probabilities and expected numbers of spills

Based on *a priori* information (CH2M Hill 1993) and one update of reagent use once the thickener was part of the high grade ore processing (Golder Associates, Inc. 2004), I estimated the number of trips to Fort Knox Mine with hazardous materials from 1996-2002 and 2003-2020 to find the total number of miles traveled by trucks carrying hazardous materials, the expected number of spills based on Harwood and Russell's (1990) spill rate per truck mile, and the probability of there being at least one spill along the transportation corridor, assuming the spills followed a Poisson distribution (Table 6.13). More than 1,000,000 miles of truck travel resulted in an expected value of 0.21 spills between 2003-2020, and or an 18.7% probability of at least one spill along the transportation route during that time.

Table 6.13. Order of magnitude estimate of expected transportation spills of hazardous materials and the probability of there being at least one such spill using Harwood and Russell's (1990) spill rate and a rough estimate of 1,880 hazardous loads/year from 1996-2002 and 1,600 hazardous loads/year from 2003-2020.

Descriptor	Value
Hazardous materials loads/year 1996-2002	1,880
Years 1996-2002 (inclusively)	7
Trips with hazardous materials 1996-2002	13,160
Hazardous materials loads/year 2003-2020	1,600
Years 2003-2020 (inclusively)	18
Trips with hazardous materials 2003-2020	28,800
Trips with hazardous materials 1996-2020	41,960
Miles per load (from Fairbanks to Fort Knox)	26
Total miles traveled 1996-2020	1,090,960
Spills per mile	1.9×10^{-7}
Expected number of spills	0.21
Probability of at least one spill	18.7%

Spills discussed in the environmental audits

Environmental audits of Fort Knox give an evolving view of the number of spills. Kinross Gold Company (2009) had nothing to report at the time it was published, as

> The Fort Knox Toxic Release Inventory (TRI) is being completed for the reporting year of 2009. The TRI report is expected to be completed by March 2009. The TRI report will accurately represent all of the materials to provide the community and all citizens of the chemical hazards that exist in their areas. The 2008 chemical inventory information will be made publicly available on several EPA databases.

By 2012, there were case studies and discussions of individual spills and explicit mention of communication between Fort Knox and ADEC's Spill Prevention and Response (SPAR) program (SRK Consulting 2012). SPAR noted that FGMI was "timely and thorough" in reporting spills (SRK Consulting 2012). SRK Consulting (2012) included a description of May 4, 2010, spill of 305,300 gallons of process solution containing cyanide, which spilled into containment. Approximately 35,000 gallons broke secondary containment, thus releasing of 34.8 pounds of cyanide. The resultant excavation of contaminated soil, site clean-up, and testing were detailed. (ADEC (2021) lists six sodium cyanide solution spills from 2000 to 2009 in volumes from 7.45-300 gallons, two hydrogen cyanide spills of 0.5-198 gallons in 2010 and 2012 at Fort Knox, and 77 process water spills. See Table 6.20.) The 2019 environmental audit described spills of 1,500 gallons of diesel at the northeast corner of the Barnes Creek Waste Rock Dump on October 7, 2015, and a 6,000-gallon release of untreated tailing storage facility seepage water on May 22, 2018 (SRK Consulting 2019).

There is a lack of clarity about which spills are reported. As noted in SRK Consulting (2019) (italicized emphasis added):

> Per the FGMI Spill Reporting Procedures and Waste Disposal (FGMI 2017), releases of hydrocarbons and hazardous materials *which enter the environment* are reported to ADEC Division of Spill Prevention and Response and are remediated. *Since 2014*, FGMI has reported releases consisting of brake fluid, hydraulic oil, coolant, compressor oil, automatic transmission fluid, engine oil, ethylene glycol, propylene glycol, process solution, ammonium nitrate, diesel fuel, and gear oil. A spot check of online records (https://dec.alaska.gov/Applications/SPAR/PublicMVC/PERP/FacilityDetails?FacilityID=85173) indicates these incidents appear to have been adequately addressed and closed by SPAR. *Some of the data on the SPAR site does not match what was reported by FGMI*.
>
> *According to FGMI, reportable releases have been decreasing at a steady rate* (M. Huffington, personal communication, July 17, 2018). Much of the decrease can be attributed to FGMI identifying equipment parts failures and working with the manufacturer to reduce the frequency of failure. A review of the *142 out-of-pit spills reported by FGMI since 2012* indicated:
>
> - 9% of the spills were less than one gallon;
> - 68% of the spills ranged between one and ten gallons;
> - 14% of the spills ranged between 11 and 54 gallons; and

- 9% of the spills were greater than 55 gallons.

Based on SRK's operational experience, the number of spills reported is not excessive when considering the extreme climate and amount of equipment in 24-hour operation.

Several questions arise:

- Are spills that do not enter the environment not reported to ADEC? If so, does that mean all the spills incidents associated with Fort Knox which are listed in ADEC (2021) entered the environment? Or are all spills reported and only the ones that reach the environment remediated?
- Have spill releases of substances like the ones listed (brake fluid, hydraulic oil, coolant, etc.) only been reported since 2014, and, if so, why?
- How long a spill record was used in considering a decrease in reportable releases?
- How many spills occurred since 2012 and what proportion does the 142 spills that were out-of-pit represent, both in spill numbers and volume released? (See next section for comparison against ADEC (2021).)
- What would an excessive number of spills be? How is that determined?

Kinross Gold Company (2020) gave a more detailed look at spill records, but only for one quarter of 2019, and then included a more complete list of spill incidents in that year as an appendix (Figure 6.6):

> Petroleum, Hazardous Substances, and Process Solution Spills
>
> During the 4th Quarter 2019 Fort Knox had 11 petroleum spills, 7 ethylene glycol spills, 2 propylene glycol spills and 1 process solution spill. The spills were reported to the ADEC in accordance with discharge notification and reporting requirements, and there was no contamination of surface water or groundwater. The Fort Knox Spill Reporting Log, containing a list of the year to date spills, has been included in Attachment G for your review.

(For a comparison of the spill history characterization given in SRK Consulting (2019) and Kinross Gold Company (2020) to the records from the ADEC database, see the next section.)

Fort Knox Mine Spill Log 2019

Spill Number	Date	Time	Location	Material	Quantity	Units	Equipment	Department	Cause	Cleanup Measures	Disposal	Agency Notified	Date	Time
19-05-01	1/1/2019	6:56 AM	Phase 8 West-1300 Level	Ethylene Glycol	70	Gallons	HT-464	MEM	Heater Hose Failure	Excavation/Absorbs	Rock to Fish Creek/Absorbs to Smart Ash Burner	ADEC Spill Hotline-Mona	1/1/2019	9:06 AM
19-01-02	1/5/2019	7:03 PM	Phase 8 West	Hydraulic Oil	30	Gallons	SH-108	MEM	Boom Cylinder Failure	Excavation/Absorbs	Rock to Fish Creek/Absorbs to Smart Ash Burner	ADEC Spill Hotline-Responder	1/5/2019	1:38 PM
19-01-03	1/11/2019	9:00 AM	Fish Creek Waste Rock Dump	Hydraulic Oil	50	Gallons	LDR-153	MEM	Rear Trunnion Failure	Excavation/Absorbs	Rock to Fish Creek/Absorbs to Smart Ash Burner	ADEC Spill Response-Bonnie	1/11/2019	10:05 AM
19-05-04	1/14/2019	8:45 AM	Phase 8 East-1090 Level	Hydraulic Oil	30	Gallons	SH-109	MEM	Radiator Fan Failure	Excavation/Absorbs	Rock to Yellow Pup/Absorbs to Smart Ash Burner	ADEC Spill Response-Bonnie	1/14/2019	9:35 AM
19-01-05	1/22/2019	1:44 AM	Phase 8 West-1300 Level	Hydraulic Oil	72	Gallons	HT-461	MEM	O-Ring Failure	Excavation/Absorbs	Rock to Barnes Creek/Absorbs to Smart Ash Burner	ADEC Spill Hotline-Spill Responder	1/22/2019	4:50 AM
19-01-06	1/26/2019	12:15 AM	A Grade Stockpile	Hydraulic Oil	67	Gallons	LDR-153	MEM	O-Ring Seal Failure	Excavation/Absorbs	Rock to Yellow Pup/Absorbs to Smart Ash Burner	ADEC Spill Hotline-Mona	1/26/2019	12:55 PM
19-01-07	2/10/2019	2:45 AM	Phase 8 West-1240 Level	Hydraulic Oil	150	Gallons	SH-108	MEM	Control Valve Failure	Excavation/Absorbs	Rock to Barnes Creek/Absorbs to Smart Ash Burner	ADEC Spill Hotline-Sean	2/10/2019	4:30 AM
19-01-08	2/10/2019	4:51 AM	Phase 8 West-1270 Level	Hydraulic Oil	98	Gallons	SH-105	MEM	Suction Hose Failure	Excavation/Absorbs	Rock to Barnes Creek/Absorbs to Smart Ash Burner	ADEC Spill Hotline-Mona	2/10/2019	7:31 AM
19-05-09	2/11/2019	2:28 PM	Fish Creek Waste Rock Dump	Ethylene Glycol	10	Gallons	HT-464	MEM	Coolant Drain Hose Failure	Excavation/Absorbs	Rock to Fish Creek/Absorbs to Smart Ash Burner	ADEC Spill Response-Bonnie Workman	2/11/2019	2:33 PM
19-05-10	2/12/2019	11:10 AM	Fish Creek Waste Rock Dump	Ethylene Glycol	10	Gallons	HT-485	MEM	Water Pump Seal Failure	Excavation/Absorbs	Rock to Fish Creek/Absorbs to Smart Ash Burner	ADEC Spill Response-John Ebel	2/12/2019	12:48 PM
19-01-11	2/15/2019	3:30 PM	Phase 8 East-1690 Level	Hydraulic Oil	5	Gallons	GR-258	MEM	Hydraulic Filter Housing Failure	Excavation/Absorbs	Rock to Fish Creek/Absorbs to Smart Ash Burner	ADEC Spill Response-Bonnie	3/8/2019	2:57 PM
19-05-12	2/16/2019	9:45 PM	Phase 8 East-1690 Level	Ethylene Glycol	20	Gallons	HT-465	MEM	Heater Hose Failure	Excavation/Absorbs	Rock to Fish Creek/Absorbs to Smart Ash Burner	ADEC Spill Hotline-Sean	2/16/2019	10:06 PM
19-05-13	2/24/2019	9:50 PM	Heap Leach Pad	Ethylene Glycol	2	Gallons	HT-479	MEM	Heater Hose Failure	Absorbs	Absorbs to Smart Ash Burner	ADEC Spill Hotline-Sean	2/24/2019	10:40 PM
19-05-14	2/25/2019	4:42 PM	Phase 8 West	Ethylene Glycol	15	Gallons	HT-480	MEM	Coolant Hose Failure	Excavation/Absorbs	Rock to Fish Creek/Absorbs to Smart Ash Burner	ADEC Spill Hotline-Tracy	2/25/2019	6:13 PM
19-01-15	3/1/2019	2:00 PM	Fish Creek Waste Rock Dump	Hydraulic Oil	2	Gallons	FLR-026	Heap Leach	Hydraulic Hose Failure	Absorbs	Absorbs to Smart Ash Burner	ADEC Spill Response-EOM Report	4/1/2019	8:00 AM
19-01-16	3/8/2019	2:54 AM	Phase 8 West	Hydraulic Oil	15	Gallons	HT-464	MEM	Hydraulic Hoist Line Failure	Excavation/Absorbs	Rock to Fish Creek/Absorbs to Smart Ash Burner	ADEC Spill Response-Bonnie Workman	3/8/2019	9:50 AM
19-01-17	3/10/2019	12:30 PM	Phase 8 East-1645	Hydraulic Oil	380	Gallons	SH-107	MEM	Hose Failure in Pump Room	Excavation/Absorbs	Rock to Barnes Creek/Absorbs to Smart Ash Burner	ADEC Spill Hotline-Mona	3/10/2019	1:50 PM
19-01-18	3/19/2019	12:19 AM	Phase 8 West 1300 Level	Hydraulic Oil	390	Gallons	SH-105	MEM	Hydraulic Hose Failure	Excavation/Absorbs	Rock to Barnes Creek/Absorbs to Smart Ash Burner	ADEC Spill Hotline-Mona	3/19/2019	12:35 AM
19-05-19	3/23/2019	12:25 PM	ALPM Containment	Ethylene Glycol	25	Gallons	Coolant Tank	MEM	Used Coolant Tank Overfill	Recovery/Absorbs	Coolant Recycled/Absorbs to Smart Ash Burner	ADEC Spill Hotline-Mona	3/23/2019	3:47 PM
19-01-20	3/24/2019	7:45 AM	Phase 8 West	Hydraulic Oil	10	Gallons	SH-108	MEM	O-Ring Failure	Absorbs	Absorbs to Smart Ash Burner	ADEC EOM Report	4/1/2019	8:00 AM
19-05-21	3/24/2019	8:22 AM	Phase 8 East	Ethylene Glycol	10	Gallons	HT-405	MEM	Heater Hose Failure	Absorbs	Absorbs to Smart Ash Burner	ADEC Spill Hotline-Mona	3/24/2019	9:54 AM
19-01-22	3/31/2019	12:30 AM	Phase 8 East	Hydraulic Oil	40	Gallons	SH-107	MEM	O-Ring Failure/Hardline Failure	Excavation/Absorbs	Rock to Barnes Creek/Absorbs to Smart Ash Burner	ADEC Spill Hotline-Tracy	3/31/2019	12:13 PM
19-04-23	4/4/2019	7:00 AM	Employee Parking Lot	Gasoline	3	Gallons	Employee POV	Employee	Fuel Pump Failure	Absorbs	Absorbs to Smart Ash Burner	ADEC Spill Response-Bonnie Workman	4/4/2019	8:07 AM
19-01-24	4/9/2019	9:45 PM	Phase 8 West-1150 Level	Hydraulic Oil	400	Gallons	SH-108	MEM	Control Valve Plug Failure	Excavation/Absorbs	Rock to Barnes Creek/Absorbs to Smart Ash Burner	ADEC Spill Hotline-Isaac Lovato	4/9/2019	10:08 PM
19-01-25	4/18/2019	12:01 AM	Phase 8 East 1600 Level	Hydraulic Oil	274	Gallons	SH-107	MEM	O-Ring & Hydraulic Hose Failure	Excavation/Absorbs	Rock to Barnes Creek/Absorbs to Smart Ash Burner	ADEC Spill Hotline-Isaac Lovato	4/18/19	1:17 AM
19-01-26	4/23/2019	4:45 AM	Phase 8 West-1270 Level	Hydraulic Oil	150	Gallons	SH-105	MEM	Hydraulic Hose Clamp Failure	Excavation/Absorbs	Rock to Barnes Creek/Absorbs to Smart Ash Burner	ADEC Spill Hotline-David	4/23/2019	4:45 AM
19-05-27	4/24/2019	4:00 PM	Phase 8 East	Ethylene Glycol	2	Gallons	SH-109	MEM	Leaking Radiator Core	Excavation/Absorbs	Rock to Barnes Creek/Absorbs to Smart Ash Burner	ADEC Spill Hotline-David	4/24/2019	6:10 PM
19-01-28	5/6/2019	8:05 PM	Heap Leach Haul Road	Hydraulic Oil	30	Gallons	HT-463	MEM	Hydraulic Steering Hose Failure	Excavation/Absorbs	Rock to Barnes Creek/Absorbs to Smart Ash Burner	ADEC Spill Response-Bonnie Workman	5/6/2019	8:41 AM
19-01-29	5/7/2019	7:20 AM	Phase 8 East-1555 Level	Hydraulic Oil	183	Gallons	SH-109	MEM	Hydraulic Hose Failure	Excavation/Absorbs	Rock to Yellow Pup/Absorbs to Smart Ash Burner	ADEC Spill Response-Patrick Sartz	5/8/2019	8:50 AM
19-01-30	5/17/2019	9:18 PM	Phase 8 West-1210 Level	Hydraulic Oil	109	Gallons	SH-108	MEM	Hydraulic Hose Failure	Excavation/Absorbs	Fish Creek/Absorbs to Smart Ash Burner	ADEC Spill Hotline-Responder	5/17/2019	11:07 PM
19-05-31	5/19/2019	7:03 PM	Phase 8 East-1555 Level	Ethylene Glycol	5	Gallons	SH-109	MEM	Radiator Core Failure	Excavation/Absorbs	Rock to Yellow Pup/Absorbs to Smart Ash Burner	ADEC Spill Hotline-Responder	5/19/2019	7:30 PM
19-01-32	5/20/2019	1:17 AM	Phase 8 East-1510 Level	ATF Oil	15	Gallons	Drill 215	MEM	Oil Cooler Failure	Excavation/Absorbs	Rock to Yellow Pup/Absorbs to Smart Ash Burner	ADEC Spill Response-Paul Lhotka	5/20/2019	2:36 AM
19-01-33	6/1/2019	7:15 AM	Phase 8 West 1210 Level	Hydraulic Oil	60	Gallons	SH-108	MEM	Return Line Coupler Failure	Excavation/Absorbs	Rock to Barnes Creek/Absorbs to Smart Ash Burner	ADEC Spill Hotline-Mona	6/1/2019	7:33 AM
19-10-34	6/3/2019	1:45 PM	RO3 Water Plant	Blue Deodorant	2	Gallons	RO3 Blue Hose	Fort Knox	Operator Spilled Blue Hose Deodorant	Absorbs and H2O Flush	Absorbs to FNSB Landfill	ADEC Spill Response	6/3/2019	2:04 PM
19-01-35	6/23/2019	7:15 AM	Bull Rail/T-Bar	Engine Oil	2	Gallons	Ambulance FDE 003	Safety	Oil Filter Failure	Absorbs	Absorbs to Smart Ash Burner	ADEC Spill Response-Patrick Sartz	7/8/2019	3:22 PM
19-05-36	6/25/2019	12:50 PM	ALPM Shop	Ethylene Glycol	3	Gallons	Sourdough Truck	Contractor	Loose Hose Clamp	Absorbs	Absorbs to Smart Ash Burner	ADEC Spill Response-Paul Lhotka	6/25/2019	2:04 PM
19-01-37	7/9/2019	10:24 AM	Phase 8 West	Hydraulic Oil	30	Gallons	SH-108	MEM	Hydraulic Brake Line Failure	Excavation/Absorbs	Rock to Barnes Creek/Absorbs to Smart Ash Burner	ADEC Spill Response-Paul Lhotka	7/10/2019	10:01 AM
19-01-38	7/14/2019	7:30 PM	B Stockpile 1610 Level	Hydraulic Oil	10	Gallons	LDR-150	MEM	Hoist Cylinder Bolt Failure	Excavation/Absorbs	Rock to Barnes Creek/Absorbs to Smart Ash Burner	ADEC Spill Response-Patrick Sartz	7/14/2019	8:05 AM
19-01-39	7/18/2019	3:20 AM	Phase 8 West	ATF Oil	40	Gallons	Drill 207	MEM	Compressor Line Failure	Excavation/Absorbs	Rock to Barnes Creek/Absorbs to Smart Ash Burner	ADEC Spill Response-Jill	7/18/2019	9:16 AM
19-01-40	7/18/2019	5:10 AM	Phase 8 West	Hydraulic Oil	391	Gallons	SH-108	MEM	Hydraulic Return Coupler Failure	Excavation/Absorbs	Rock to Barnes Creek/Absorbs to Smart Ash Burner	ADEC Spill Response-Jill	7/18/2019	9:18 AM
19-05-41	7/21/2019	1:58 AM	Phase 8 West	Ethylene Glycol	40	Gallons	HT-464	MEM	Cooler Gasket Failure	Excavation/Absorbs	Rock to Fish Creek/Absorbs to Smart Ash Burner	ADEC Spill Hotline	7/21/2019	3:12 AM
19-01-42	8/4/2019	6:05 AM	Phase 8 West 1090 Level	Hydraulic Oil	75	Gallons	SH-105	MEM	Hydraulic Coupler Failure	Excavation/Absorbs	Rock to Fish Creek/Absorbs to Smart Ash Burner	ADEC Spill Hotline-Mona	8/4/2019	8:03 AM
19-05-43	8/19/2019	5:58 PM	Administration Building-East End	Propylene Glycol	0.75	Gallons	Heating System	Bld Maint	Air Bleed Valve Failure	Absorbs/Recovery	Absorbs to Smart Ash Burner/Recycle Glycol-Water	ADEC Spill Hotline-Tracy	8/19/2019	7:07 PM
19-01-44	8/25/2019	6:00 PM	Tailings Dam	Hydraulic Oil	10	Gallons	Rental D-6 Dozer	AAP	Hydraulic Hose Failure	Excavation/Absorbs	Rock to Fish Creek/Absorbs to Smart Ash Burner	ADEC Spill Response-Bonnie	8/30/2019	8:33 AM
19-03-45	8/30/2019	7:25 AM	Phase 8 West	Diesel Fuel	30	Gallons	SH-105	MEM	Automatic Shut Off Failure	Excavation/Absorbs	Rock to Fish Creek/Absorbs to Smart Ash Burner	ADEC Spill Response-Bonnie	8/30/2019	8:33 AM
19-03-46	9/11/2019	9:30 AM	TSF Barge	Diesel Fuel	1	Gallons	Godwin Pump 903	Mill	Overfilled Fuel Tank	Absorbs	Absorbs to Smart Ash Burner	ADEC Spill Response EOM	10/3/2019	3:32 PM
19-01-47	9/16/2019	2:28 PM	Barnes Creek Waste Rock Dump	Hydraulic Oil	100	Gallons	HT-467	MEM	Wheel Seal Failure	Excavation/Absorbs	Rock to Fish Creek/Absorbs to Smart Ash Burner	ADEC Spill Response-Colin Taylor	9/16/2019	3:15 PM
19-01-48	9/24/2019	4:30 PM	Phase 8 West	Hydraulic Oil	80	Gallons	HT-477	MEM	Hydraulic Hose Failure	Excavation/Absorbs	Rock to Fish Creek/Absorbs to Smart Ash Burner	ADEC Spill Hotline-Tracy Peterson	9/24/2019	8:05 PM
19-05-49	10/3/2019	7:55 PM	Phase 9 West	Ethylene Glycol	4	Gallons	HT-448	MEM	Coolant Hose Failure	Excavation/Absorbs	Rock to Barnes Creek/Absorbs to Smart Ash Burner	ADEC Spill Hotline-Isaac Lovato	10/3/2019	9:08 PM
19-05-50	10/10/2019	7:30 AM	MEM Wash Bay	Propylene Glycol	5	Gallons	Heating System Valve	MEM	Valve Inadvertainly Bumped Open	Absorbs	Absorbs to Smart Ash Burner	ADEC Spill Response-Bonnie Workman	10/10/2019	8:13 AM
19-01-51	10/15/2019	9:15 PM	Phase 8 East-1420 Level	Hydraulic Oil	155	Gallons	SH-107	MEM	Center Swivel Plug Failure	Excavation/Absorbs	Rock to Fish Creek/Absorbs to Smart Ash Burner	ADEC Spill Hotline-Spill Responder	10/15/2019	12:15 AM
19-01-52	10/17/2019	4:35 AM	ALPM Bulk Containment	Rock Oil	650	Gallons	Rock Oil Pump	MEM	Rock Oil Pump Fitting Failure	Excavation/Absorbs	All Rock Oil Recovered	ADEC Spill Hotline-Spill Responder	10/17/2019	4:55 AM
19-06-53	10/22/2019	11:10 AM	Detox Pump Alley	Process Solution	24,100	Gallons	F29PP211 Valve	Mill	Valve Failure	Excavation	Rock Taken To Heap Leach	ADEC Spill Response-Paul Lhotka	10/22/2019	12:30 PM
19-05-54	10/22/2019	12:37 PM	Phase 8 West	Ethylene Glycol	30	Gallons	Drill 213	MEM	Engine Failure	Excavation/Absorbs	Rock to Fish Creek/Absorbs to Smart Ash Burner	ADEC Spill Response-Scott Joyce	10/22/2019	4:11 PM
19-01-55	10/28/2019	4:15 AM	Phase 9 West	Hydraulic Oil	10	Gallons	SH-105	MEM	Fan Motor Failure	Excavation/Absorbs	Rock to Barnes Creek/Absorbs to Smart Ash Burner	ADEC Spill Response-Bonnie Workman	11/1/2019	2:02 PM
19-01-56	11/3/2019	3:20 AM	Phase 8 West-970 Level	Hydraulic Oil	30	Gallons	SH-108	MEM	Hydraulic Return Coupler Failure	Excavation/Absorbs	Rock to Barnes Creek/Absorbs to Smart Ash Burner	ADEC Spill Response-Bonnie Workman	11/4/2019	9:16 AM
19-01-57	11/5/2019	12:43 AM	Phase 8 West-1000 Level	Hydraulic Oil	2	Gallons	SH-108	MEM	Hydraulic Return Coupler Failure	Excavation/Absorbs	Rock to Barnes Creek/Absorbs to Smart Ash Burner	ADEC Spill Response-Bonnie Workman	11/14/2019	11:19 AM
19-05-58	11/5/2019	9:00 AM	Admin Boiler Room	Propylene Glycol	5	Gallons	Pressure Valve	MEM	Relief Valve Failure	Absorbs	Absorbs burned in Smart Ash Burners	ADEC Spill Response-Bonnie Workman	11/5/2019	9:42 AM
19-05-59	11/6/2019	4:00 AM	Phase 8 West	Ethylene Glycol	10	Gallons	HT-487	MEM	Engine Failure	Excavation/Absorbs	Rock to Fish Creek/Absorbs to Smart Ash Burner	ADEC Spill Hotline-Isaac Lovato	11/6/2019	4:23 AM
19-01-60	11/24/2019	1:37 PM	Fish Creek Waste Rock Dump	Hydraulic Oil	20	Gallons	LDR-152	MEM	Hydraulic Return Coupler Failure	Excavation/Absorbs	Rock to Barnes Creek/Absorbs to Smart Ash Burner	ADEC Spill Hotline-Mona	11/24/2019	2:48 PM
19-01-61	11/25/2019	11:39 PM	Phase 8 East	Hydraulic Oil	100	Gallons	SH-108	MEM	Hydraulic Hose Failure	Excavation/Absorbs	Rock to Fish Creek/Absorbs to Smart Ash Burner	ADEC Spill Response-Bonnie Workman	11/26/2019	11:24 AM
19-01-62	11/27/2019	12:15 PM	Mill Lab Parking Lot	ATF Oil	2	Gallons	Skid Steer #75	Mill	Hydraulic Hose Leak	Excavation/Absorbs	Snow to Wash Bay/Absorbs to Smart Ash Burner	ADEC Spill Response-	12/16/2019	9:17 AM
19-01-63	12/4/2019	3:15 AM	Phase 9 West	Hydraulic Oil	5	Gallons	Drill 207	MEM	Oil Filter Failure	Excavation/Absorbs	Rock to Fish Creek/Absorbs to Smart Ash Burner	ADEC Spill Response-	12/16/2019	9:17 AM
19-05-64	12/9/2019	2:50 PM	Security Scale	Ethylene Glycol	0.5	Gallons	Contractor Truck	Carlisle	Coolant Hose Leak	Excavation/Absorbs	Snow to Barrel/Absorbs to Smart Ash Burner	ADEC Spill Response-Scott Joyce	12/9/2019	3:35 PM
19-05-65	12/11/2019	12:30 PM	Phase 8 East	Ethylene Glycol	45	Gallons	Dozer-322	MEM	Lower Coolant Hose Failure	Excavation/Absorbs	Rock to Barnes Creek/Absorbs to Smart Ash Burner	ADEC Spill Hotline-Spill Dispatcher	12/12/2019	12:57 AM
19-01-66	12/12/2019	1:30 AM	Phase 8 West	Hydraulic Oil	30	Gallons	Fuel Truck 703	MEM	Hydraulic Pump Failure	Excavation/Absorbs	Rock to Barnes Creek/Absorbs to Smart Ash Burner	ADEC Spill Response-Paul Lhotka	12/12/2019	10:57 AM
19-05-67	12/21/2019	7:00 AM	Barnes Creek Ramp-1800 Level	Ethylene Glycol	10	Gallons	HT-477	MEM	Heater Hose Failure	Excavation/Absorbs	Rock to Barnes Creek/Absorbs to Smart Ash Burner	ADEC Spill Hotline-Mona	12/21/2019	7:42 AM
19-05-68	12/25/2019	3:00 AM	Barnes Creek Haul Road Ramp	Ethylene Glycol	70	Gallons	HT-477	MEM	Heater Hose Failure	Excavation/Absorbs	Rock to Barnes Creek/Absorbs to Smart Ash Burner	ADEC Spill Hotline-Isaac Lovato	12/25/2019	4:18 AM
19-01-69	12/27/2019	12:40 PM	Barnes Creek Waste Rock Dump	Hydraulic Oil	45	Gallons	HT-467	MEM	Final Dup Core Seal Failure	Excavation/Absorbs	Rock to Barnes Creek/Absorbs to Smart Ash Burner	ADEC Spill Hotline-Rachael	12/27/2019	3:35 PM

Spill Number Key: 1-Oil, 2-Grease, 3-Diesel, 4-Gas, 5-Ethylene or Propylene Glycol, 6-Process Solution, 7-Reagent, 8-Blasting Emulsion, 9-Ammonium Nitrate-10-Other, 11-Seed Based Oil

Figure 6.6. Fort Knox Mine Spill Log for 2019 (Appendix G of Kinross Gold Company 2020, pdf p. 110).

Spill record from ADEC

I sorted the more than 12,000 spills in the Interior Alaska subarea (ADEC 2021) by *responsible party*. There were 1,266 spills attributed to Fairbanks Gold Mining, Incorporated (and variants of that name) and 608 spills attributed to Fort Knox (and variants). In addition, there were 43 spills with Alaska West Express and 32 spills from Lynden Transport along the Steese Highway, Elliot Highway, or in Fairbanks City or Fairbanks North Star Borough. If all the Alaska West Express and Lynden Transport spills are included with the Fort Knox/True North spills, there were a total of 1,949 spills associated with those mines from July 1995-December 2020 (Appendix B4).

The spills at Fort Knox occurred in the *extremely hazardous substance* (16 spills), *hazardous substance* (533 spills), *non-crude oil* (1,322 spills), and *process water* classes (78 spills) (Tables 6.14 and 6.15) Hydrochloric acid, sodium cyanide, diesel, and flocculant were mentioned in the environmental assessment (CH2M Hill 1993) and/or later documents (Golder Associates, Inc. 2004, Kinross 2009) and were spilled more than 250 times between 1995-2020. Most of the substances listed in ADEC (2021) were not mentioned in the environmental assessment (Table 6.14). The most frequently spilled substance was hydraulic oil, with 846 recorded incidents (43.5% of the number of incidents) and 42,433 gallons released (8.0% of the total volume) (Figure 6.7).

More than 88% of the spills were <100 gallons in size, and 1.5% were ≥1,000 gallons (Table 6.16, Figure 6.8). The spills of <100 gallons collectively accounted for 5.9% of the total volume released, and spills ≥1,000 gallons accounted for 85.3% of the volume (Table 6.17, Figure 6.8). Spills classed as *hazardous substances* and *non-crude oil* had the largest numbers, but the largest volume spills were of *process water* (Tables 6.16 and 6.17, Figures 6.8 and 6.9).

Table 6.14. There were 1,944 recorded spill incidents at Fort Knox/True North Mines from July 1995-2020 with quantities given in gallons (ADEC 2021). Total values for each substance subtype have been rounded to the tenth of a gallon. Substances in shaded rows were not discussed in CH2M Hill (1993) or Golder Associates Inc. (2004).

		Volume (gallons)	
	n	Range	Total
Extremely hazardous substances			
Chlordane	1	0.032	0.032
Formaldehyde	1	10	10
Hydrochloric acid	1	5	5
Hydrogen cyanide	2	0.5-198	198.5
Phosphoric acid, dimethyl 4- (methylthio)	1	0.5	0.5
Sodium cyanide (solution)	6	7.45-300	819.95
Sulfuric acid	1	1	1
Total	13		1,035
Hazardous substances			
Acid, other	1	1	1
Caustic alkali liquids (caustic soda)	1	1	1
Emulsion breaker	1	5	5
Ethyl alcohol (ethanol)	2	5-45	50
Ethylene glycol (antifreeze)	439	0.008-200	7,174.8
Glycol, other	21	0.125-47	210.1
Lead	1	0.25	0.25
Methyl alcohol (methanol)	12	0.085-50	122.1
Mill slurry	6	5.84-2,572	2,662.8
Other*	29	0.026-800	3,612.7
Propylene glycol	17	2-120	609
Sodium hypochlorite	1	1	1
Solvent	1	200	200
Tetrachloroethene	1	20	20
Total	533		14,670

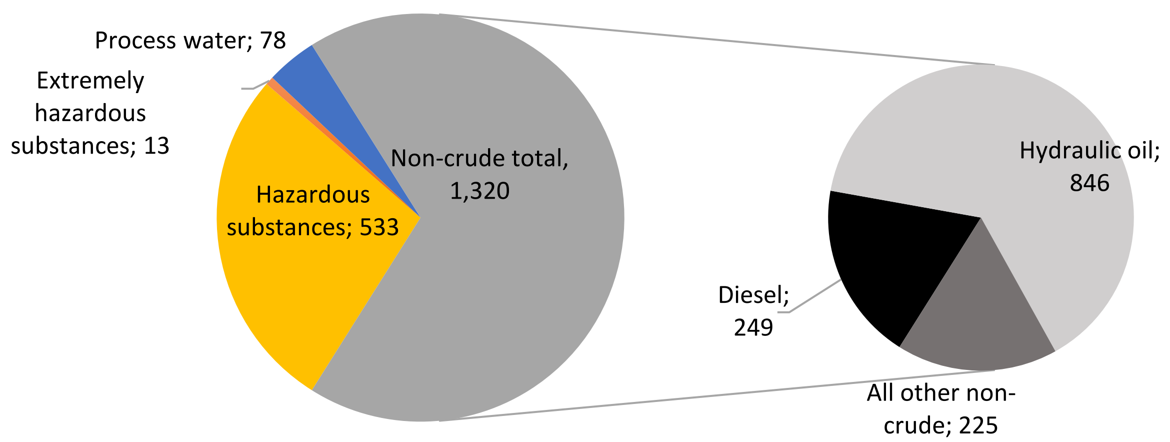
* Other hazardous substances listed in the spill names include sodium hydroxide, “NAICO EC1567S”, “ChemTreat”, process solution (3 spills), cyanide briquettes, “Blue House Deodorant”, flocculent, cyanide, and diisobutyl ketone. Eighteen spills of other hazardous substances had blank spill names.

Table 6.14. (Continued.)

	n	Volume (gallons)	
		Range	Total
Non-crude oil			
Aviation fuel	1	5	5
Diesel	249	0.5-1,100	8,891.2
Engine lube oil	118	0.125-800	2,874.1
Engine lube/gear oil	2	2-10	12
Gasoline	5	1.5-17	26.5
Grease	5	1-60	69
Hydraulic oil	846	0.5-670	42,443.4
Other	8	5-1,000	2,025
Synthetic oil	5	2-9	29
Transmission oil	73	0.25-1,000	2,711.3
Used oil (all types)	8	1-20	61
Total	1,320		59,147
Process water			
Process water	77	1-305,370	452,281.2
Source water	1	400	400
Total	78		452,681

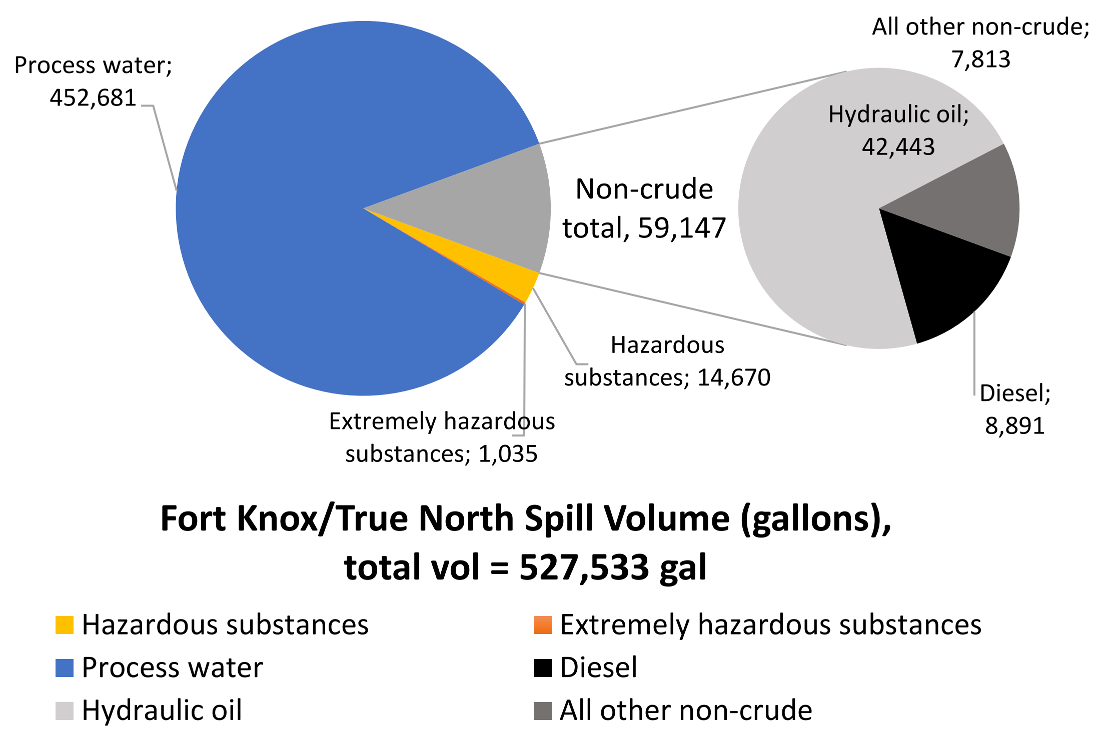
Table 6.15. There were five recorded spill incidents at Fort Knox/True North Mines from July 1995-2020 with quantities given in pounds (ADEC 2021). Total values for each substance subtype have been rounded to the tenth of a pound.

	n	Quantity (pounds)	
		Range	Total
Hazardous substances			
Bases	1	5,000	5,000
Other	2	1-3	4
Non-crude oil			
Grease	2	10	20



Total Fort Knox/True North spills by substance (*n* = 1,944)

a.



b.

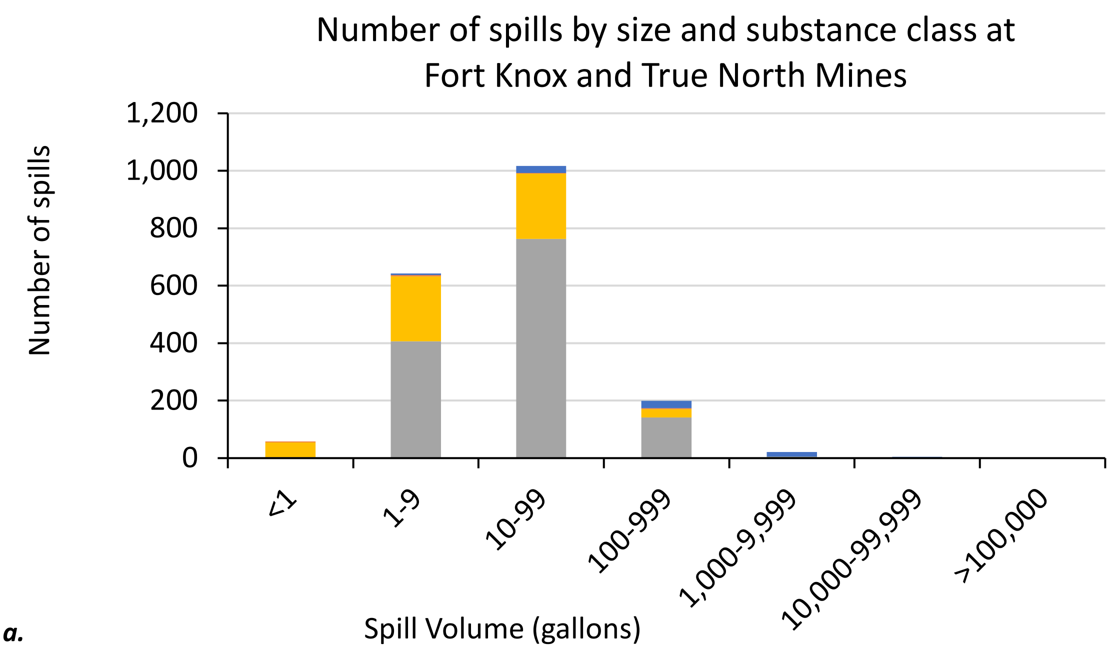
Figure 6.7. Relative proportions of (a) number and (b) volume from different substance classes at Fort Knox and True North mines from 1995-2020 with non-crude oil spills further broken down to show the amounts due to diesel and hydraulic oil spills.

Table 6.16. Counts of Fort Knox and True North Mine spills from July 1995-December 2020 by substance class and size category (ADEC 2021).

Substance class	Number of spills per size class								
	Spill Size Class (gallons)							Total	Percent
	<1	1-9	10-99	100-999	1,000-9,999	10,000-99,999	≥100,000		
Ex Haz Sub	3	4	2	4				13	0.7%
Haz Sub	51	226	227	28	1			533	27.4%
Non-crude	4	407	763	142	4			1,320	67.9%
Process water		6	25	25	16	5	1	78	4.0%
Total	58	643	1,017	199	21	5	1	1,944	
Percent	3.0%	33.1%	52.3%	10.2%	1.1%	0.3%	0.1%		

Table 6.17. Cumulative volume released through Fort Knox and True North Mine spills from July 1995-December 2020 by substance class and size category (ADEC 2021).

Substance class	Cumulative volume spilled per size class (gallons)								
	Spill Size Class (gallons)							Total	Percent
	<1	1-9	10-99	100-999	1,000-9,999	10,000-99,999	≥100,000		
Ex Haz Sub	1	21	20	993				1,035	0.2%
Haz Sub	17	756	5,893	5,433	2,572			14,670	2.8%
Non-crude	1	1,627	21,859	31,561	4,100			59,147	11.2%
Process water		26	908	8,685	27,300	110,392	305,370	452,681	85.8%
Total	19	2,429	28,679	46,672	33,972	110,392	305,370	527,533	
Percent	0.0%	0.5%	5.4%	8.8%	6.4%	20.9%	57.9%		



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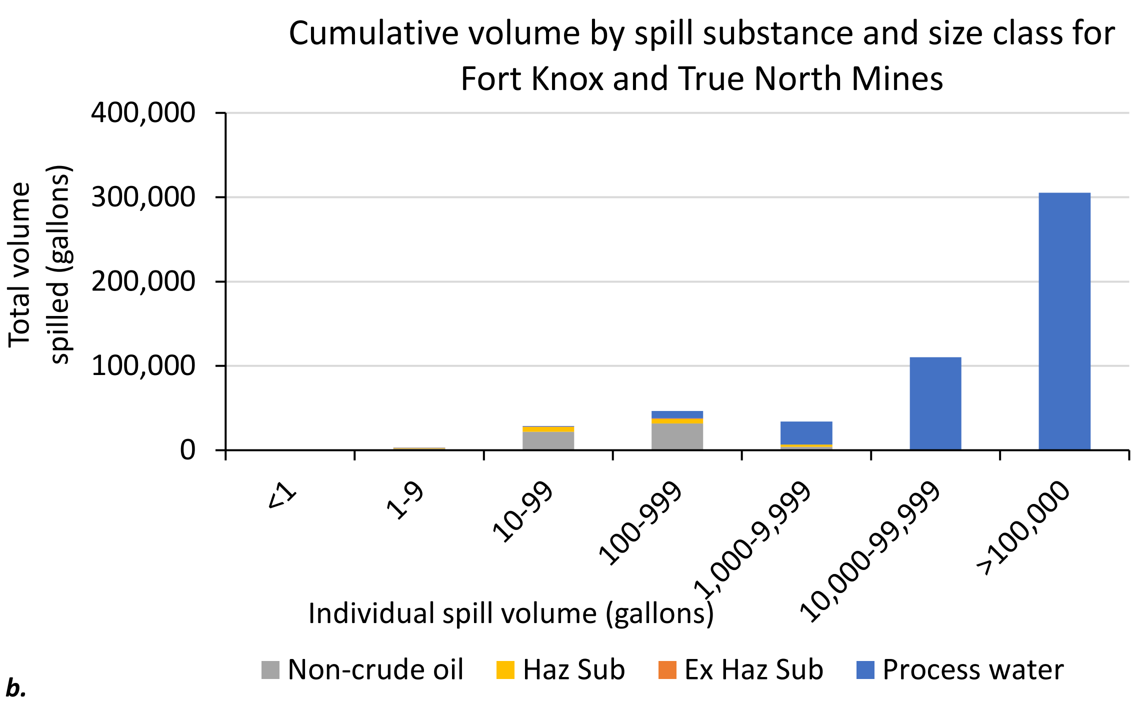


b.

Figure 6.8. Number of spill incidents (a) and cumulative gallons spilled (b) for non-crude oil, hazardous substances, extremely hazardous substances, and process water in different spill size classes for Fort Knox and True North Mines from July 1995-December 2020 based on ADEC (2021).

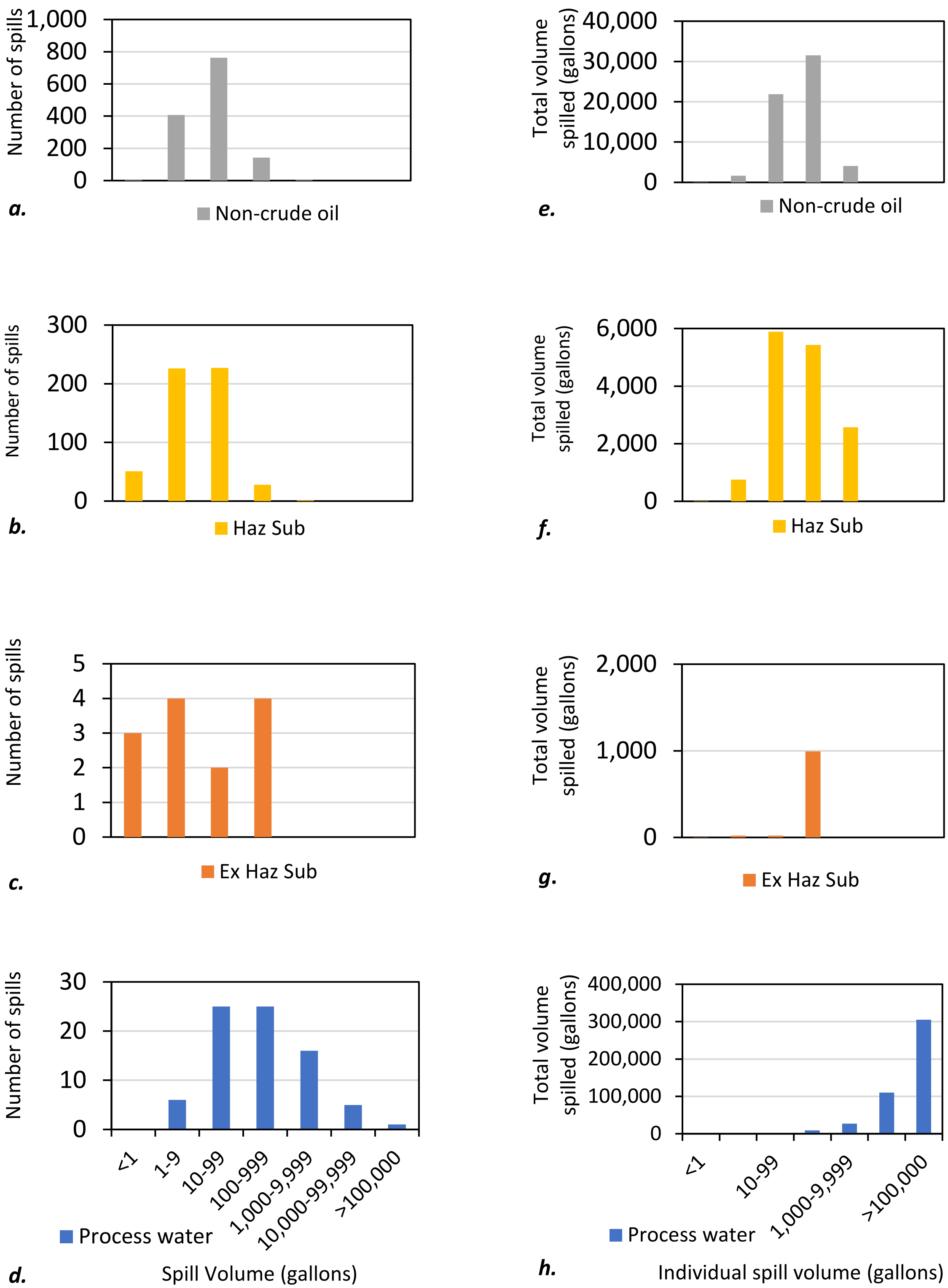


Figure 6.9. Number of spill incidents (a-d) and cumulative gallons spilled (e-h) for non-crude oil (a, e), hazardous substances (b, f), extremely hazardous substances (c, g) and process water (d, h) in different spill size classes for Fort Knox and True North Mines from July 1995-December 2020 based on ADEC (2021). All subfigures have the same x-axes.

The ADEC issued the *Summary of Oil and Hazardous Substances Spills by Subarea (July 1, 1995 – June 30, 2005)* in 2007. Fort Knox and True North Mines lie within the Interior Alaska subarea. ADEC (2007) listed 11 spills of at least 1,000 gallons associated with Fort Knox Mine from 1995-2005, a list which excludes spills reported in pounds and potential spills (Table 6.18). There were 28 spills of at least 1,000 gallons associated with Fort Knox Mine from 1995-2020 recorded in the ADEC (2021) (Table 6.19), with some significant discrepancies between ADEC (2007) and ADEC (2021). The list of large spills in ADEC (2007) is an incomplete record. First, it is at least 15 years out of date. Also, the records for Fort Knox/True North from ADEC (2021) include 5 spills given in gallons that occurred between 1995 and 2005 that were not listed in ADEC (2007).

Table 6.18. Extracts from "Major Spills in the Interior Alaska Subarea" (ADEC 2007) showing 11 major spills related to Fort Knox/True North Mines by 2005.

Date	Spill Name	Product	Gallons
06/11/2003	Fort Knox Gold Mine, Spill to containment	Process Water	24,092
06/18/2002	Fort Knox Gold Mine, NE of Mill Yard	Process Water	12,800
06/02/2003	Fort Knox Gold Mine, Process water release	Process Water	10,500
4/25/2003	Fort Knox Gold Mine, Equipment failure	Process Water	4,200
11/2/2005	Fort Knox Gold Mine, Equipment failure	Process Water	3,000
7/15/2003	Fort Knox Gold Mine, Process water release	Process Water	2,500
3/29/2004	Fort Knox Gold Mine, Equipment failure	Process Water	2,500
7/6/2003	Fort Knox Gold Mine, SE Corner of Mill	Process Water	2,000
6/25/2004	Fort Knox Gold Mine, Mill Yard	Process Water	1,500
11/4/2004	Fort Knox Gold Mine, Line Failure	Process Water	1,500
10/7/2004	Fort Knox Gold Mine, Sag mill overload	Process Water	1,300

Table 6.19. There were 28 recorded spills of at least 1,000 gallons from July 1995-December 2020 at the Fort Knox/True North Mines (ADEC 2021). Shaded rows indicate spills also listed in Table 6.18. Rows in bold occurred before July 2005 but were not listed in ADEC (2007). Spill names are from ADEC (2021) unless noted as "Responsible party:…"

Date	Spill Name	Product	Gallons
5/4/2010	Ft Knox 305,370 Gal Process Solution Spill	Process Water	305,370
8/23/2012	Fort Knox Heap Leach Cyanide Solution	Process Water	45,000
6/11/2003	Responsible party: FAIRBANKS GOLD MINING INC	Process Water	24,092
10/22/2019	Fort Knox Detox Bldg.18Kgal P.Water w/Cyanide	Process Water	18,000
6/18/2002	Responsible party: FAIRBANKS GOLD COMPANY, INC.	Process Water	12,800
6/2/2003	Responsible party: FAIRBANKS GOLD COMPANY, INC.	Process Water	10,500
6/19/2013	Fort knox Mine Blast truck rollover mine pit	Bases	5,000
4/25/2003	Responsible party: FAIRBANKS GOLD MINING, INC .	Process Water	4,200
11/2/2005	Responsible party: FAIRBANKS GOLD MINING INC.	Process Water	3,000
7/20/2013	Fort Knox Mine- Barron Solution Spill 2572 gallons	Mill Slurry	2,572
7/15/2003	Responsible party: FAIRBANKS GOLD MINING INC	Process Water	2,500
3/29/2004	Responsible party: FAIRBANKS GOLD MINING INC	Process Water	2,500
7/6/2003	Responsible party: FAIRBANKS GOLD MINING INC	Process Water	2,000
6/25/2004	Responsible party: FAIRBANKS GOLD MINING, INC	Process Water	1,500
11/4/2004	Responsible party: FAIRBANKS GOLD MINING, INC	Process Water	1,500
10/10/2013	Fort Knox 1500 Gal Process Solution	Process Water	1,500
10/7/2004	Responsible party: FAIRBANKS GOLD MINING, INC .	Process Water	1,300
6/30/2014	Fort Knox, Mill Tank 1300 Gal Process Water	Process Water	1,300
10/7/2015	Ft Knox New Fuel Island diesel spill	Diesel	1,100
3/26/2010	Truck Accident: Mine Site:	Diesel	1,000
6/1/2011	Alaska West Rail Spur Stain	Other	1,000
3/15/2002	**Responsible party: FAIRBANKS GOLD COMPANY, INC.**	**Process Water**	**1,000**
7/21/2003	**Responsible party: FAIRBANKS GOLD MINE, INC.**	**Process Water**	**1,000**
1/19/2005	**Responsible party: FAIRBANKS GOLD MINING, INC.**	**Process Water**	**1,000**
6/20/2005	**Responsible party: FAIRBANKS GOLD MINING, INC.**	**Process Water**	**1,000**
9/9/2005	**Responsible party: FAIRBANKS GOLD MINING INC.**	**Process Water**	**1,000**
9/29/2011	Fort Knox Mine: North Side of Mill	Process Water	1,000
10/16/2010	Inside new ALPM shop	Transmission Oil	1,000

There has been an average of 76.8 spills per year at Fort Knox from 1996-2020, but the number of spills has varied over time (Table 6.20, Figure 6.10). The main factor in the number of spills per year is the number of *non-crude oil* spills. Spills of *hazardous substances* became more frequent in 2010. (Recall that the heap leach facility was added in 2009.) There is little seasonal variability in the average number of spills per month (Table 6.21, Figure 6.10).

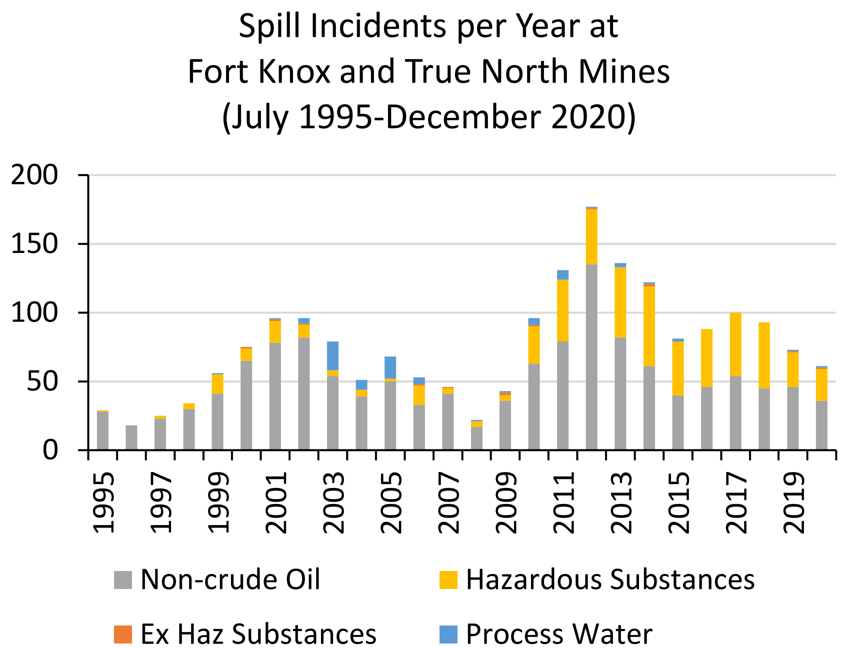
Table 6.20. Spills per year by substance type at Fort Knox/True North Mines from July 1995-December 2020 based on ADEC (2021).

Year	Spills				
	Ex Haz Sub	Haz Sub	Non-crude	Process water	Total
1995		1	28		29
1996			18		18
1997		2	23		25
1998		4	30		34
1999		14	41	1	56
2000	1	9	65		75
2001	1	16	78	1	96
2002	1	9	82	4	96
2003		4	54	21	79
2004		5	39	7	51
2005		2	50	16	68
2006	1	14	33	5	53
2007	1	4	41		46
2008		4	17	1	22
2009	2	4	36	1	43
2010	1	27	63	5	96
2011		45	79	7	131
2012	1	40	135	1	177
2013		51	82	3	136
2014	2	58	61	1	122
2015		39	40	2	81
2016		42	46		88
2017		46	54		100
2018		48	45		93
2019	1	25	46	1	73
2020	1	23	36	1	61
total	13	536	1,322	78	1,949
mean*	0.5	21.4	51.8	3.1	76.8
sd*	0.7	19.0	25.6	5.2	38.5

* for years with complete data (1996-2020)

Table 6.21. Total spills per month by substance type at Fort Knox/True North Mines from July 1995-December 2020 based on ADEC (2021).

Month	Spills				
	Ex Haz Sub	Haz Sub	Non-crude	Process water	Total
January		36	126	5	167
February		47	90	1	138
March	1	41	117	5	164
April	1	38	121	4	164
May	2	41	117	6	166
June	1	58	122	10	191
July	3	57	93	16	169
August	1	50	97	8	156
September	2	38	111	6	157
October		51	133	7	191
November	1	34	102	8	145
December	1	45	93	2	141
Total	13	536	1,322	78	1,949



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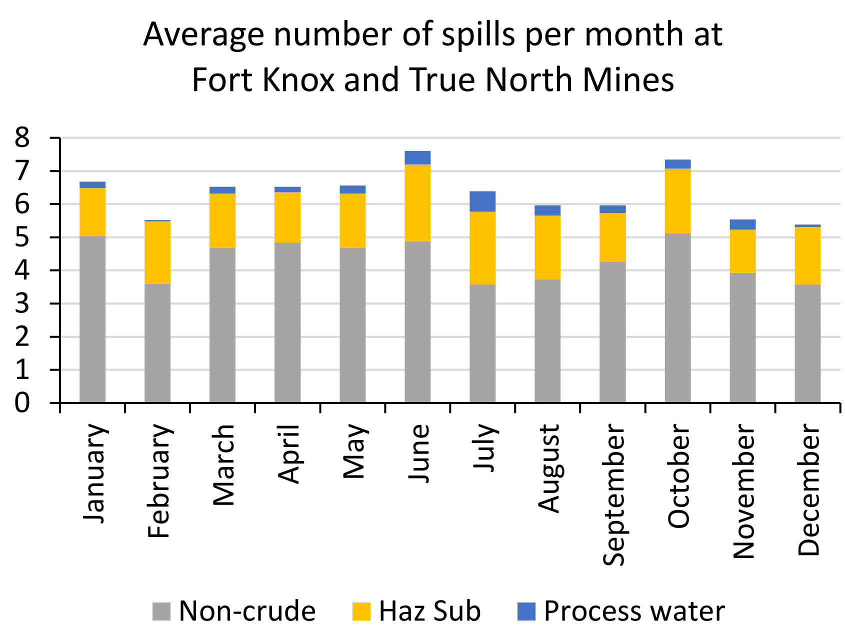


b.

Figure 6.10. Fort Knox and True North (a) spills by year and (b) average spills per month from July 1995-December 2020 based on records from ADEC (2021).

Hazardous substance spills were most frequently caused by *equipment failure* (320 spills), followed by *line failure* (61 spills), *leaks* (45 spills), and *human error* (24 spills) (Table 5.22). *Non-crude oil* spills were mainly attributed to *equipment failure* (584 spills), *line failure* (278 spills), and *human error* (88 spills). *Process water* spills arose from *equipment failure* (25 spills), *human error* (12 spills), and *line failures* (10 spills).

Table 6.22. Spills associated with Fort Knox and True North Mines by cause sub-type and substance category. Five spills with quantities given in pounds are excluded.

Cause subtype	Extremely Hazardous Substances		Hazardous Substances		Non-crude oil		Process Water	
	n	volume range (gal)	*n*	volume range (gal)	*n*	volume range (gal)	*n*	volume range (gal)
Cargo not secured			7	0.25-25	12	2-200		
Collision/allision			4	0.5-240	7	4-106		
Containment overflow	3	10-245	5	20-200	1	10	5	40-500
Corrosion					2	1-25	2	20-500
Crack			4	1-5	7	1.5-20	2	30-400
Equipment failure	1	7.45	320	0.008-800	584	0.25-1,100	25	5-305,370
Erosion							2	500-1,000
External factors	1	10	2	0.25	9	2-50	6	40-2,000
Gauge/site glass failure							2	1,000-3,000
Hull failure					2	5-35		
Human error	2	0.5-5	24	0.25-200	88	0.125-1,000	12	3-45,000
Intentional release			1	30	2	12-30		
Leak	2	0.032-0.5	45	0.125-500	57	1-391		
Line failure	3	7.5-300	61	0.025-100	278	1-670	10	1-1,500
Overfill			6	8-50	57	0.5-400	2	25-30
Puncture	1	1	3	0.5-9	11	1-30		
Rollover/capsize			3	1-10	17	1-300		
Seal failure			12	0.026-350	72	1-100		
Support structure failure					1	20		
Tank failure			1	2,572	2	5-10		
Valve failure			9	2-500	30	1-120	3	300-500
Vehicle leak, all			11	0.5-50	30	1-100		
Other			4	20-150	17	1-600	5	16-1,500
Unknown			11	0.5-100	34	1-200	2	40-12,800
Total spills and volume range (gal)	13	0.032-300	533	0.008-2,572	1,320	0.125-1,100	78	1-305,370

I estimated the number of spills related to transportation by sorting the ADEC (2021) database by *facility type*, *source type*, and *cause subtype*. For Fort Knox Mine spills, I found that at least 301 spills were associated with transportation (Table 6.23). This table is incomplete because sorting by *facility type, source type*, and *cause subtype* is an imperfect algorithm used in a database with gaps and inconsistencies. For example, a spill of 1,000 gallons of diesel on March 26, 2010, was listed as having *facility type* = *mining operation*, *source type* = *heavy equipment*, and *cause subtype* = *human error*, was not included in Table 6.23, even though the spill name was "truck accident: mine site:". Of the 65 total spills attributed to Alaska West Express and Lynden Transport, only 31 had combinations of *facility type*, *source type,* and *cause subtype* that are shown in Table 6.23 (Table 6.24). Transportation spills represent ~15% of all recorded spills at Fort Knox at minimum.

Most of the transportation spills, both numerically and by volume, involved hydraulic oil, which represented 52.2% of the incidents and 60.4% of the roughly 11,630 gallons released. The next four most frequently spilled substances were transmission oil, diesel, engine lube oil, and ethylene glycol (Table 6.25). The largest transportation spill was a 1,000-gallon release of "other" from a bulk fuel terminal on June 1, 2011. (This spill is one of 43 attributable to Alaska West Express. Some of those may not be related to True North or Fort Knox Mines.)

Table 6.23. Transportation related spills from Fort Knox/True North Mines from June 1995-December 2020.

Facility type	Source type	Cause subtype	*n*
Air transportation	Tank, aboveground, other	Overfill	1
Air transportation	[blank]	Leak	1
Bulk fuel terminal	RR tank car	Human Error	1
Bulk fuel terminal	Trailer, tanker	Human Error	1
Maintenance yard/shop	Heavy equipment	Cargo not secured	1
Maintenance yard/shop	Heavy equipment	Vehicle leak, all	3
Maintenance yard/shop	Tank, other, mobile	Various	6
Maintenance yard/shop	Trailer, tanker	Overfill	2
Mining operation	Battery	Cargo not secured	1
Mining operation	Container, other	Cargo not secured	9
Mining operation	Drill	Vehicle leak, all	1
Mining operation	Drum(s)	Cargo not secured	3
Mining operation	Fuel pump	Vehicle leak, all	1
Mining operation	Heavy equipment	Cargo not secured	1
Mining operation	Heavy equipment	Collision/allision	8
Mining operation	Heavy equipment	Rollover/capsize	13
Mining operation	Heavy equipment	Vehicle leak, all	33
Mining operation	Tank, other, mobile	Rollover/capsize	3
Mining operation	Trailer, tanker	Equipment failure	1
Mining operation	Trailer, tanker	Line failure	1
Mining operation	[blank]	Cargo not secured	2
Mining operation	[blank]	Collision/allision	1
Mining operation	[blank]	Rollover/capsize	1
Other	Drum(s)	Cargo not secured	1
Other	[blank]	Cargo not secured	1
Vehicle	Battery	Puncture	1
Vehicle	Heavy equipment	Various	11
Vehicle	Hydraulic system	Line failure	1
Vehicle	Other	Various	5
Vehicle	Pipe or line	Vehicle leak, all	1
Vehicle	Tank, other, aboveground	Various	2
Vehicle	Tank, other, mobile	Various	4
Vehicle	Trailer, other	Valve failure	1
Vehicle	Unknown	Vehicle leak, all	1
Vehicle	[blank]	Various	177
Total			301

Table 6.24. Rough percentage of transportation spills as fraction of total spills associated with Fort Knox and True North Mines.

	Fort Knox and Fairbanks Gold Mining Spills	AWE and Lynden Transport Spills	All possible spills
All spills	1,874	65	1,949
Transportation spills shown in Table 6.23	270	31	301
Percent of spills due to transportation	14.4%		15.4%

Table 6.25. Substances spilled in the 301 transportation incidents in Table 6.23.

	n	Volume (gallons)	
		Maximum released in one incident	Total
Extremely hazardous substances			
Sulfuric acid	1	1	1
Hazardous substances			
Emulsion breaker	1	5	5
Ethylene glycol	30	125	500
Glycol, other	3	15	17.25
Lead	1	0.25	0.25
Methyl alcohol	6	50	82.1
Propylene glycol	2	25	35
Other*	4	278	240
Total	47		917.6
Non-crude oil			
Aviation fuel	1	5	5
Diesel	41	400	1,458.2
Engine lube oil	33	50	445
Gasoline	1	17	17
Grease	1	10 lb	10 lb
Hydraulic oil	157	325	7,030
Transmission oil	46	400	736
Used oil	1	1	1
Other	2	1,000	1,020
Total	253		10,712.2 gal + 10 lb

* All spill name fields were blank.

Comparison of ADEC and Fort Knox spill records

SRK Consulting (2019) stated that:

> A review of the 142 out-of-pit spills reported by FGMI since 2012 indicated:
>
> - 9% of the spills were less than one gallon;
> - 68% of the spills ranged between one and ten gallons;
> - 14% of the spills ranged between 11 and 54 gallons; and
> - 9% of the spills were greater than 55 gallons.

SRK Consulting (2019) came out in February 2019, and therefore I assume the most recent spills considered in the 142 out-of-pit spills would have been from 2018. It is important to distinguish if "since 2012" means since the beginning or the end of calendar year 2012. I compared SRK Consulting's (2019) characterization of the observed spills to the ADEC (2021) spill record from 2012-2018 (Table 6.26) and 2013-2018 (Table 6.27) to get a rough estimate of the proportion of spills that are "out-of-pit" as a fraction of all the spill sizes and by spill size category. If "since 2012" includes calendar year 2012, then out-of-pit spills represent 17.8% of the total spills. If "since 2012" begins in January 2013, then out-of-pit spills represent 22.9% of the total spills. SRK Consulting (2019) indicated that 91% of out-of-pit spills are less than 55 gallons. For spills in- and out-of-pit, the number of spills <55 gallons is 85.8% for 2012-2018 and 82.7% for spills from 2013-2018. Comparisons of larger spills in- and out-of-pit are not possible because SRK Consulting (2019) did not further differentiate beyond >55 gallons, nor was a cumulative volume released given. If "since 2012" includes calendar year 2012 and the heap leach facility is considered out-of-pit, then the 45,000-gallon spill of Fort Knox heap leach cyanide solution on August 23, 2012, which was listed as a *process water* spill from a *pipe or line* in ADEC (2021), would be included in the out-of-pit spills.

Table 6.26. Fort Knox and True North spills from 2012-2018 based on ADEC (2021). There was also one spill of 5,000 lb of bases on June 19, 2013. SRK Consulting (2019) did not break down the >55-gallon spill size class into further groups.

Fort Knox and True North spills from 2012-2018 based on ADEC (2021)					Out of pit spills since 2012	
Spill size class (gallons)	*n*	Percent	Cumulative volume (gallons)	Percent	*n*	Percent
<1	41	5.2	12.596	0.0	13	9
1-10	368	46.2	1,807.03	2.3	96	68
11-54	274	34.4	7,268.2	9.4	10	14
55-99	39	4.9	2,936	3.8	13*	9*
100-999	69	8.7	13,747.5	17.8	*	*
1,000-9,999	4	0.5	6,472	8.4	*	*
≥10,000	1	0.1	45,000	58.3	*	*
Total	796		77,243.33		142	

Table 6.27. Fort Knox and True North spills from 2013-2018 based on ADEC (2021). There was also one spill of 5,000 lb of bases on June 19, 2013. SRK Consulting (2019) did not break down the >55-gallon spill size class into further groups.

Fort Knox and True North spills from 2013-2018 based on ADEC (2021)					Out of pit spills since 2012	
Spill size class (gallons)	*n*	Percent	Cumulative volume (gallons)	Percent	*n*	Percent
<1	27	4.4	8.58	0.0	13	9
1-10	260	42.0	1,301.28	4.3	96	68
11-54	225	36.3	5,977.2	19.9	10	14
55-99	35	5.7	2,666	8.9	13	9*
100-999	68	11.0	13,600.5	45.3	*	*
1,000-9,999	4	0.6	6,472	21.6	*	*
≥10,000	0	0.0	0	0.0	*	*
Total	619		30,025.56		142	

Kinross Gold Company (2020) reported that "[d]uring the 4th Quarter 2019 Fort Knox had 11 petroleum spills, 7 ethylene glycol spills, 2 propylene glycol spills and 1 process solution spill". Based on the 23 spills recorded in ADEC (2021) for the fourth quarter of 2019, a 10-gallon spill of formaldehyde and a 45-gallon spill of ethyl alcohol were missing from the list in Kinross Gold Company (2020) (Table 6.28). It is also worth noting that the "1 process solution spill" was 18,000 gallons of cyanide-laden process water.

Table 6.28. ADEC (2021) lists 23 spills in the fourth quarter of 2019 from Fort Knox Mine. Spills in the shaded rows were not mentioned Kinross Gold Company (2020).

Date	Spill Name	Quantity (gallons)	Substance
10/3/2019	Fort Knox Mine 4gal Ethylene Glycol	4	Ethylene Glycol
10/10/2019	Ft Knox, MEM Wash Bay, 5gal Propylene Glycol	5	Propylene Glycol
10/15/2019	Fort Knox Gold Mine 155gal Hyd	155	Hydraulic Oil
10/17/2019	Fort Knox Gold Mine 650gal Rock Oil	650	Other
10/22/2019	Ft Knox, Phase 8 West, 30gal Ethylene Glycol	30	Ethylene Glycol
10/22/2019	Fort Knox Detox Bldg.18Kgal P.Water w/Cyanide	18,000	Process Water
10/28/2019	Ft Knox, Phase 9 West, 10gal Hydraulic Oil	10	Hydraulic Oil
11/3/2019	Fort Knox Phase 8 W. 30gal Hyd	30	Hydraulic Oil
11/5/2019	Fort Knox Admin. Boiler Rm. 5gal Prop.Glycol	5	Propylene Glycol
11/5/2019	Ft Knox, Phase 8 West 1000 Level, 2gal Hydr. Oil	2	Hydraulic Oil
11/6/2019	Fort Knox Mine 10gal Ethylene Glycol	10	Ethylene Glycol
11/14/2019	Fort Knox SaniCan ~10gal Blue Dyed Formaldehyde	10	Formaldehyde
11/24/2019	Fort Knox Fish Wast Rock Dump, 20gal Hyd	20	Hydraulic Oil
11/25/2019	Fort Knox Phase 8 E., 160gal Hyd	160	Hydraulic Oil
11/27/2019	Fort Knox, Mill Parking Lot, 2gal ATF	2	Transmission Oil
12/4/2019	Fort Knox Phase 9 West 5gal Hyd	5	Hydraulic Oil
12/12/2019	Fort Knox Phase 8 East, 45gal Coolant	45	Ethyl Alcohol
12/12/2019	Fort Knox Phase 8 W. 30gal Hyd	30	Hydraulic Oil
12/21/2019	Fort Knox Mine, Phase 8, 45gal Coolant	45	Ethylene Glycol
12/21/2019	Fort Knox Pit Phase 8 45gal Coolant	45	Ethylene Glycol
12/21/2019	Fort Knox Mine, 10gal Ethylene Glycol	10	Ethylene Glycol
12/25/2019	Fort Knox Mine 70gal Coolant	70	Ethylene Glycol
12/27/2019	Fort Knox Barnes Creek 45gal Hyd	45	Hydraulic Oil

Kinross Gold Company (2020) Appendix G listed 69 spills at Fort Knox in 2019 (Figure 6.6). ADEC (2021) listed 73 spills at Fort Knox in 2019 (Table 6.29). I compared the spill records between the two lists and found five spills that were listed in Kinross Gold Company (2020) but not in ADEC (2021) and eight or nine spills in ADEC (2021) that were not in Kinross Gold Company (2020). (There were two listings of 45-gallon ethylene glycol spills on December 21, 2019, that had different spill ID numbers in ADEC (2021) and might represent a duplicate listing.) The combined list encompasses 77 or 78 spill incidents. In addition to the missing spills, there was a volume discrepancy. The process solution spill on October 19, 2019, was listed in Kinross Gold Company (2020) as 24,100 gallons and in ADEC (2021) as 18,000 gallons. The spill name in ADEC (2021) describes the incident as "Fort Knox Detox Bldg.18Kgal P.Water w/Cyanide" caused by *equipment failure*.

Table 6.29. Spill listings for Fort Knox in 2019 from Kinross (2020) Appendix G and ADEC (2021). Discrepancies are indicated by shaded rows.

Date	Material	Quantity (gallons)	Cause	Kinross (2020) Appendix G	ADEC (2021)
1/1/2019	Ethylene glycol	76	Heater hose failure	x	x
1/5/2019	Hydraulic oil	30	Boom cylinder failure	x	x
1/11/2019	Hydraulic oil	50	Rear transom failure	x	x
1/14/2019	Hydraulic oil	30	Radiator fan failure	x	x
1/22/2019	Hydraulic oil	72	O-ring failure	x	x
1/26/2019	Hydraulic oil	62	O-ring seal failure	x	x
2/10/2019	Hydraulic Oil	60	Equipment Failure		x
2/10/2019	Hydraulic oil	150	Control valve failure	x	x
2/10/2019	Hydraulic oil	96	Suction hose failure	x	
2/11/2019	Ethylene glycol	10	Coolant drain hose failure	x	x
2/12/2019	Ethylene glycol	10	Water pump seal failure	x	x
2/15/2019	Hydraulic oil	5	Hydraulic filter housing failure	x	x
2/16/2019	Ethylene glycol	20	Heater hose failure	x	x
2/24/2019	Ethylene glycol	2	Heater hose failure	x	x
2/25/2019	Ethylene glycol	15	Coolant hose failure	x	x
3/1/2019	Hydraulic oil	2	Hydraulic hose failure	x	x
3/8/2019	Hydraulic oil	15	Hydraulic hoist line failure	x	x
3/8/2019	Hydraulic Oil	20	Equipment Failure		x
3/10/2019	Hydraulic oil	380	Hose failure in pump room	x	x

Table 6.29. (Continued.)

Date	Material	Quantity (gallons)	Cause	Kinross (2020) Appendix G	ADEC (2021)
3/19/2019	Hydraulic oil	390	Hydraulic hose failure	x	x
3/23/2019	Ethylene glycol	25	Used coolant tank overfill	x	x
3/24/2019	Ethylene glycol	10	Heater hose failure	x	x
3/24/2019	Hydraulic oil	10	O-ring failure	x	
3/31/2019	Hydraulic oil	40	O-ring failure/hardline failure	x	x
4/4/2019	Gasoline	3	Fuel pump failure	x	x
4/9/2019	Hydraulic oil	400	Control valve plug failure	x	x
4/18/2019	Hydraulic oil	274	O-ring and hydraulic hose failure	x	x
4/23/2019	Hydraulic oil	150	Hydraulic hose clamp failure	x	x
4/24/2019	Ethylene glycol	2	Leaking radiator []	x	x
5/2/2019	Diesel	5	Human Error		x
5/6/2019	Hydraulic oil	30	Hydraulic shearing hose failure	x	x
5/7/2019	Hydraulic oil	183	Hydraulic hose failure	x	x
5/17/2019	Hydraulic oil	109	Hydraulic hose failure	x	x
5/19/2019	Ethylene glycol	5	Radiator [] failure	x	x
5/20/2019	ATF oil	15	Oil cooler failure	x	x
6/1/2019	Hydraulic oil	60	Return line [] failure	x	x
6/3/2019	Blue deodorant	2	Operator spilled blue house deodorant	x	x
6/23/2019	Engine oil	2	Oil filter failure	x	x
6/25/2019	Ethylene glycol	3	Loose hose clamp	x	x
7/9/2019	Hydraulic oil	30	Hydraulic brake line failure	x	x
7/14/2019	Hydraulic oil	10	Hoist cylinder bolt failure	x	x
7/18/2019	ATF oil	40	Compressor line failure	x	x
7/18/2019	Hydraulic oil	391	Hydraulic return coupler failure	x	x
7/21/2019	Ethylene glycol	40	Cooler [] failure	x	x
8/4/2019	Hydraulic oil	75	Hydraulic coupler failure	x	x
8/19/2019	Propylene glycol	0.75	Air bleed valve failure	x	x
8/25/2019	Hydraulic oil	10	Hydraulic hose failure	x	x
8/30/2019	Diesel	30	Automated shut off valve failure	x	x
9/11/2019	Diesel	1	Overfilled fuel tank	x	x
9/15/2019	Hydraulic Oil	100	Equipment Failure		x
9/16/2019	Hydraulic oil	100	Wheel seal failure	x	x
9/24/2019	Hydraulic oil	80	Hydraulic hose failure	x	x
10/3/2019	Ethylene glycol	4	Coolant hose failure	x	x

Table 6.29. (Continued.)

Date	Material	Quantity (gallons)	Cause	Kinross (2020) Appendix G	ADEC (2021)
10/10/2019	Propylene glycol	5	Valve inadvertently bumped open	x	x
10/15/2019	Hydraulic oil	155	Center [] plug failure	x	x
10/17/2019	Rock oil	650	Rock oil pump filling failure	x	x
10/22/2019	Ethylene glycol	30	Engine failure	x	x
10/22/2019	Process solution	24,100	Valve failure	x	x
10/26/2019	Hydraulic oil	10	Fan motor failure	x	
10/28/2019	Hydraulic Oil	10	Equipment Failure		x
11/3/2019	Hydraulic oil	30	Hydraulic return coupler failure	x	x
11/5/2019	Propylene glycol	5	Relief valve failure	x	x
11/5/2019	Hydraulic oil	2	Hydraulic return coupler failure	x	x
11/6/2019	Ethylene glycol	10	Engine failure	x	x
11/14/2019	Formaldehyde	10	External Factors		x
11/24/2019	Hydraulic oil	20	Hydraulic return coupler failure	x	x
11/25/2019	Hydraulic oil	160	Hydraulic hose failure	x	x
11/27/2019	ATF oil	2	Hydraulic hose leak	x	x
12/4/2019	Hydraulic oil	5	Oil filter failure	x	x
12/9/2019	Ethylene glycol	0.5	Coolant hose leak	x	
12/11/2019	Ethylene glycol	45	Lower coolant hose failure	x	
12/12/2019	Hydraulic oil	30	Hydraulic pump failure	x	x
12/12/2019	Ethyl Alcohol (Ethanol)	45	Equipment Failure		x
12/21/2019	Ethylene glycol	10	Heater hose failure	x	x
12/21/2019	Ethylene Glycol (Antifreeze)	45	Equipment Failure		x
12/21/2019	Ethylene Glycol (Antifreeze)	45	Equipment Failure		x
12/25/2019	Ethylene glycol	70	Heater hose failure	x	x
12/27/2019	Hydraulic oil	45	Final [] cone seal failure	x	x

Environmental enforcement and Notices of Violations

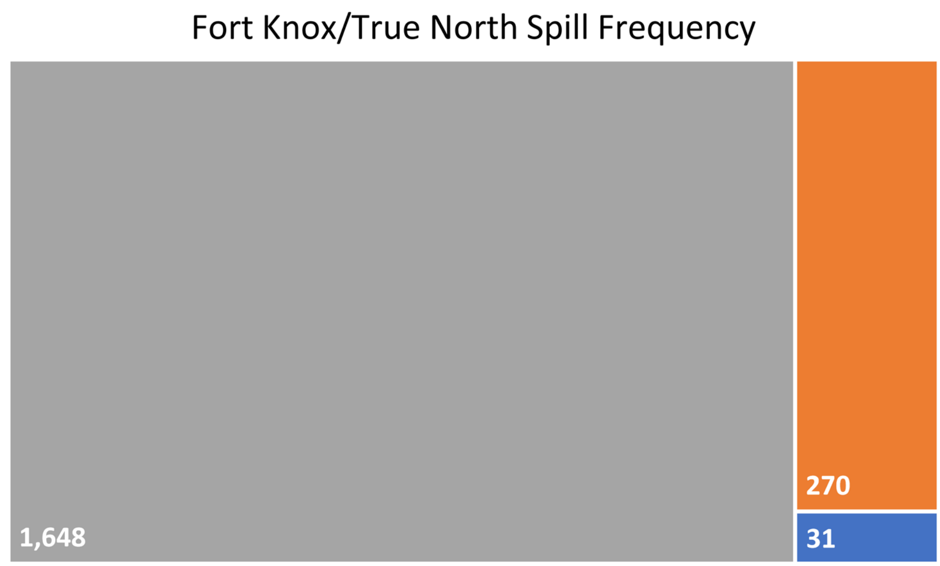
Fort Knox's compliance history includes an identified Clean Air Act violation in the fourth quarter of 2019, as well as Clean Water Act violations from July 2019 to June 2020 (EPA ECHO 2021). The Clean Water Act violations were for exceeding limits on copper and WAD cyanide and for improper/incorrect reporting. (According to the environmental assessment, the "maximum probable WAD cyanide levels in the tailing impoundment after mixing would be 10 mg/L" (CH2M Hill 1993). Informal enforcement actions include a Letter of Violation/Warning Letter in October 2016 and a Notice of Violation in May 2020, both involving Clean Water Act statutes. The state collected a $15,017 penalty for violations of the Clean Water Act in November 2020.

How well were the recorded spills predicted?

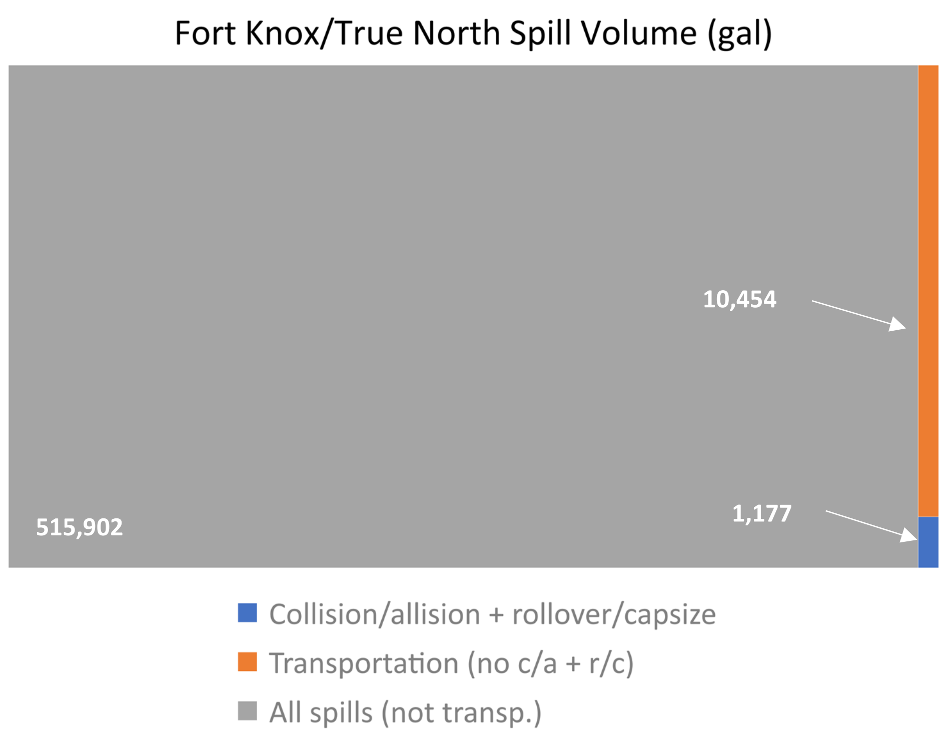
The environmental assessment (CH2M Hill 1993) did not include any predictions about spill risks along the transportation corridor or any other aspects of Fort Knox Mine. If we use the $N = RT$ model for expected number of spills with the Harwood and Russell (1990) spill frequency per truck mile with an estimated number of annual truck trips from 1996-2020, we can derive a predicted number of truck accident spills that accounts for the changing amounts of reagents used once the thickener was used starting in 2003. Only 0.21 spills would have been expected due to truck accidents along the transportation corridor under that model (Table 6.30). There were 31 *collision/allision* and *rollover/capsize* spills recorded for Fort Knox and True North Mines, which were 10.3% of the 301 spills related to transportation. (The estimated number of transportation spills is likely an undercount.) In all, there were 1,949 spills associated with Fort Knox and True North mines (Figure 6.11).

Table 6.30. Predicted and observed spills at Fort Knox/True North Mines from 1995-2020 based on modeled years of exposure risk and ADEC (2021) spill records.

Descriptor	Number of spills
Transportation spills expected based on number of trips/year, miles per trip, and using the Harwood and Russell (1990) spill rate	0.21
Observed spills with cause subtypes of collision/allision and rollover/capsize	11 + 20 = 31
All transportation spills, based on facility type, source type, and cause subtype	301
All spills	1,949



a.



b.

Figure 6.11. A comparison of the relative (a) number and (b) cumulative volume of (collision/allision and rollover/capsize spills) compared to the remaining transportation spills and non-transportation spills at Fort Knox and True North mines from 1995-2020.

Fort Knox and True North Mines Summary

Fort Knox Mine is a conventional open-pit gold mine 26 miles northeast of Fairbanks, Alaska. Fort Knox's initial major components were the mine site, the development rock and overburden stockpiles, the mill site, the tailings impoundment, and the water and power supplies (CH2M Hill 1993). After permitting in 1994, Fort Knox's construction began in 1995, and gold has been produced there since 1996 (SRK Consulting 2019). True North was a satellite deposit 12.5 miles away from Fort Knox, with the ore mined at True North hauled to Fort Knox for processing. The first ore from True North was processed at Fort Knox in March 2001 (Fairbanks Gold Mining, Inc., 2001), and True North Mine was closed in 2012 (SRK Consulting 2012). The Walter Creek Valley Heap Leach Facility (WCVHLF) at Fort Knox was authorized in 2007, with ore placement and leaching beginning in 2009 (SRK Consulting 2019).

Since the 1997, the average milling rate at Fort Knox has been above 36,000 tons per day, with a nominal milling rate of 36,287 tons per day (Sims 2015). Fort Knox has an operating capacity of 35,000 to 50,000 tons of ore per day to produce approximately 300,000 ounces of gold each year. Before the introduction of the heap leach facility, the steps for processing the ore were crushing, grinding, gravity concentration, cyanide leaching, gold recovery, cyanide detoxification, and discharge of tailings (CH2M Hill 1993). For higher grade ore, the mill at Fort Knox uses the conventional processes of crushing and finely grinding the ore in ball mills, followed by gravity concentration and agitated cyanide leaching, and finally a carbon-in-pulp (CIP) circuit for gold adsorption on carbon and carbon stripping. Lower grade ore is processed in a "run-of-mine valley-fill cyanide heap leaching operation where gold is recovered using two parallel carbon-in-column (CIC) circuits" (Sims 2015). The addition of a thickener to the ore process decreased the need for some reagents in 2002.

Fort Knox is about 26 miles from Fairbanks, and True North was 12 miles from Fort Knox. The route from Fairbanks to Fort Knox goes along the Steese Highway to Cleary Summit and then around Pedro Dome. Reagents in use at Fort Knox have included lime, sodium cyanide, sodium hydroxide, hydrochloric acid, sulfur dioxide, copper sulfate, lead nitrate, and ammonium nitrate, among others. Reagent quantities were given for cyanide, ammonium bisulfite, and copper sulfate in an environmental audit of Fort Knox (Golder Associates, Inc. 2004) and in a technical report a decade later (Sims 2015), but the original environmental assessment (CH2M Hill 1993) did not include the quantities required and load sizes, and neither were any associated environmental or health hazards.

Within the environmental assessment (CH2M Hill 1993), the possibility of accidental releases was acknowledged in the context of medical training and response, but there were no prospective estimates of the number of spills that might be associated with Fort Knox Mine, either at the mine and milling site or along the transportation corridor.

After estimating the quantities of reagents, fuel, and blasting materials for Fort Knox/True North based on the partial information given and on reagent use at Pogo Mine, I estimated the number of truckloads of six reagents, ammonium nitrate, and diesel to be shipped to Fort Knox as 1,492 annually through 2002 and 1,272 in 2003 and later. With an additional daily trip for the remaining reagents, I used an estimate of 1,880 trips per year through 2002 and 1,600 annual trips in 2003 and later. Using the $N = RT$ model with Harwood and Russell's (1990) estimate of R, Fort Knox would have been expected to have 0.21 spills from transportation accidents from 1996-2020, with an 18.7% chance of there being at least one spill over that period.

Based on records from ADEC (2021), there were 31 *collision*/*allision* and *rollover*/*capsize* spills recorded for Fort Knox and True North Mines, which were 10.3% of the 301 spills related to transportation. More than 11,600 gallons were released due to transportation spills.

In all, there were 1,874 spills associated with Fort Knox and True North Mine and 75 spills associated with Alaska West Express and Lynden Transport along the Steese Highway, Elliot Highway, or in Fairbanks City or Fairbanks North Star Borough. If all the Alaska West Express and Lynden Transport spills are included with the Fort Knox/True North spills, there were a total of 1,949 spills associated with those mines from July 1995-December 2020.

The most frequently spilled substance was hydraulic oil, with 846 recorded incidents (43.5% of the number of incidents) and 42,433 gallons released (8.0% of the total volume). More than 88% of the spills were <100 gallons in size, and 1.5% (28 incidents) were ≥1,000 gallons. The spills of <100 gallons collectively accounted for 5.9% of the total volume released, and spills ≥1,000 gallons accounted for 85.3% of the volume. Spills classed as *hazardous substances* and *non-crude oil* had the largest numbers, but the largest volume spills were of *process water*. The largest individual spill was 305,370 gallons of process solution in May 2010.

Environmental audits (SRK Consulting 2012, 2019), a technical report (Sims 2015), and a waste management report (Kinross Gold Company 2020) considered spills at Fort Knox at various levels of detail. The description of spills in SRK Consulting (2019) allowed for an estimate that ~18 to 23% of spills at Fort Knox from 2012-2019 were out-of-pit. There were discrepancies in the spill records listed in Kinross Gold Company (2020) and ADEC (2021) for the fourth quarter of 2019.

CHAPTER 7
Red Dog Mine

Location and description

Red Dog Mine is an open pit lead and zinc mine, roughly 82 miles north of Kotzebue and 47 miles inland from the coast of the Chukchi Sea (EPA 1984, 2009) (Figure 7.1). Red Dog's current annual output of 1,000,000 pounds of zinc concentrate represents ~4-6% of global zinc productions (AIDEA and Arcadis 2017). While many of the mine components (mine, mill, tailings pond, housing, and water supply facilities) are on private land owned by the NANA Regional Corporation, the transportation corridor goes through Cape Krusenstern National Monument (EPA 1984, 2009). Red Dog Mine went through an initial EIS process in 1984 (EPA 1984), with ore processing beginning in 1989 (EPA 2009), followed by a supplemental EIS for expansion into the Aqqaluk ore deposit in 2009 (EPA 2009). The initial estimates of the ore deposit were that >85 million tons of ore, containing lead (5%), zinc (17.1%), silver (2.4 oz/ton) and barite, were present (EPA 1984). The expected life of the mine was at least 40 years, with a longer project lifespan possible if more ore were to be found (EPA 1984). However, instead of the main deposit lasting until 2024 or later, "[t]he Red Dog Mine Main Deposit [was] expected to be depleted between 2011 and 2012. Teck propose[d] to begin mining the Aqqaluk Deposit, which is adjacent to the Main Deposit, by 2010, to ensure continuing operations through 2031" (EPA 2009, p. 1-1).

Red Dog "is currently scheduled to operate until at least 2032" (ADEC DSPR 2021c). Teck is "evaluating several options to potentially extend the overall project's life beyond [2031] through mining of other nearby ore bodies. Some of these ore bodies are located at depth, requiring underground mining practices which would significantly increase operational costs and decrease potential throughputs. Recent announcements provide significant promise for the development of a new deposit and the continuation of operations at Red Dog" (AIDEA and Arcadis 2017). The new deposits being explored, such as the Aktigiruk deposit, are primarily located on State lands (AIDEA and Arcadis 2017). If those other ore deposits are to be mined, more permitting could be anticipated soon:

> Teck has performed significant exploration activities in the Red Dog region over the past several years, intending to identify and "prove-up" significant new ore reserves, both within the Aqqaluk deposit and within other nearby deposits. Depending upon the size, location, environmental factors, economics, and other arrangements necessary for developing these potential ore bodies, the existing mill and supporting DMTS operations may be extended beyond 2031. However, since the timing for achieving all necessary approvals to develop a new ore body will likely take ten years or more, significant planning efforts must be started within the next few years to ensure continuous project operations. Later sections in this report provide greater detail on the potential future of the project. (AIDEA and Arcadis 2017)

The locations of the ore deposits being explored now may make little economic sense. As noted, "Importantly though, many of these ore bodies exist at depth, which will require underground mining for their extraction. Typical underground mining costs are an order of magnitude more than those of surface mining operations and high continuous throughputs are difficult to achieve" (AIDEA and Arcadis 2017).

Red Dog by the numbers

The shifting scale of the mine components as described in EPA (1984) and EPA (2009) are shown in Tables 7.1 and 7.2, respectively. Mine ore concentrate production doubled between the expanded production described in EPA (1984) and the amount shown in EPA (2009). That increase necessitated an increase in reagent and fuel use. The Delong Mountain Transportation System (DMTS), described as the southern corridor in the EPA (1984), doubled the number of bridges and culverts from EPA (1984) to EPA (2009) (Tables 7.1 and 7.2), although the SEIS has some inconsistencies in the details (Table 7.2).

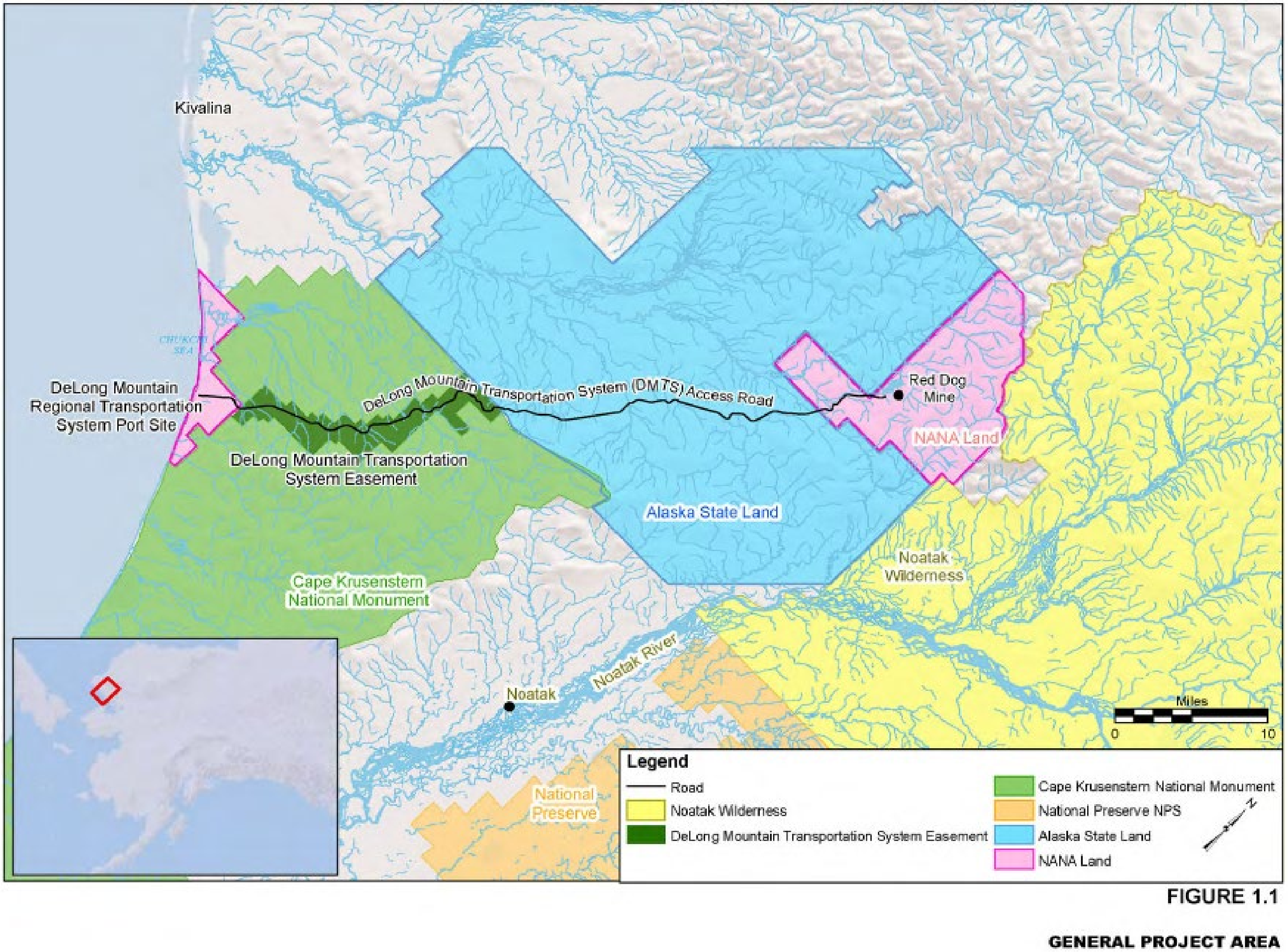


Figure 7.1. Screenshot of figure 1.1 from EPA (2009).

Table 7.1. Quantitative descriptions of ore production, reagent use, fuel use, the transportation corridor, and waste rock and tailings produced from the initial Red Dog Mine EIS (EPA 1984).

Quantity and unit	Description	Page number(s)
	Ore, ore concentrate	
85 million tons	ore body known in 1984	p. II-6
1,057,000 tons	initial annual extraction ore production rate	p. II-4
3,000 tons/day	ore sent each the concentrator (mill) for upgrading during initial operating basis	p. II-4
5,600 tons/day	ore sent each the concentrator (mill) for upgrading during expanded operating basis	p. II-2
479,000 tons/yr	combined concentrates transported during first 5 years of production	pp. iv-v
754,000 tons/yr	combined concentrates transported after first 5 years of production	pp. iv-v
9 to 12 trips/day	truck/trailer round trips to carry concentrates to the port site at initial production rates during first 5 years	p. II-16
10 trips/day	truck/trailer round trips to carry concentrates during the initial production period	Appendix 2, p. 17
16 to 20 trips/day	truck/trailer round trips to carry concentrates to the port site at expanded production rates after 5 years	p. II-16
150 tons ore concentrate/load	"two [75-ton capacity] trailers and a tractor will make up one unit" for lead and zinc ore concentrate shipping, leading to a "potential for a spill of up to 150 tons of concentrates in a single event"	Appendix 2, pp. 16-17; Appendix 2, p. 33
188,500 tons	three months concentrate production storage at the deepwater dock	Appendix 2, p. 9
534,083 tons	8.5 months concentrate production storage at the main storage facility	Appendix 2, p. 9
	Reagents	
≤10 trips per day	reagent deliveries	Appendix 2, p. 16
6,400 gallons/load (~49 tons/load)	sulfuric acid transport, approximately once every 10 days	Appendix 2, p. 16
1,800 ft. long	6 in. diameter pipeline will then convey the [sulfuric] acid into a 30 ft. high by 30 ft. diameter heat traced and insulated mild steel storage tank	Appendix 2, p. 12
5,530 tons/yr	concentrator reagents used in years 1-5 (initial production)	p. II-10
11,731 tons/yr	concentrator reagents used in years 6+ (expanded production)	p. II-10
≤100 tons	"small reagent lots" to be "directly transported to the mill site" from the port	Appendix 2, p. 12

Table 7.1. (Continued.)

Quantity and unit	Description	Page number(s)
	Fuel	
21,000 gal/load	fuel delivery in units consisting of two 10,500 gallon capacity trailers; ~1 load per day	Appendix 2, p. 17
200,000 gallon	fuel tank near the mill will provide the main fuel storage for the power plant and mobile equipment at the site	Appendix 2, pp. 19-20
50,000 gallon	emergency supply tank located adjacent to the accommodation complex	Appendix 2, pp. 19-20
5.5 million gallons	No. 1 grade diesel for electric power generation annually in years 1-5	Appendix 2, p. 8
7.0 million gallons	No. 1 grade diesel for electric power generation annually in years 6+	Appendix 2, p. 8
9.4 million gallons	deepwater dock fuel storage	Appendix 2, p. 9
	Transportation corridor	
56.2 mi	proposed southern corridor	pp. iv-v; p. II-16
1 major bridge	proposed southern corridor	pp. iv-v; p. II-16
4 minor bridges	proposed southern corridor	pp. iv-v; p. II-16
~ 182 culverts	proposed southern corridor	pp. iv-v; p. II-16
	Waste rock, tailings, and wastewater	
1,365,000 tons	material would be removed during preproduction	p. II-4
585 acres	tailings pond	pp. iv-v
60%	solids by weight in the thickened tailings slurry from the mill concentrating process with the liquid portion consisting of excess process water, dissolved minerals and perhaps some residual reagents	p. II-6; p. V-8
1,650 tons/day (dry weight)	tailings would enter the tailings pond during the initial five years of production	p. V-8
3,450 tons/day (dry weight)	tailings would enter the tailings pond during the expanded phase of production	p. V-8
10 tons/ operating day	sludge solids as a 25 percent pulp density slurry would be produced from the wastewater treatment plant	p. II-12

Table 7.0.2. Quantitative descriptions of ore production, reagent use, fuel use, the transportation corridor, and waste rock and tailings produced from the Red Dog Mine supplemental EIS (EPA 2009).

Quantity and unit	Description	Page number(s)
	Ore, ore concentrate	
61.4 million tons	projected total tonnage of ore mined from the Aqqaluk Deposit	p. 2-18
7.7 million tons	low grade ore would be produced over the duration of mining of the Aqqaluk Deposit	p. 2-19
120-ton	concentrate truck capacity	p. 3-275
130-ton	concentrate truck capacity	p. 2-25
109-ton	concentrate truck capacity after 2001 (hydraulic steel covers added)	p. 3-276
36 trips/day	concentrate trucks	p. 2-25; p. 3-110
52 miles	9" diameter pipeline for 55 percent solids concentrate slurry (Alternative C)	p. ES-5; p. 2-26
≤1.5 million tons	concentrate shipped from the port site annually	pp. 2-30 and 2-31
27 ore carriers	anchor in deep waters offshore from the port facility annually	p. 3-280
	Reagents	
1.2 trips/day	supply trucks	p. 2-30
15,841 tons/year	froth flotation process reagents	p. 2-29
	Fuel	
24,900 gallons	single tanker truck capacity for bulk fuel	p. 3-275
2.3 million gallons	diesel fuel stored at the mine site in two single-walled tanks (combined capacity)	p. 2-27
400,000 gallons	Jet A fuel stored on site in two double-walled tanks (combined capacity)	p. 2-27
46,000 gallons	diesel fuel used daily	p. 2-27
150,000 gallons	jet fuel used annually	p. 2-27
25,000 gallons	tanker truck capacity	p. 2-27
16,710,880 gal/yr	average diesel use 2000-2006	p. 2-28

Table 7.2. (Continued.)

Quantity and unit	Description	Page number(s)
	Transportation corridor	
52-mile	DMTS road	pp. 2-29 and 2-30
9 bridges	DMTS road	pp. 2-29, 30; p. 3-275
4	major culvert crossings along the DMTS road	pp. 2-29 and 2-30
3	major culvert crossings along the DMTS road	p. 3-275
451	minor culvert crossings along the DMTS road	pp. 2-29 and 2-30
445	minor culvert crossings along the DMTS road	p. 3-275
49 trips per day	in 2003 for concentrate trucks, fuel trucks, supply trucks, and light vehicles	p. 3-110
	Waste rock, tailings, and wastewater	
94.7 million tons	waste rock produced over the duration of mining the Aqqaluk deposit	pp. 2-18 and 2-19
61.7 million tons	waste rock in the Main Pit at the end of operations in 2011 or 2012	p. 2-19
260 acres	Main Pit areal extent at the end of operations in 2011 or 2012	p. 2-19
4.2 billion gallons	volume held in tailings impoundment	p. 2-21
17 million gal/yr; (47,000 gal/day)	domestic wastewater from the mill, mine site PAC, and the services.	p. 2-25
6,000 to 7,500 gal/day	port site water treatment plant discharges to the Chukchi Sea during the shipping season	p. 2-25
~ 2,500 gal/day	port site water treatment plant discharges to the Chukchi Sea during the winter.	p. 2-25
1.5 billion gal/yr	treated wastewater discharge to Red Dog Creek	p. 2-5
6,500-foot	tailings pipeline from the mill to the tailings impoundment (Alternative C)	p. 2-20
3,000 gal/minute	wastewater would be carried through the pipeline to a location in the Chukchi Sea	p. 2-24
800 gal/minute	estimated volume of concentrate wastewater generated in the filtration process	p. 2-24

Process

According to the initial environmental review (EPA 1984):

> The approximately 14 ha (35 ac) [proposed mill] complex would include a water treatment plant, a diesel-based power plant, fuel storage and distribution facilities, and a vehicle maintenance/warehouse structure in addition to facilities integral to the milling process.
>
> The project would use a selective flotation milling process to concentrate valuable minerals. The floatation process would consist of three major steps: size reduction, selective mineral concentration and moisture reduction of the concentrates... After grinding, the ore would be suspended in a water slurry and transported to flotation cells (tanks) where the valuable minerals would be separated from waste materials in a froth flotation process... Following separation of the ore minerals from waste rock, dewatering of the concentrates would take place using lead and zinc thickeners, followed by filtration and thermal drying...The upgraded lead and zinc concentrates (which would also contain silver) would be shipped to smelters outside of Alaska for processing to refined metals. The mill would be a major consumer of water and, as such, recirculation of process water would be used to the fullest extent possible.

The mill production rate was expanded in the 1990s under the Production Rate Increase project to process up to 3.5 million tons of ore annually and move 1.3 million tons of ore concentrate (both lead and zinc) through the port (AIDEA and ARCADIS 2017). This expansion was followed by a Value Improvement Project (VIP) to increase mine throughput, and in 2017 a VIP2 was planned to upgrade the processing equipment at the mill to maintain ore concentrate production levels as lower grade and harder ore from the Aqqaluq deposit are processed (AIDEA and ARCADIS 2017). The economics of the project depend on keeping the exports of mine concentrate near 1,000,000 tons per year (AIDEA and ARCADIS 2017).

Characterization of transportation corridor

The initial EIS considered three options for the transportation corridor, some with sub-options; four options for the transportation system; five options for the port site; and four options for the transfer facility (EPA 1984, Chapter III). Water quality was an area of concern for three sub-options along the southern route for the transportation corridor. Two of those sub-options had spill risks as moderate sources of potential impact, with the southern corridor route through Krusenstern listed as having a lower relative impact from spills (EPA 1984, p. III-21).

Roads

As described (EPA 1984), the southern corridor was shorter, had 60% as many stream crossings, fewer icing locations, and fewer fish passages at bridges and culverts than the northern corridor (Table 7.3). The southern corridor option was selected and became the Delong Mountain Transportation System (DMTS) (Figure 7.2). By 2009, the number of stream crossings had increased to nine bridges and ~450 culverts (Table 7.2).

Table 7.3. Reproduction of "Table V-14. Estimated number and type of stream crossings required for southern and northern transportation corridors" (EPA 1984, p. V-48).

	Southern Corridor	Northern Corridor
Length of road	89.9 km (56.2 mi)	117.0 km (73.1 mi)
Major bridges[1]	1	6
Minor bridges[2]	4	7
Major culverts[3]	49	81
Minor culverts[4]	133	219
Total stream crossings	187	313
Icing locations at culverts	14	24
Fish passages at bridges and culverts	11	13

[1] Bridge span ≥ 30.5 m (100 ft).

[2] Bridge span < 30.5 m (100 ft).

[3] Culverts ≥137 cm (54 in) diameter, or the equivalent of using two to three smaller culverts.

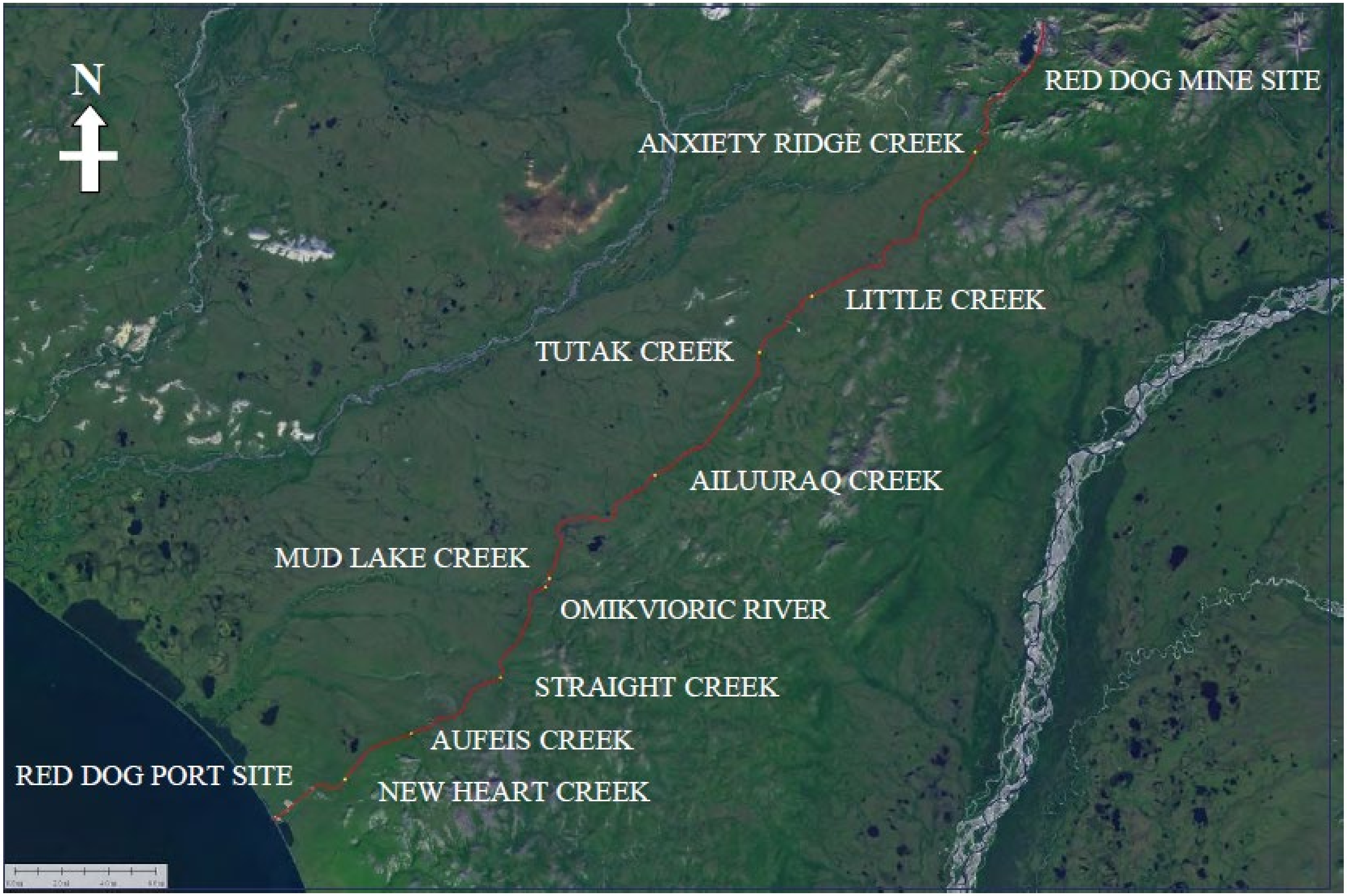
[4] Culverts <137 cm (54 in) diameter at gullies, grassy swales and seasonal drainages.

As described by AIDEA and Arcadis (2017):

> The full DMTS includes the following infrastructure:
>
> - A 52-mile, 30-foot wide all-weather gravel industrial haul road, constructed primarily over permafrost with a 5-foot minimum gravel depth, from the mine site to the port facility…; the road includes 9 bridges for creek crossings …
> - A shallow water dock to receive supplies, fuel, equipment, and personnel
> - An offshore conveyor system to load zinc and lead concentrate to lightering vessels (barges) that can convey the concentrate to larger ships further offshore
> - A fuel distribution facility including 6 bulk tanks capable of storing approximately 15 million gallons of fuel for port and mine use
> - Storage facilities, including two Concentrate Storage Buildings (CSBs) with approximately 1.2 million tons of ore storage capacity
> - On-site power production, other utilities (water and wastewater treatment) and residential quarters for up to 96 workers
> - Port site lay down yards, exterior storage areas, and stormwater/runoff water treatment facilities
> - New lime slacking facility to allow on-site production of calcium hydroxide

The DMTS "provides an on-going revenue stream for [AIDEA]", and "provid[es] between $15 – 30 million annually before debt service, depending upon annual throughputs and zinc prices" (AIDEA and Arcadis 2017). As noted under Project Goals/Purpose (AIDEA and Arcadis 2017):

> The DMTS is constructed as a "public" facility/system and is "open" for use by other mines or users. As the first user, Teck has priority for the current capacity and DMTS operations. Since its inception, Teck has been the only user for the DMTS infrastructure/facilities. DMTS' sustainability is therefore currently dependent upon the success of the Red Dog Mine. The DMTS provides the only means for shipment (to market) of Red Dog's mined zinc and lead concentrates. Red Dog is the most significant private industry and employer in the Northwest Arctic Borough (NWAB). The partnership between NANA, Teck, and AIDEA was formed to facilitate the Red Dog Mine and the DMTS construction and operations, which continues to provide economic development in this remote, arctic region of Alaska.


N
RED DOG MINE SITE
ANXIETY RIDGE CREEK
LITTLE CREEK
TUTAK CREEK
AILUURAQ CREEK
MUD LAKE CREEK
OMIKVIORIC RIVER
STRAIGHT CREEK
AUFEIS CREEK
RED DOG PORT SITE
NEW HEART CREEK

Pipelines

The SEIS considered the impacts of adding ore concentrate slurry and wastewater pipelines, the costs and benefits of changing to sealed containers for transporting ore concentrate, modifications to the wastewater treatment system and release location, and improved dust control measures, among others (EPA 2009).

Alternative C in the SEIS included three pipelines, one each for ore slurry from the mill to the port, for tailings impoundment water release at the port instead of at Red Dog Creek, and for moving diesel from the port to the mine (EPA 2009). At the close of operations, all three pipelines would have been removed (EPA 2009). While it was recognized that transporting fuel and ore concentrate by pipeline rather than by truck would "reduce the truck traffic between the mine and the port … [which] would reduce fugitive dust emissions and would decrease the potential for direct mortality associated with vehicle collisions and disturbance from human activity along the DMTS road" (EPA 2009, p. 3-136), it was noted that "trucks carrying various chemicals and explosives would still transit the DMTS road, so the chance of spills would not be entirely eliminated" (EPA 2009, p. 3-136), and that pipeline spills were possible (EPA 2009, p. 3-136 and pp. 3-158, 3-159). (See *Trip frequency by transportation method,* which shows that the analysis in the SEIS estimated that number of truck trips with hazardous materials would have been reduced from an average of 38.9 trips/day to 1.2 trips/day under Alternative C (Table 7.8).)

EPA (2009), pp. 3-158 and 3-159:

> The presence of three individual pipelines crossing nine bridges means a potential for spills of concentrate slurry, diesel fuel, and treated water prior to discharge in the event of a pipeline failure. While contingencies for spills would be designed into the pipelines to minimize the volume associated with a spill, a pipeline leak or failure at or near a stream crossing would result in the release of contaminants to the stream. The concentrate slurry would consist of finely ground material with high metals concentrations that would be readily carried downstream. Depending on the volume lost, a concentrate spill to a stream channel could cause adverse effects downstream for a distance proportional to the size of the spill. The slurry would be toxic for large areas of the streams, should a spill occur directly to a stream, because of the high concentrations of metals. The fines in the concentrate could also smother eggs and adversely affect spawning gravels until flushed or otherwise removed from the system.
>
> A break in the diesel pipeline could send diesel fuel downstream, where again, the distance affected would depend on the volume of fuel leaked. Effects would range from direct mortality to reduced feeding and growth, reduced reproductive success, avoidance of the stream segments, and disruption of migration. Since diesel is a volatile hydrocarbon, effects would be relatively short-lived (less than a year).
>
> Although the wastewater in the discharge pipeline would have been treated, a spill from the pipeline could result in some adverse effects to downstream aquatic resources since the water would not necessarily meet WQS for the surface water receiving the spill. The impacts would depend upon the quantity, receiving water conditions, and effectiveness of response actions.

> All three pipelines would be designed to minimize the likelihood of a leak or failure. Management practices, including regular integrity monitoring, would minimize the amount of slurry or water that would be lost including that which could enter a stream. Overall, spills would result in adverse effects to aquatic organisms downstream of the spill. The effects of any spill would generally be short-lived since cleanup measures would be required by EPA and ADEC. In these fast-moving stream systems new individuals would be expected to repopulate affected stream segments relatively quickly with most organisms fully recovered within a year. However, some species, especially fish, may take several years to recolonize, depending on the persistence of the pollution following a spill (Yount and Neimi 1990).

Although Red Dog Mine pledged to build a pipeline diverting the wastewater from Red Dog Creek to the Chukchi Sea in 2009 (*Anchorage Daily News* 2014b), Alternative C was not implemented. After spending $1.7 million to study the feasibility of a wastewater pipeline and paying an $8 million civil penalty for violations of the Clean Water Act, Red Dog Mine chose not to spend an estimated $216 million for an aboveground pipeline (*Anchorage Daily News* 2014a).

Port

The EPA also mentioned but did not conduct a quantitative analysis of the potential for spills associated with storage and transfers at the port.

EPA (1984), pp. iv-v:

> [A]ctivity at the port site would be limited to the receipt of supplies and fuel during the summer sealift, and the shipment of concentrates from late June until early October, [requiring that] adequate storage facilities for concentrates, fuel, and other supplies exist at the port site.

EPA (1984), p. V-56 (Marine Birds and Mammals):

> Transfers of concentrates from the short causeway to the lighter, the lighter to the ballasted ship, and from the latter to the bulk carriers would create an unknown risk of spillage, as would movement of petroleum products, reagents and other toxic chemicals in the opposite direction. Chronic spillage or a severe spill could have significant impacts on both marine birds and mammals, depending on the time of year and local weather conditions.

In 2005 Teck undertook a study to consider the costs and benefits associated with a deep draft port, including a draft EIS (AIDEA and Arcadis 2017). Although an initial feasibility report indicated a favorable cost to benefit ratio, a second analysis did not, and the project was halted in 2007.

List of hazardous materials to be transported

Ore concentrate

Although the expected initial ore concentrate production amounts were 479,000 tons/yr in the first five years and 754,000 tons/year in years six and later (Table 7.4), the actual production is up to 1.5 million tons shipped from the port site annually (EPA 2009, p. 2-31). Blasting materials, reagents, fuel, and tailings quantities scale up with the quantity of ore concentrate produced.

Table 7.4. Reproduction of "Table II-1. Concentrate Production Schedule" (EPA 1984, p. II-2). Note that this table assumes 350 days of production per calendar year (EPA 1984, p. II-11).

	Initial Production Rate		Expanded Production Rate	
Daily Production (Average Amount/Day)	Mg[1]	Tons	Mg[1]	Tons
Ore	2,721	3,000	5,079	5,600
Lead Concentrate	204	225	308	340
Zinc Concentrate	907	1,000	1,515	1,670
Barite Concentrate	127	140	127	140
Tailings	1,678	1,850	2,766	3,050
Annual Production				
Ore	958,700	1,057,000	1,779,534	1,962,000
Lead Concentrate	71,650	79,000	107,933	119,000
Zinc Concentrate	317,450	350,000	530,595	585,000
Barite Concentrate	45,350	50,000	45,350	50,000
Tailings	542,250	578,000	1,095,656	1,208,000

[1] 1 Mg (megagram) = 1.102 tons

1 ton = 0.907 Mg

Source: Cominco, Alaska, Inc.

Reagents

Both the original (EPA 1984) and supplemental (EPA 2009) EISs for Red Dog Mine include lists of reagents, but they are incomplete and inconsistent. The first lists nine *concentrator reagents* (EPA 1984) and the second lists 12 *reagents used in froth flotation processes* (EPA 2009) (Table 7.5). Appendix 2 Table 2.1 (EPA 1984) lists values of 4,182 tons per year during the initial production phase and 6,553 tons per year once expanded production begins for hydrated lime, which differ from the values given in the main FEIS (Table 7.5). While "[t]he majority of chemicals used on the site are required for the froth flotation process" (EPA 2009, p. 2-28), Red Dog also requires water treatment chemicals, such as lime, flocculants (EPA 1984, p. II-12), and/or barium hydroxide (EPA 2009), and chemicals for treating spills and releases, such as calcium hypochlorite or sodium hypochlorite (EPA 1984), which are not listed among the concentrator and froth flotation process reagents. Blasting agents were also not included among the chemicals being shipped to and used at the mine, even though "[a]mmonium nitrate would be used as a blasting agent to recover the ore. This compound would be shipped and stored in sacks, and is not reactive until mixed with fuel oil and detonated” (EPA 1984, p. II-4). Blasting is expected to occur approximately once per day through 2031 (EPA 2009, p. 2-44).

Although the EIS states that, “The agencies will be notified in advance of any planned changes in the nature or quantities of the materials utilized or produced at Red Dog” (EPA 1984, Appendix 2, p. 20), only five reagents ((hydrated) lime, copper sulfate, zinc sulfate, sodium cyanide, and methyl isobutyl carbinol) appear on both lists. Furthermore, the expected total weight of the reagents used approximately tripled between the quantities needed for initial production given in 1984 and those in 2009 (Table 7.5). (Ore concentrate production also roughly tripled from 479,000 tons/year to ≤1.5 million tons/year over that time.) According to the SFEIS, “No changes in reagent use are expected” (EPA 2009, p. 2-28), but given the changes between the chemicals specified in 1984 and 2009, the list of reagents transported to and used at Red Dog Mine given in EPA (2009) may be out of date for both the specific reagents that are in use and in the quantities being moved and consumed.

EPA (1984) included brief descriptions of the potential hazards associated with the nine concentrator reagents (Table 7.6). The FSEIS did not include a similar summary, but “Teck maintains a chemical inventory and material safety data sheets (MSDS) of process reagents, fuels, and other chemical products used in the mine operations. Updated MSDS are provided through a third-party service” (EPA 2009, p. 3-253). For more details about the properties of the reagents, see Appendix A.

Table 7.5. Reagent use (tons/year) from reproductions of "Table II-2. Red Dog Concentrator Reagents" (EPA 1984, p. II-10) and "Table 2.3-3. Reagents used in Froth Flotation Processes" (EPA 2009, p. 2-29).

	Table II-2.		Table 2.3-3.	Use
	Initial	Expanded		
Zinc sulfate ($ZnSO_4$)	529	982	360	Depressant in the lead circuit
Copper sulfate ($CuSO_4$)	529	982	4,900	Activator in the zinc circuit
Sodium cyanide (NaCn) (*sic*)	106	197	200	Depressant
Methylisobutyl carbinol	53	98	77	Frother
Sodium isopropyl xanthate	529	982		
Sodium isobutyl xanthate			660	Collector in the zinc circuit
Sodium cetylsulfonate	79	79		
Sulfuric acid (H_2SO_4)	1,057	1,962		
Hydrated lime [$Ca(OH)_2$]*	2,642	6,443		
Lime			8,400	pH modifier, water treatment
Polyacrylamide flocculant*	6	6		
Potassium ethyl xanthate			450	Collector in lead circuit
Sodium meta bi-sulfite			310	Scavenger
Sodium Sulfide (Na_2S)			250	Precipitation agent
Dextrin			127	Organic depressor
Magnafloc			69	Clarification in water treatment and thickening
Antiscalent			38	Dispersant for process water
Total	5,530	11,731	15,841	

* <u>Note</u>: Part of the lime and all of the flocculant supply would be used in the wastewater treatment process (EPA 1984).

Table 7.6. Descriptions of reagent toxicity in the main FEIS text and Appendix 2 (EPA 1984).

Reagent Shipping container characteristics	Description of potential toxicity	
	Chapter 2 of main FEIS (pp. II-10 and II-11)	Appendix 2 (pp. 4-5)
Zinc sulfate ($ZnSO_4$) 2,000 lb capacity reinforced plastic bags in bulk	toxic environmental hazards well known	slightly acid, water soluble salt
Copper sulfate ($CuSO_4$) 2,000 lb capacity reinforced plastic bags in bulk	toxic environmental hazards well known	slightly acid, water soluble salt
Sodium cyanide (NaCn) (*sic*) 2,000 lb capacity reinforced plastic bags in lump form	a toxic reagent and must, at all times, be stored and handled in isolation from other chemicals, particularly those which are acidic in nature, including sulfate salts	a water soluble and toxic reagent which must be stored and handled in isolation form other chemicals, particularly those which are acidic in nature
Methylisobutyl carbinol (MIBC) 400 lb capacity steel drums	moderately toxic to aquatic life	a flammable alphatic liquid alcohol which is lighter than and has only a modest solubility in water
Sodium isopropyl xanthate 2,000 lb capacity reinforced plastic bags as pellets	very toxic in the environment… A problem with xanthate is that it may deteriorate from prolonged contact with moisture and then would require disposal as it would be unusable as a reagent.	an essential sulfide mineral collector in the floatation process
Sodium cetylsulfonate (EC-111) 400 lb capacity steel drums	essentially nontoxic and has been approved for use in food applications	a paste-like surface active agent used for barite flotation that has only moderate solubility in water. It is essentially non-toxic and has been used in food applications.
Sulfuric acid (H_2SO_4) Bulk tanks	a hazard to aquatic life… spills would be difficult to contain and the chemical could have long lasting impacts on vegetation recovery unless lime were applied as a neutralizing agent	the concentrated 93% acid form does not attack mild steel in normal conditions. It should be generally regarded as being corrosive and great care required in materials selection
Hydrated lime [$Ca(OH)_2$]* 2,000 lb capacity reinforced plastic bags	only toxic in concentrations which result in high alkalinity	moderately water soluble and only toxic in concentrations which result in high alkalinity
Polyacrylamide flocculant* (Percol 730) 50 lb sacks on pallets; must be protected from temperature extremes in storage	relatively nontoxic	slowly water soluble; relatively nontoxic

Diesel

Diesel has several uses at Red Dog mine, including power generation, equipment operation, and fueling vehicles (EPA 2009). The initial estimates of the amount of diesel required for Red Dog Mine were 5.5 million gallons/year for initial production, increasing to 7.0 million gallons per year once expanded production started (EPA 1984). (This is less than the proposed 9.4-million-gallon storage capacity for diesel at the deepwater dock (EPA 1984, Appendix 2, p. 9).) According to Teck (as cited by EPA 2009), an average of 16.7 million gallons of diesel were used in the years 2000-2006 (Table 7.7). Initially the port facility had four 2.5 million-gallon tanks for diesel, which were supplemented in 1997 and again 2001 by an additional 2.5 million-gallon tank (AIDEA and Arcadis 2017).

Table 7.7. Reproduction of "Table 2.3-1. Average Volume of Diesel used in Existing Operations" (EPA 2009, p. 2-28).

Application	Volume of Diesel Consumed (gallons/year*)
Generators, Mine	13,353,820
Generators, Port	1,950,675
Mobile Sources, Mine	741,694
Material Transportation (concentrate, fuel, supplies)	664,691
Total	16,710,880

*Numbers represent the average use between 2000 and 2006

Source: Teck 2008 (Fuel)

Load sizes by transportation method

Lead and zinc ore concentrates are moved in bulk form in tractor-trailer combinations hauling 150 tons of ore concentrate (two trailers holding 75 tons each per truck) (EPA 1984 Appendix 2). The SEIS shows slightly smaller load sizes of 120 tons (EPA 2009, p. 3-275) or 130 tons (EPA 2009, p. 2-25) of ore concentrate. Sulfuric acid was to be transported in dedicated tanker units carrying 6,400 gallons (49 tons) (EPA 1984 Appendix 2), with the remaining reagents to be brought to the mine site in loads of 100 tons or less (EPA 1984, Appendix 2). Diesel transport changed from deliveries of 21,000 gallons in two 10,500-gallon trailers (EPA 1984 Appendix 2) to single tanker trucks hauling 24,900 gallons of fuel (EPA 2009).

Trip frequency by transportation method

During the first five years of production, there were expected to be approximately 10 trips per day for hauling lead and zinc ore concentrates from the mine to the port, and number which increased to 16-20 trips per day with expanded production in year 6 (EPA 1984), and then increased to 36 trips per day (EPA 2009). While "up to 10 trips per day are potentially available for reagents, … the normal frequency will be substantially less as general supplies must also be moved. Sulfuric acid will be transported approximately once every 10 days" (EPA 1984 Appendix 2). The initial FEIS estimate was that one trip per day would be necessary for supply maintenance (EPA 1984 Appendix 2), which was similar to the 1.2 supply trips per day shown in the SEIS (EPA 2009) (Table 7.8). There was an average of 1.7 fuel deliveries per day in 2003 (EPA 2009) (Table 7.8).

Table 7.8. Reproduction of "Table 2.3-4. Daily DMTS Road Traffic Estimate" (EPA 2009, p. 2-30).

Traffic Category	Number of Units in Use/Day per Unit*	Average Trips/Day per Unit	Maximum Trips/Day	Total Average Trips/Day*	Percentage of Total Daily Trips
Concentrate Trucks	7 or 8	5	6	36	73.6
Fuel Trucks	Up to 2	1.7	4	1.7	3.5
Supply Trucks	1 to 2	1.2	4	1.2	2.5
Maintenance Equipment	Up to 5	N/A	N/A	N/A	N/A
Light Vehicles	3 to 10	1	2	10	20.4
Total				48.9	100

*Based on NANA/Lynden shipping records for 2003.

N/A = not applicable. Maintenance equipment generally does not make "trips," but remains in its working area.

Open water at the port facility is limited to ~100 days from June-October, which means that the port facility requires storage for ore concentrate to be exported to world markets and for supplies the mine will need year-round (EPA 1984, 2009). The initial estimate of concentrate ships per year was 13 (EPA 1984) (Table 7.9), which increased to 27 ore carriers by 2009 (EPA 2009). Ore concentrate production rose from an expected 754,000 tons/year in expanded production (EPA 1984) to up to 1.5 million tons/year (EPA 2009), so the doubling of concentrate ships is proportional.

Table 7.9. Reproduction of "Table V-15. Transfer and Shipping Frequency" (EPA 1984, p. V-64).

	Alternatives	
	1 & 2	3
Number of concentrate ships/year	13	13
Number of concentrate barges/year	420	84
Number of concentrate transfers/year	853	468
Number of concentrate transfers/year at an unstable platform	0	84
Number of material and equipment ships/year	13	13

Note: Transfer = movement from one ship to a dock or another ship on or over water.

Unstable platform = a floating ship or barge subject to sea conditions

Spill risks and impacts discussed in the permitting documents

The 1984 and 2009 EISs generally identified the potential impacts from spills that can affect wetlands and vegetation, terrestrial wildlife and birds, marine life, and nearby communities (EPA 1984, 2009), but neither included comprehensive, quantitative risk assessments. The original EIS contained the Spill Prevention, Control, and Countermeasure (SPCC) Plan (EPA 1984 Appendix 2). The Preface is reproduced below (EPA 1984, Appendix 2, p. iii, emphasis in the original):

> Preface
>
> This report is preliminary in nature. It is based on the level of conceptual engineering design detail necessary to establish capital and operating costs only for financial feasibility. Operatin (*sic*) details are based on concepts developed from experience at other Cominco operations. Final design details will develop more optimum solutions to some of the problems discussed herein… The general philisphy (*sic*) and commitment by Cominco as a responsible coperate (*sic*) citizen to ensure a minimal disruption to the environment will not change upon finalizatio (*sic*) of this SPCC plan.

The "preliminary" nature of the Spill Prevention, Control, and Countermeasure Plan is abundantly clear in that the largest contributors to hazardous materials spill risks were not addressed and that relevant details about spill prevention programs and remediation were absent. The appendix explicitly states that the "haulage of mine waste and ore… is outside the scope of this report" (EPA (1984), Appendix 2, p. 13), that "[c]omprehensive and detailed programs to prevent spills and minimize their environmental impacts will be implemented before the start of operations and specifically, during the detailed design of project facilities" (EPA 1984, Appendix 2, p. 20), that "[t]he detailed specification of resources which will be available solely for spills control is not possible at this time, but will be done in the procurement phase of the project" (EPA (1984), Appendix 2, p. 23), and that "the selection of equipment specifically for oil spills control will be made later in the project development and with agency consultation" (EPA (1984), Appendix 2, pp. 26-27). Nonetheless, the reader is assured that

> It will be the policy of Cominco Alaska to document all material spills whether or not they result in external discharge and environmental impairment… Notification of spills with at least the potential for environmental impact will be promptly made to EPA, ADEC, and the Coast Guard (river or marine situations). (EPA 1984, Appendix 2, p. 20)

(For a comparison of spill records, see *Spills reported prior to and in 2009 FSEIS (EPA 2009) and Spill record from ADEC.)*

Spill risks come from many acknowledged sources in the original and supplemental EISs (EPA 1984, 2009), although serious consideration was belated (italicized emphasis added):

> Another *issue identified after operation of the mine began was the potential for exposure to contaminants*. There is the potential for spillage of chemicals used for mining and milling processes, including petroleum hydrocarbons, milling reagents, and blasting agents. Spills could occur during transit, storage, and use… (EPA 2009, p. 3-110)

Spills can occur during construction, at the port, especially during poor weather (EPA 1984, Appendix 2, p. 27), from storage facilities, at the mill site, along the transportation corridor, or at transfer points between any of those. The initial EIS was clear that mill site chemical spills were not expected to affect the environment:

> The environment is most protected from materials spills at [the mill site] by the integral nature of operations. Through long established design management, concentrators contain internal facilities for spills management and recovery. Simply put, there is no physical possibility of spills being discharged from the concentrator building. A final line of defence (sic) is the tailing pond which would serve to trap all materials and contaminated runoff emanating from the entire mill area... Appreciable concentrations of [reagents] will not occur in the tailings pond water since, by virtue of their chemical properties, there is a vital requirement for carefully managed application in the process... Concentrator spills will be reclaimed by internal systems and the housing of storage areas and conveyor galleries will prevent the wind borne transport of these materials. Tailing will contain residual metal sulfide values but unacceptable losses to tailing could not be tolerated for economic as well as environmental reasons. (EPA 1984, Appendix 2, p. 34)

A safety data sheet from Teck for zinc metal describes zinc as “essentially non-toxic to humans” and “does not meet [the] criteria” for acute toxicity, skin corrosion/irritation, eye damage/eye irritation, and respiratory or skin sensitization, among other health effects (Appendix A). Teck further stated that has “relatively low bioavailability and poses no immediate ecological risks” but acknowledges that “[d]epending on physico-chemical characteristics (e.g., pH, water hardness), compounds of zinc metal can be toxic, particularly in the aquatic environment. Zinc also has the potential to bioaccumulate in plants and animals in both aquatic and terrestrial environments” and “processing of the product or extended exposure in aquatic and terrestrial environments may lead to the release of zinc compounds in bioavailable forms. Zinc is highly mobile, and can be toxic in the aquatic environment with water hardness, pH and dissolved organic carbon content being major regulating factors. Zinc also has the potential to bioaccumulate in plants and animals in both aquatic and terrestrial environments. In soils, zinc is moderately mobile in accordance with soil properties (e.g., cation exchange capacity, pH, redox potential, chemical species); these properties also influence its bioavailability to terrestrial plants.” In contrast, the safety data sheet from ThermoFisher Scientific for zinc metal powder has an extensive lists of hazards associated with that material, including the possibility of spontaneous ignition from combustible dust or flammable gases that are released when it contacts water (Appendix A). ThermoFisher Scientific further described zinc metal powder as “Very toxic to aquatic life with long lasting effects” (Appendix A).

Transportation

Transportation spill risks would depend on the number of trips required to bring various hazardous materials to and from the mine each year and the number of years those trips would be necessary (EPA 2009). Hazardous materials include ore concentrate, reagents for the ore processing, water treatment chemicals, fuel, blasting agents, and even the chemical countermeasures to accidental releases (EPA 2009). Water treatment, and therefore the need to transport water treatment chemicals to the mine site (EPA 2009), is expected to continue in perpetuity. The initial EIS left the transportation corridor risks as "undetermined probabilit[ies]" (EPA 1984, p. V-50). The supplemental EIS stated that "Traffic statistics using accident and spill data will be used to assess the effects of changes in transportation among the alternatives" (EPA (2009), p. 3-280).

Although no data were cited, driver error or carelessness, vehicle and road maintenance issues, and vehicle collisions were the three transportation release causes that were to be minimized for the Reg Dog project (EPA 1984 Appendix 2). Spills along the transportation corridor would affect not only the communities adjacent to the road but could also affect groundwater quality (EPA 1984). While there were chemical remediations suggested for treating potential spills of cyanide or sulfuric acid to the ground, methods for addressing spills of other reagents to streams were not developed by the time the original EIS was published (EPA 1984 Appendix 2). The large number of stream crossings along the DMTS also mean that there is a great chance of accidental release of hazardous materials to a stream, with fuel tankers being of particular concern (EPA 1984), and a recognition that "it would be impossible to contain a fuel spill at the point of a stream crossing, but there may be downstream locations of opportunity at which containment could be effected" (EPA 1984 Appendix 2). In the event of a transportation accident, it was assumed that most reagent containers would not leak or that any leaks would be minor, although it was acknowledged that it would not be possible to contain any water soluble reagents that were spilled into a stream (EPA 1984 Appendix 2). A similar argument minimized the risk of potential spills to the marine environment from the port (EPA 1984 Appendix 2).

Spills reported prior to and in the 2009 FSEIS (EPA 2009)

The initial EIS (EPA 1984) had no site-specific data to base spill risk estimates on, but such data were available for the SEIS (EPA 2009). The locations of 29 ore concentrate spills that had occurred through the summer of 2002 were noted along the length of the DMTS (Turner 2003) (Figure 7.3). There were seven concentrate spills on NANA land around the mine site, 15 ore concentrate spills on Alaska state land, five spills on the DMTS easement through the Cape Krusenstern National Monument, and two spills on NANA land at the Red Dog port site.

While "[h]istorically, there have been truck spills of lead and zinc ore concentrates along the DMTS road as well as spills of petroleum hydrocarbons, such as diesel fuel, engine oil, hydraulic oil, and other materials" (EPA 2009), the only reported incidents in the SEIS were for ore concentrate and fuel:

> Incidents of concentrate truck spills reported from 1990 through 2007 are summarized in Table 3.15-2 [reproduced as Table 7.10]... the train assemblies and the tandem trailers were updated in the fall of 2001. The number of spills and the corresponding amount of concentrate that spilled markedly decreased after that point. (EPA 2009, p. 3-276)

and

> Based on the average daily trips in 17 years more than 200,000 concentrate and 10,000 fuel truck trips have occurred … In that 34 documented spills have resulted in over 1,000 tons of concentrate being spilled. From 2000 through 2007 one fuel truck spill of 7,000 gallons occurred. In recent years the truck spill frequency has been reduced to 0 to 2 per year. (EPA 2009, p. 3-159)

Note that there is a slight discrepancy in the spill records through 2002. The SEIS (EPA 2009) shows 31 ore concentrate spills from 1990 to 2002 (Table 7.10), but Turner (2003) showed the locations for 29 ore concentrate spills. ADEC (2021) includes 12 transportation related incidents involving zinc ore concentrate spills between December 1996 and December 2001, in which a total of 422,960 lb were spilled. (See *Spill Record from ADEC* section.)

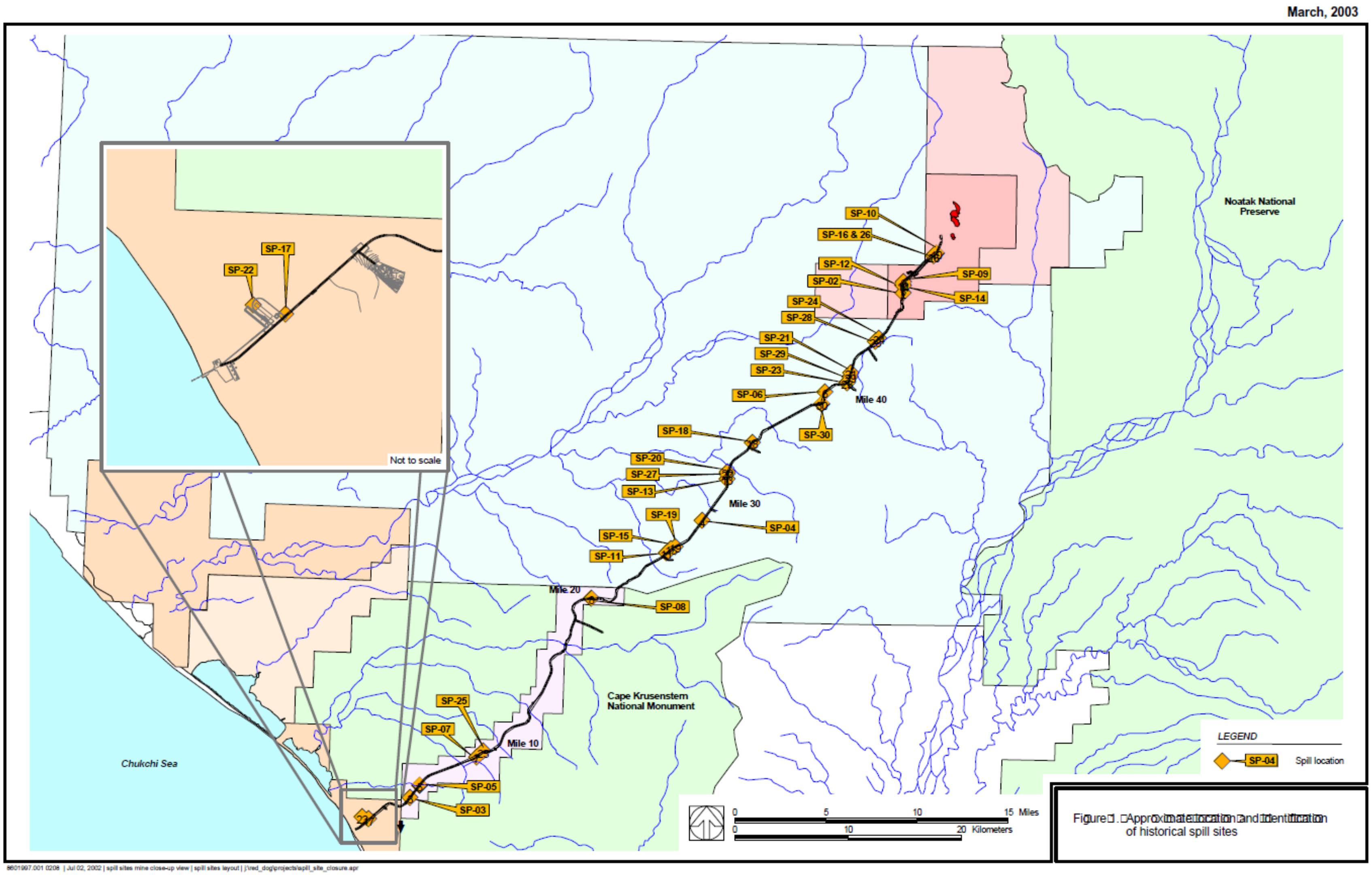


Figure 7.3 Turner (2003), "Figure 1: Approximate location and identification of historical spill sites." along the DMTS.

Table 7.10. Reproduction of "Table 3.15-2 Health and Safety Record Summary" (EPA 2009, p. 3-277). The shaded total row was not part of the cited table.

Year	Number of Spills	Tons of Concentrate Spilled	Volume of Fuel Spilled (gallons)
1990	5	194	N/A
1991	1	30	N/A
1992	3	124	N/A
1993	2	63	N/A
1994	1	36	N/A
1995	0	0	N/A
1996	2	72	N/A
1997	3	42	N/A
1998	7	199.4	N/A
1999	3	176.5	N/A
2000	2	70	0
2001	2	24	0
2002	0	0	0
2003	0	0	0
2004	0	0	7,048
2005	1	120	0
2006	2	1.45	0
2007	0	0	0
Total	34	1,152.35	≥7,048

N/A = Not available

There were 34 recorded concentrate spills and at least one fuel spill over 18 years (Table 7.10), for an average of 1.9 ore concentrate spills per year since 1990. In response to concerns about fugitive dust, in 2001 Red Dog changed the configuration of the trucks hauling ore concentrate to have securely fitting tops instead of tarps. The goals were to reduce fugitive dust released and other ore concentrate spills. Concentrations of zinc, lead, and cadmium in the dust surrounding the DMTS are determined in part by the side of the road (north or south, which have different topography and wind conditions) and the distance from the road, and the addition of the tops may have significantly reduced the amount of fugitive dust along the roadway (Neitlich et al. 2017) (Figure 7.4). The EPA (2009) estimated that "[b]ased on the record since using the B-Train tractor trailer units, less than one spill a year (0.6) would be expected for the duration of operations … Spill volume could range from less than 1 ton to 109 tons, which would represent the entire contents of the truck" (EPA 2009).

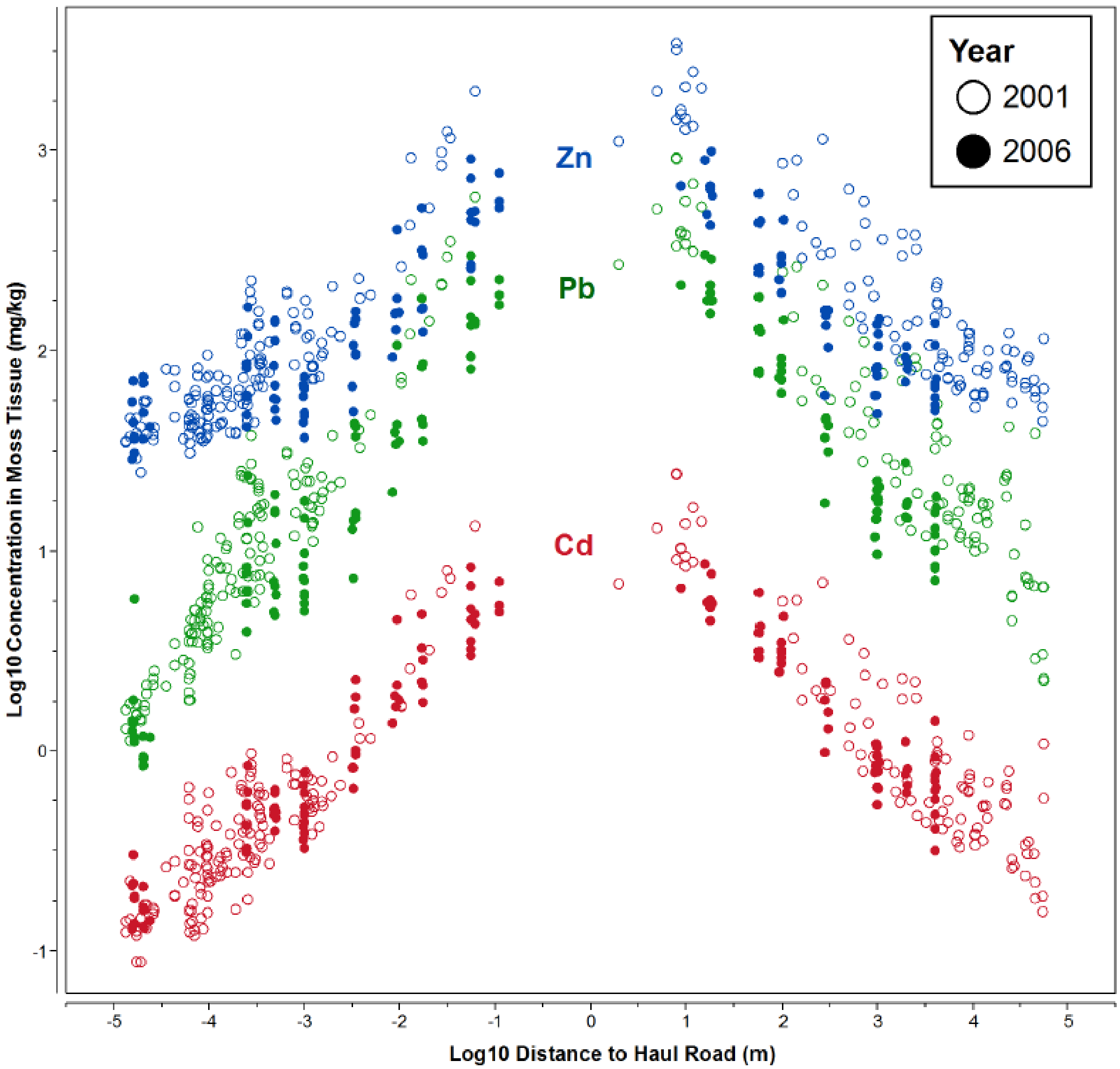


Fig 4. Concentrations of Zn, Pb, and Cd away from haul road, 2001 and 2006. Elemental concentrations of Zn, Pb, and Cd in *Hylocomium splendens* tissue vs. distance to the Red Dog haul road plotted on a $\log_{10}$-$\log_{10}$ scale. Each dot represents a moss sample point in either 2001 (open circles) or 2006 (solid circles). Sample points north of the road are plotted as positive distances, while those south of the road are negative. Table 4 displays the regression coefficients of this plot using natural logarithms.

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Figure 7.4. Neitlich et al. (2017)'s Figure 4 showed the concentrations of zinc, lead, and cadmium before and after the change in truck configuration along the DMTS through Cape Krusentstern National Monument were influenced by distance from the road and local wind and topography.

Example quantitative spill probabilities and expected numbers of spills

Trucking related spill estimates

Unlike the other mines in this case study, Red Dog used site specific data to estimate the truck accident spill rate for ore concentrate spills along the DMTS (EPA 2009). This rate differs from the Harwood and Russell (1990) rate in that it is 0.6 spills *per year* rather than 1.87 x 10^{-7} spills *per truck mile*. One important question is how much those two rates agree with one another and with the observed number of spills along the DMTS. A simple point of comparison is the number of expected ore concentrate spills based on the Harwood and Russell (1990) spill rate that has been cited for other mines and the observed ore concentrate spill rate along the DMTS. These calculations allow for an assessment of using a generic value for rural two-lane roads instead of site-specific observations and for apples-to-apples comparisons to similar estimates for the other mines in this report.

EPA (2009) did not cite Harwood and Russell's (1990) expected rate of 1.87 x 10^{-7} spills per truck mile, but it can be applied here to the 52-mile DMTS from 1990-2007. Based on an average of 36 trips per day for ore concentrate and 1.7 trips per day for diesel, there would have been 236,520 loads of ore concentrate and 11,169 loads of diesel hauled in 17 years. If the *N* = *RT* model is true, the expected numbers of ore concentrate and diesel spills along the transportation corridor in 17 years would have been:

$$236{,}520\ ore\ concentrate\ trips\ \times \frac{52\ miles}{trip} \times \frac{1.87\ x\ 10^{-7}\ spills}{mile} = 2.34\ ore\ concentrate\ spills$$

and

$$11{,}169\ diesel\ trips\ \times \frac{52\ miles}{trip} \times \frac{1.87\ x\ 10^{-7}\ spills}{mile} = 0.11\ diesel\ spills$$

The annual spill rates based on Harwood and Russell (1990) imply that for the period from 1990-2007 (18 years, inclusively), there would have been 2.34 ore concentrate spills and 0.11 diesel spills expected. Looking at those numbers on an annual basis, if the spill frequencies along the DMTS followed the frequency of Harwood and Russell (1990), there would be 0.13 ore concentrate spills per year and 0.006 diesel spills per year expected along the transportation corridor.

If the annual rate from EPA (2009), based on a very short time period after the change in truck configuration had taken effect (albeit a period with many ore concentrate trips), is accurate, the predicted rate of 0.6 ore concentrate spills/yr (EPA 2009) is more than quadruple the annual rate that would have been predicted using Harwood and Russell (1990). At 0.6 ore concentrate spills/year and an expected mine life of 20 years for the Aqqaluk Deposit, roughly 12 ore concentrate spills would be expected along the transportation corridor from 2012-2031, but the SEIS made no mention of that.

A more complicated analysis involves not just the movement of ore concentrate and diesel individually, but also in combination with other hazardous materials and under different production rate scenarios and time frames.

First, we can consider the information given in EPA (1984) to estimate the number of trips during initial production (1989-1993) and to the present (1994-2020). The estimate of total exposure assumes that the transportation of concentrate, reagents, fuel, explosives, and any hazardous wastes described in the initial EIS (EPA 1984) were accurate for the project life (Table 7.11). These values show the total exposure (in number of truck miles) that would have accrued if the original EIS description had been valid from the time the mine was constructed through 2020. Had the ore production and reagent use followed what was in EPA (1984), the total number of truck trips for transporting hazardous materials to and from the mine site would have been at least 170,000 loads.

Next, we can consider the information given in EPA (2009) to estimate the number of trips during initial production (1989-1993), expanded production (1994-2002), and to the present (2003-2020) by updating the materials and quantities (Table 7.12). The transition date from expanded to present production levels is based on the date of the NANA/Lynden shipping records from 2003 (EPA 2009, Table 2.3-4) and the diesel usage from 2000-2006 (EPA 2009, Table 2.3-1). The reagents list in EPA (2009) changed from the chemicals and quantities specified in EPA (1984). The number of annual trips with hazardous materials increased from ~3,700/year, to ~5,600/year, to ~14,000/year (Tables 7.11 and 7.12).

Note that these estimates, while based on information in EPA (1984) and EPA (2009), do not match the expected number of reagent trips described. Up to 10 trips per day (up to 3,650 trips per year) could be used for reagents during initial and expanded production (EPA 1984 Appendix 2), but there were 66-138 trips per year for the reagent quantities listed (Table 7.11). Similarly, 1.2 supply trucks would be needed each day (438 supply trucks/yr) to bring the necessary reagents to process 36 trucks worth of ore concentrate every day (EPA 2009), but the reagents listed would only require 158.4 trips/year (Table 7.12). It is possible that reagents and non-hazardous materials are both carried on supply trucks, so that more trips are required to bring smaller quantities per trip. It is also possible that not all the chemicals and supplies used at the mine are listed with the concentrator and froth flotation process reagents.

Table 7.11. Estimated loads per year for concentrate, diesel, chemical reagents, and blasting agents during initial and expanded production from 1989-2020 at Red Dog Mine based on the initial EIS (EPA 1984). The loads/year in the shaded cells are used in Table 7.13.

		Initial production (1989-1993): 3,000 tons per day		Expanded production (1994-2020): 5,600 tons per day		Total loads (1989-2020)
	Unit	Annual quantity	Loads per year	Annual quantity	Loads per year	
Ore concentrate[a]	tons	479,000	3,193	754,000	5,027	151,687
Concentrator reagents[b]						
Zinc sulfate ($ZnSO_4$)	tons	529	5.29	982	9.82	292
Copper sulfate ($CuSO_4$)	tons	529	5.29	982	9.82	292
Sodium cyanide (NaCN)	tons	106	1.06	197	1.97	58
Methylisobutyl carbinol (MIBC)	tons	53	0.53	98	0.98	29
Sodium isopropyl xanthate	tons	529	5.29	982	9.82	292
Sodium cetylsulfonate (EC-111)	tons	79	0.79	79	0.79	25
Sulfuric acid (H_2SO_4)	tons	1,057	22	1,962	40	1,189
Hydrated lime [$Ca(OH)_2$]	tons	2,642	26.42	6,443	64.43	1,872
Polyacrylamide flocculant (Percol 730)	tons	6	0.06	6	0.06	2
Reagents Total	tons	5,530	66	11,731	138	4,050
Diesel[c]						
A. for the generator, on-site equipment, and regional use by villages	gal	8,988,000	428	8,988,000	428	13,696
B. for blasting (estimated, if not included in A)	gal	960,000	46	1,792,000	85	2,533
Ammonium nitrate[d]	tons	1,200	12	2,240	22.4	665
Total (with diesel A)			3,699		5,615	170,098
Total (with diesel A + B)			3,745		5,700	172,631

[a] Assumes 150 tons of ore concentrate per load (EPA 1984, Appendix 2, p. 17). [b] Assumes 100 tons per truckload for all reagents except sulfuric acid, which will underestimate the number of trips (EPA 1984, Appendix 2, p. 12). Sulfuric acid will be transported 49 tons at a time (EPA 1984, Appendix 2, p. 16). [c] Assumes diesel is hauled in 21,000-gallon tankers (EPA 1984, Appendix 2, p. 17) and 800 gallons diesel per ton of ammonium nitrate. [d] Assumes 100 tons per truckload to match the other listed reagents and 0.4 tons of ammonium nitrate per year for each ton of ore produced per day.

Table 7.12. Estimated loads per year for concentrate, diesel, chemical reagents, and blasting agents during for annual production levels described in the supplemental EIS, assuming they apply from 2003-2020 (EPA 2009). The loads/year in the shaded cells are used in Table 7.13.

	Production (2003-2020): ~10,000 tons per day			Total loads (2003-2020)
	Unit	Annual quantity	Loads per year	
Ore concentrate[a]	tons	1,432,260	13,140	236,520
Froth flotation process reagents[b]				
Lime	tons	8,400	84	1,512
Copper sulfate ($CuSO_4$)	tons	4,900	49	882
Sodium isobutyl xanthate (SIBX)	tons	660	6.6	119
Potassium ethyl xanthate (PEX)	tons	450	4.5	81
Zinc sulfate ($ZnSO_4$)	tons	360	3.6	65
Sodium meta bi-sulfite (SMBS)	tons	310	3.1	56
Sodium sulfide (Na_2S)	tons	250	2.5	45
Sodium cyanide (NaCN)	tons	200	2	36
Dextrin	tons	127	1.27	23
Methyl isobutyl carbinol (MIBC)	tons	77	0.77	14
Magnafloc	tons	69	0.69	12
Antiscalent	tons	38	0.38	7
Reagents Total	tons	15,841	158.4	2,851
Diesel[c]				
A. for the generator, on-site equipment, and regional use by villages	gal	16,710,880	668	12,024
B. for blasting (estimated, if not included in A)	gal	3,200,000	128	2,304
Ammonium nitrate[d]	tons	4,000	40	720
Total (with diesel A)			14,006	252,115
Total (with diesel A + B)			14,134	254,419

[a] Assumes 36 loads of ore concentrate per day with 109 tons of ore concentrate per load (EPA 2009, p. 3-276). [b] Assumes 100 tons per truckload (EPA 1984, Appendix 2, p. 12). [c] Assumes diesel is hauled in 25,000-gallon tankers (EPA 2009, p. 2-27) and 800 gallons diesel per ton of ammonium nitrate. [d] Assumes 100 tons per truckload to match the other listed reagents and 0.4 tons of ammonium nitrate per year for each ton of ore produced per day.

Table 7.13. Estimated loads per year for concentrate, diesel, chemical reagents, and blasting agents during initial and expanded production from 1989-2020 at Red Dog Mine based on combined production and reagent use data from the initial EIS (EPA 1984) and the supplemental EIS (EPA 2009).

	Transported substance					Total loads	
	Ore concen-trate	Diesel A	Diesel B	Rea-gents	Ammo-nium nitrate	with Diesel A	with Diesel A + B
EPA (1984) Initial production: 3,000 tons ore/day from 1989-1993 (5 years)							
Truckloads/year	3,193	428	46	66	12		
Truckloads	15,965	2,140	230	330	60	18,495	18,725
EPA (1984) Expanded production: 5,600 tons ore/day from 1994-2002 (9 years)							
Truckloads/year	5,027	428	85	138	22.4		
Truckloads	45,243	3,852	765	1,242	202	50,539	51,304
Production described in EPA (2009): 10,000 tpd from 2003-2020 (18 years)							
Truckloads/year	13,140	668	128	158	40		
Truckloads	236,520	12,024	2,304	2,851	720	252,115	254,417
Total loads	297,728	18,016	3,299	4,423	982	321,149	324,448

Even with the two rough estimates of ore concentrate production and required reagents, diesel, and ammonium nitrate, it was possible to find an approximation of the number of truck loads and miles over which hazardous materials would be transported to and from Red Dog according to the initial and supplemental EISs (EPA 1984, 2009) (Tables 7.12, 7.13, and 7.14). These calculations were not part of either EIS. At the production levels described in the first EIS (EPA 1984), 1.7 truck accidents spills would have been expected along the transportation corridor from 1989-2020, with an 81% chance of at least one spill (Table 7.14). With the higher levels of traffic associated with the production inferred from the 2009 EIS, that estimate increases to 3.2 truck accident spills and a 96% chance of at least one spill between 1989-2020 (Table 7.14).

Table 7.14. Total exposure (number of miles traveled) from 1989-2020, expected number of spills, and P(≥1 spill), reflecting the evolving mining practice in the two EISs.

EIS	EPA (1984)		EPA (2009)	
Scenario	With diesel A	With diesel A + B	With diesel A	With diesel A + B
Total trips	170,098	172,631	321,149	324,448
Total miles	8,845,096	8,976,812	16,699,748	16,871,296
Expected number of spills	1.7	1.7	3.2	3.2
Probability of at least one spill	81.4%	81.8%	95.8%	95.9%

Pipelines

A true comparison of the environmental impacts of Alternative C (EPA 2009) would have included not only an estimate of the number of trucking related spills that could occur using the road but also how many spills might be expected if pipelines were in place for diesel, ore concentrate slurry, and wastewater.

Pipeline failure rates are most developed for oil and gas pipelines (Table 7.15). Estimated pipeline failure rates available in 2009 ranged from 0.00016 failures per mi-yr (Canadian NEB) to 0.00352 failure per mi-yr (ERBC data from 2007). The only rate specific to hazardous liquids was 0.00089 failures/mi-yr (Muhlbauer 2004). In the Bristol Bay Watershed Assessment, a geometric mean of rates from URS (2000), OGP (2010), and ERBC (2013), resulted in a pipeline failure frequency estimate of 0.0016 per mi-yr (EPA 2014).

Table 7.15. Pipeline spill rate estimates from various sources. Rates available in 2009 are in bold. Note that some rates are given per km-yr and other per mi-yr.

Source	Pipeline details	Failure rate	Data used
URS 2000			
	10 smallest operators	**0.00062 per km-yr**	cited in EPA 2014
Muhlbauer 2004			
Table 14.1	USA, crude oil	**0.00011 per mi-yr**	1975-1999
	USA, refined products	**0.00068 per mi-yr**	
	USA, hazardous liquids	**0.00089 per mi-yr**	
Table 14.2	Crude oil and refined products	**0.00089 per mi-yr**	US average, 1975-1999
Table 14.3	Liquids	**0.00086 per mi-yr**	US average, 1990-1997
Canadian NEB			
		0.00010 per km	2000-2008 data
ERBC 2013 (cited in EPA 2014)	Alberta, Canada	**0.0022 per km-yr**	2007
		0.0021 per km-yr	2008
		0.0016 per km-yr	2009
		0.0015 per km-yr	2010
		0.0015 per km-yr	2011
OGP 2010			
p. 9	Onshore gas pipelines	0.00041 per km-yr	EGIG database 1970-2004
p. 8	Onshore gas pipelines	0.00017 per km-yr	EGIG database 2000-2004
Table 2.1	Onshore oil pipelines		
	Diameter < 8 inch	0.001 per km-year	
	8 inch < diam < 14 inch	0.0008 per km-year	
	16 inch < diam < 22 inch	0.00012 per km-year	
	24 inch < diam < 28 inch	0.00025 per km-year	
	Diameter > 28 inch	0.00025 per km-year	
	Onshore gas pipelines		
	Wall thickness ≤ 5 mm	0.0004 per km-year	
	5 mm < wall thickness ≤ 10 mm	0.00017 per km-year	
	10 mm < wall thickness ≤ 15 mm	0.000085 per km-year	
	Wall thickness > 15 mm	0.000041 per km-year	

Given the length of the proposed pipelines, the expected project lifetime, and the pipeline failure rate estimates, it would have been possible to quantitatively estimate the number of releases expected for each pipeline individually and collectively (Table 7.16). If we assume that pipeline failures are independent of one another, then the joint probability that none fails is the product of the probabilities that none of the individual pipelines fail:

P(0 failures across all three pipelines)

= P(0 diesel pipeline failures) x P(0 ore slurry pipeline failures) x

P(0 wastewater pipeline failures)

= (1 – P(≥1 diesel pipeline failure)) x (1 – P(≥1 ore slurry pipeline failure)) x

(1 – P(≥1 wastewater pipeline failure))

Table 7.16. Example of failure rate calculations for three pipelines carrying different materials to or from Red Dog Mine using pipeline failure rates for refined products and hazardous liquids from Muhlbauer (2004).

Pipeline	Length (mi)	Years	Failure rate per mi-yr	Expected number of failures	Probability of ≥1 failure (%)	Probability of 0 failures (%)
Diesel	50	20	0.00068	0.68	49.3%	50.7%
Ore slurry	50	20	0.00089	0.89	58.9%	41.1%
Wastewater	50	20	0.00089	0.89	58.9%	41.1%
Total				2.46	17.1%	8.6%

In this example, the total number of expected failures across three 50-mile pipelines conveying a refined petroleum product and two hazardous liquids (ore slurry and wastewater) for 20 years is 2.46 failures (Table 7.16). There is a 17.1% chance that all three pipelines experience at least one failure and an 8.6% chance that none of them suffer any, meaning that there is a 91.4% chance of at least one failure across all three pipelines. There is a 74.3% chance that one or two (but not all three) of the pipelines would experience a failure in that time. (For comparison, the Bristol Bay Watershed Assessment found that failure probability for three pipelines, each 113 km long and in use for 25 years with a failure rate of 0.001 failures per km-yr, was 95% for each and 99.9% chance that at least one would fail (EPA 2014).)

Of course, this is only an example of how such calculations can be carried out. In fact, it would not be expected that the failures would be independent of one another, especially those caused by environmental and physical processes or human errors that are not related to manufacturing defects or associated with the liquids being transported. Similarly, the failure rates used here, while drawing on published values, might not be appropriate. Still, these estimates of expected pipeline spills could have been used with the estimates of trucking-related spills to quantitatively compare transportation corridor spills risks across alternatives (Table 7.17).

Table 7.17. Example expected number of spills in 20 years with a 50-mile road or pipeline. Alternatives B and D had no pipelines. Alternative C had pipelines for diesel, ore concentrate slurry, and wastewater. Annual loads for diesel and reagents transported by truck were based on haul frequencies of 1.7 and 1.2 loads/day, respectively (Table 7.8). Spills rates for trucks were 0.6/yr for ore concentrate (EPA 2009) and 1.87 x 10^{-7} per mile for diesel and reagents (Harwood and Russell 1990).

	Expected numbers of spills	
	Alternatives B and D	Alternative C
Ore concentrate		
Trucks	12	0
Pipeline	0	0.89
Diesel		
Trucks	0.12	0
Pipeline	0	0.68
Reagents (trucks)	0.08	0.08
Wastewater (pipeline)	0	0.89
Total	12.2	2.54

A comparison of spill probabilities showing the number of expected spills still leaves many questions unanswered. The sizes of spills from trucks have a defined maximum quantity. Pipeline spill size depends on several factors, including the size of the hole or breach, the liquid's flow rate within the pipeline, the speed at which the pipeline is shut down, and the amount of fluid in the pipe between the nearest valve and the release point. As shown previously, the truck spill incident rate from Harwood and Russell (1990) is not a good match for trucks hauling ore concentrate from Red Dog to the port and may not be accurate for diesel or reagents being transported from the port to the mine.

Spill record from ADEC

To compare the predicted number of spills with the actual number, I compiled spills from the Northwest Arctic Subarea (NW Arctic) in the ADEC database (ADEC 2021), covering the period from July 1995-December 2020. There were 3,640 unique spill records once duplicate spill listings were removed. The number of records may slightly overcount the number of spills because some incidents involve releases of more than one substance and each substance is recorded. I sorted the NW Arctic spills by *responsible party*, *location*, and *facility type* and found that 2,882 spills were attributable to Red Dog Mine (Appendix B5). There were 192 incidents with quantities in pounds, and the remaining 2,690 spills amounts in gallons. For comparison against the spills listed in the SEIS (EPA 2009), I also divided the transportation spills from Red Dog into the periods 1995-2007 and 2008-2020.

I sorted the spills by *substance class* and *substance subclass* for spills given by volume (Table 7.18) and by weight (Table 7.19). *Non-crude oil* and *hazardous substance* spills accounted for 2,441 out of 2,690 spills listed in gallons, with more than 1,000 spills of hydraulic oil (Figure 7.5). The *hazardous* and *extremely hazardous substances* spilled included cyanide, sulfuric acid, and glycols, as well as ore concentrates and slurry (Tables 7.18 and 7.19). Many spills listed as "hazardous material – other" were unidentified. Most of the reagents listed in Table 7.5 appear in Tables 7.18 and 7.19, as do ammonium nitrate and sodium hypochlorite, which were not listed among the reagents but were mentioned in EPA (1984). While 56% of the spills were less than 10 gallons (Table 7.20, Figures 7.6 and 7.7), the relative infrequency of larger spills was overshadowed by their contribution the overall volume of hazardous materials released. The 10% of the spills that were of 100 gallons or more amassed 98% of the total volume accidentally released (Tables 7.20 and 7.21). More than 20% of the spills listed by weight were of at least 1,000 pounds (Table 7.22); those spills accounted for 99% of the materials released listed by weight (Table 7.23). Nearly all of the spills listed by weight instead of by volume were of *hazardous* and *extremely hazardous substances*.

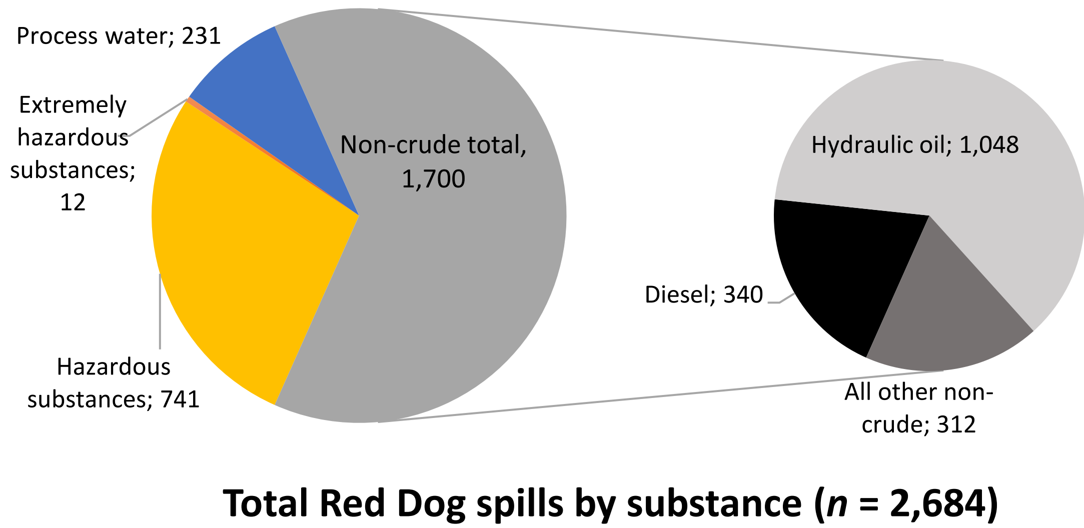
Table 7.18. There were 2,690 recorded spill incidents at Red Dog Mine from July 1995-2020 with quantities given in gallons (ADEC 2021). Total values for each substance subtype have been rounded to the tenth of a gallon. Substances in shaded rows were not discussed in EPA (1984) or EPA (2009).

		Volume (gallons)	
	n	Range	Total
Extremely hazardous substances			
Ammonia (anhydrous)	1	150	150
Sodium cyanide (solid)	1	30	30
Sodium cyanide (solution)	4	1-175	179
Sulfuric acid	6	0.125-20	27.4
Total	12		386
Hazardous substances			
Acid, other	4	3-500	538
Bases	10	5-4,000	4,637
Caustic alkali liquids	2	1-100	101
Corrosion inhibitor	1	20	20
Emulsion breaker	6	2-200	251
Ethyl alcohol	1	10	10
Ethylene glycol	223	0.25-101	1,560.2
Glycol, other	8	2-50	109
Lead	11	0-250	395.1
Magnesium oxide slurry	5	0.5-100	164.5
Methyl alcohol	9	1.5-150	304
Mill slurry	46	0.5-2,200	12,875
Propylene glycol	35	0-1,500	6,496.6
Sodium hypochlorite	2	1-5	6
Solvent	1	10	10
Zinc	11	2-3,000	5,246
Zinc concentrate	32	0.12-3,000	5,716.1
Zinc slurry	82	0.25-200,000	510,221
Other*	252	0.023-36,000	170,443.5
Total	741		719,118

* Other hazardous substances listed in the spill names include flake lime, WTP sludge, slurry, lime, waste water, rust inhibitive primer, slaked lime, flocculant, water mixed with sludge, lime milk, DEF, process water, Na Meta, xanthate, reclaimed water, ground ore, mix, prefloat, flotation feed, gypsum, lead file concentrate, filtrate water, hydrated lime, acid rock drainage water, zinc and lead ore, mill feed, mixture hazardous waste, dextrin, ammonium nitrate, pine tar resin, acrylic latex paint, battery acid, and sodium sulphite. There were also 168 spills of other hazardous substances that had blank spill names.

Table 7.18. (Continued.)

		Volume (gallons)	
	n	Range	Total
Non-crude oil			
Aviation fuel	4	1-3	6
Diesel	340	0.002-4,075	15,929
Engine lube oil	147	1-225	1,236.5
Engine lube/gear oil	12	0.01-300	356.5
Gasoline	5	3-53	79
Grease	3	0.25-12	22.2
Hydraulic oil	1,048	0.008-160	11,363.3
Other	17	1-100	280
Synthetic oil	5	2-55	124
Transformer oil	3	1-5	8
Transmission oil	88	1-90	652.5
Used oil (all types)	28	1-300	912
Total	1,700		30,969
Process water			
Process water	193	1-150,000	586,481
Produced water	36	1-78,300	113,436
Source water	2	2-5	7
Total	231		699,924
Unknown	6	1-30	64



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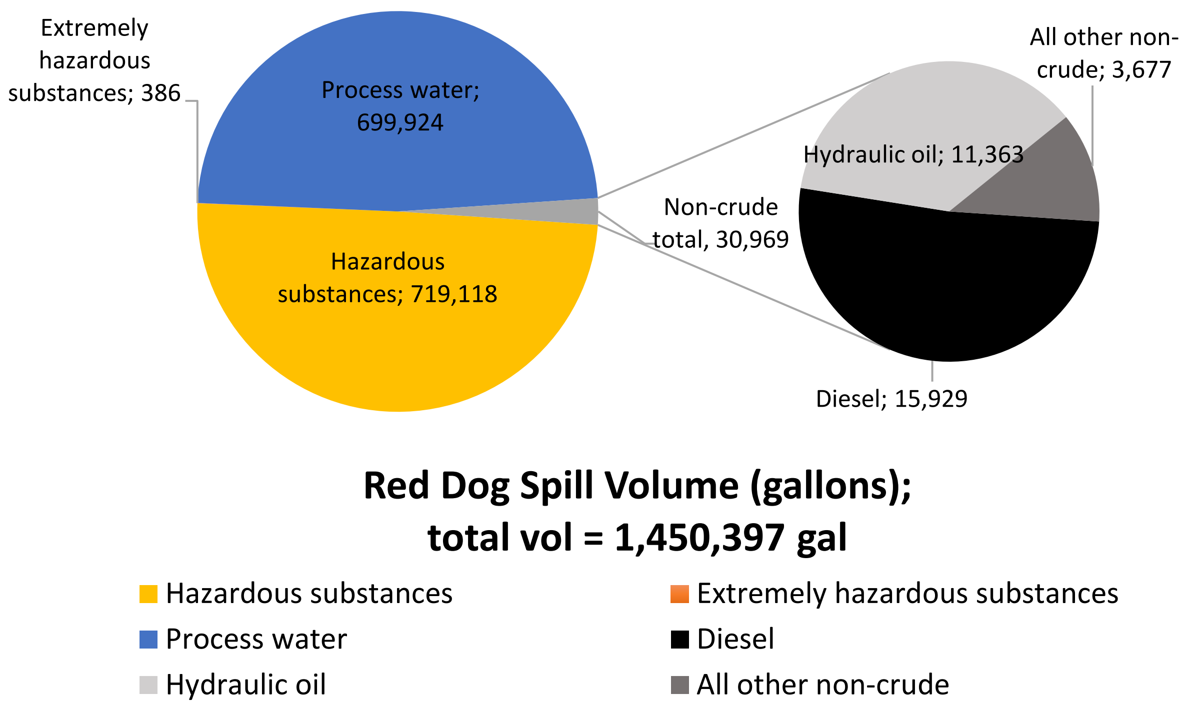


b.

Figure 7.5. Relative proportions of (a) number and (b) volume from different substance classes at Red Dog Mine from 1995-2020 with non-crude oil spills further broken down to show the amounts due to diesel and hydraulic oil spills.

Table 7.19. There were 192 recorded spill incidents at Red Dog Mine from July 1995-2020 with quantities given in pounds (ADEC). Total values for each substance subtype have been rounded to the tenth of a pound. Substances in shaded rows were not discussed in EPA (1984) or EPA (2009).

		Quantity (pounds)	
	n	Range	Total
Extremely hazardous substances			
Ammonia (anhydrous)	1	100	100
Hazardous substances			
Bases	10	1-480	764
Drilling muds	1	46,000	46,000
Emulsion breaker	1	25	25
Lead	7	1-60,000	60,337
Mill slurry	1	20	20
Urea (solid)	5	2-700	1,092
Zinc	4	10-36,900	53,933
Zinc concentrate	35	1-250,000	1,102,856
Other*	126	0.06-160,000	653,936.1
Total	190		1,918,963
Non-crude oil			
Other	1	500	500

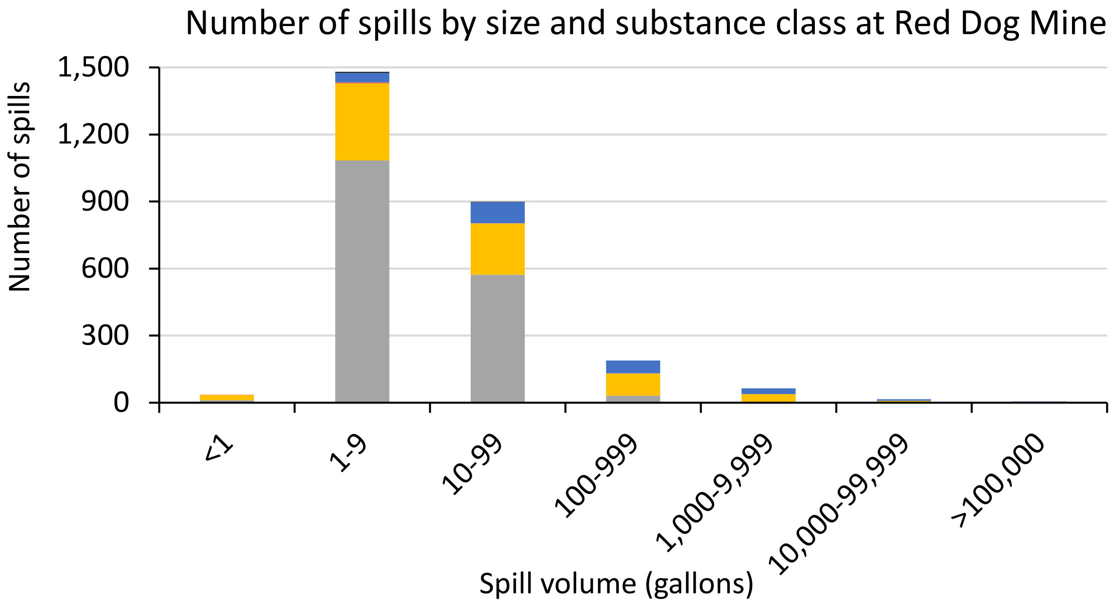
* Other hazardous substances listed in the spill names include mine waste, lime, landfill disposal, dry lime, ammonium nitrate discharge, ammonium nitrate, flocculant, quick lime, final tailings, zinc mixture, lime conex, gypsum, MagnaFloc, potassium ethyl xanthate, copper sulfate (solid), and quick lime. There were also 85 spills of other hazardous substances that had blank spill names.

Table 7.20. Counts of Red Dog Mine spills with quantities given in gallons from July 1995-December 2020 by substance class and size category (ADEC 2021).

Substance class	Number of spills								Per-cent
	Spill size class (gallons)							Total	
	<1	1-9	10-99	100-999	1,000-9,999	10,000-99,999	≥100,000		
Ex Haz Sub	2	6	2	2				12	0.4%
Haz Sub	23	343	229	99	36	8	3	741	27.5%
Non-crude	11	1,084	572	31	2			1,700	63.2%
Process water		43	94	57	27	7	3	231	8.6%
Unknown		4	2					6	0.2%
Total	36	1,480	899	189	65	15	6	2,690	
Percent	1.3%	55.0%	33.4%	7.0%	2.4%	0.6%	0.2%		

Table 7.21. Cumulative volume of Red Dog Mine spills with quantities given in gallons from July 1995-December 2020 by substance class and size category (ADEC 2021).

Substance class	Cumulative volume spilled (gallons)								Percent
	Spill size class (gallons)							Total	
	<1	1-9	10-99	100-999	1,000-9,999	10,000-99,999	≥100,000		
Ex Haz Sub	0.4	11	50	325				386	0.0%
Haz Sub	6	1,049	6,101	26,432	70,132	157,000	458,398	719,118	49.6%
Non-crude	3	3,367	12,628	8,196	6,775			30,969	2.1%
Process water		133	2,803	14,049	61,500	243,440	378,000	699,924	48.3%
Unknown		9	55					64	0.0%
Total	9	4,568	21,637	49,002	138,407	400,440	836,398	1,450,461	
Percent	0.0%	0.3%	1.5%	3.4%	9.5%	27.6%	57.7%		



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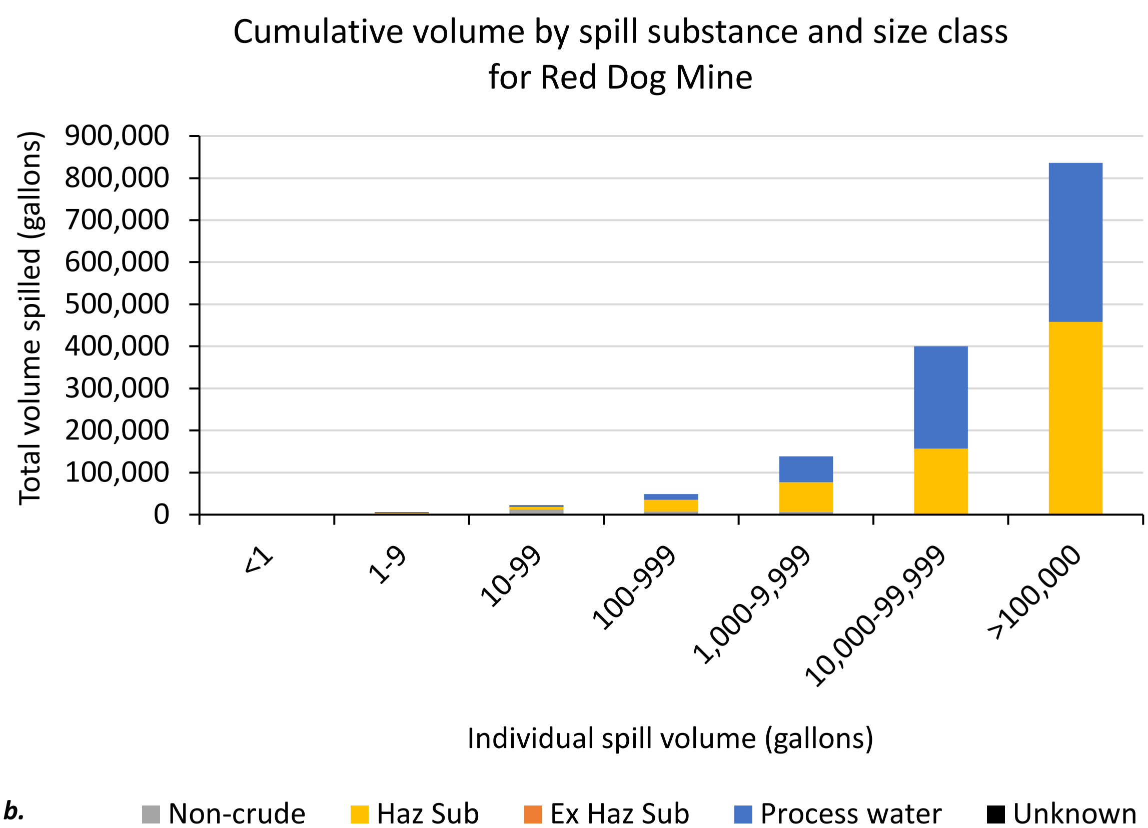


b.

Figure 7.6. Number of spill incidents (a) and cumulative gallons spilled (b) for non-crude oil, hazardous substances, extremely hazardous substances, and process water in different spill size classes for Red Dog from July 1995-December 2020 based on ADEC (2021).

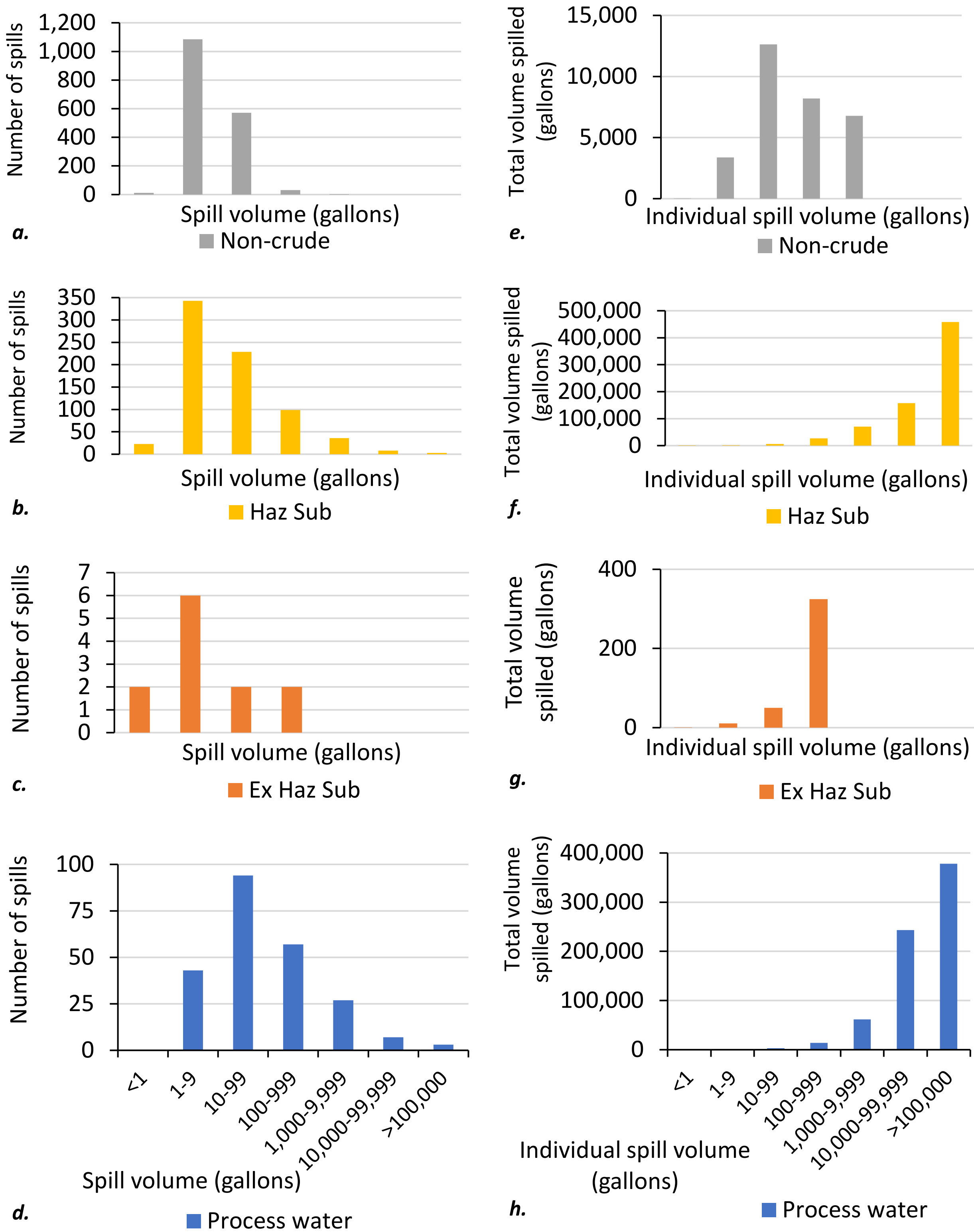


Figure 7.7. Number of spill incidents (a-d) and cumulative gallons spilled (e-h) for non-crude oil (a, e), hazardous substances (b, f), extremely hazardous substances (c, g) and process water (d, h) in different spill size classes for Red Dog Mine from July 1995-December 2020 based on ADEC (2021). All subfigures have the same x-axes.

Table 7.22. Counts of Red Dog Mine spills with quantities given in pounds from July 1995-December 2020 by substance class and size category (ADEC 2021).

Substance class	Number of spills								Percent
	Spill size class (pounds)							Total	
	<1	1-9	10-99	100-999	1,000-9,999	10,000-99,999	≥100,000		
Ex Haz Sub				1				1	0.5%
Haz Sub	4	53	51	40	15	22	5	190	99.0%
Non-crude				1				1	0.5%
Total	4	53	51	42	15	22	5	192	
Percent	2.1%	27.6%	26.6%	21.9%	7.8%	11.5%	2.6%		

Table 7.23. Cumulative weight of Red Dog Mine spills with quantities given in pounds from July 1995-December 2020 by substance class and size category (ADEC 2021).

Substance class	Cumulative weight of spills (pounds)								Percent
	Spill size class (pounds)							Total	
	<1	1-9	10-99	100-999	1,000-9,999	10,000-99,999	≥100,000		
Ex Haz Sub				100				100	0%
Haz Sub	1.11	162	1,426	14,451	42,540	1,020,183	840,200	1,918,963	100%
Non-crude				500				500	0%
Total	1.11	162	1,426	15,051	42,540	1,020,183	840,200	1,919,563	
Percent	0.0%	0.0%	0.1%	0.8%	2.2%	53.1%	43.8%		

The ADEC issued the *Summary of Oil and Hazardous Substances Spills by Subarea (July 1, 1995 – June 30, 2005)* in 2007. Red Dog Mine lies within the Northwest Arctic subarea. (ADEC 2007) noted that "[a]lthough only 6% of the spills reported statewide occur in the Northwest Arctic subarea, mining operations were responsible for 80% of these spills and 69% of the volume spilled in this subarea. The majority of these spills occurred from unregulated components associated with the mine." Specifically, Red Dog Mine "was responsible for 1,190 of the 1,483 spills and 901,843 of the 1,105,220 gallons spilled in the Northwest Arctic subarea for the reporting period" (ADEC 2007). ADEC (2007) listed 35 spills of at least 1,000 gallons associated with Red Dog Mine from 1995-2005, a list which excludes spills reported in pounds and potential spills (Table 7.24). The list of large spills in ADEC (2007) is an incomplete record in three ways. First, it is at least 15 years out of date. Second, it explicitly does not include spills with quantities given in pounds rather than gallons. Third, there were 128 spills of at least 1,000 gallons or pounds associated with Red Dog Mine from 1995-2020 recorded in the ADEC database (Table 7.25), with some significant discrepancies between ADEC (2007) and ADEC (2021). Specifically, at least 12 spills in Table 7.25 that occurred before July 2005 and had quantities given in gallons (spills in bold without asterisks) were not listed in Table 7.24. According to AIDEA and Arcadis (2017), "The largest spill (fuel) related to port operations occurred on July 31, 1993, when an estimated 5,000-8,000 gallons of fuel from the bulk storage tanks at the port was released into the impoundment/dike area surrounding the tanks." This spill predates the records contained in ADEC (2021). There is a diesel spill listed in ADEC (2007) from Red Dog's port site on July 29, 2003, but it is listed at 36,000 gallons (Table 7.24). (See also *State and Federal compliance and enforcement*.)

Table 7.24. Extracts from "Major Spills in the Northwest Arctic Subarea" (ADEC 2007) showing 35 major spills related to Red Dog Mine by 2005. The spill in the shaded row was from 1993 and is not part of the spills shown in Table 7.25. Amounts with an * were listed in gallons in ADEC (2007) and in pounds in ADEC (2021). Product names in bold differ from their counterparts in Table 7.25.

Date	Spill name	Product	Gallons
5/31/1998	Red Dog Mine	**Magnesium Oxide (Slurry)**	200,000
11/24/2003	Red Dog Mine	**Tailings**	158,398
3/2/1999	Red Dog Mine	**Grey Water**	100,000
12/28/2000	Red Dog Mine Port Road	Zinc Concentrate	80,000*
10/9/2000	Red Dog Mine Port Road	Lead	60,000*
7/29/93	Cominco Red Dog mine port site, pit #2	Diesel	36,000
4/13/1998	Red Dog Mine	**Process Water**	36,000
6/2/2001	Red Dog Mine	**Reclaim Water**	29,000
1/24/2004	Red Dog Mine	Process Water	21,000
2/13/1999	Red Dog Mine	**Reclaim Water**	20,000
3/6/2000	Red Dog Mine	Produced Water	20,000
8/3/2000	Red Dog Mine	**Process Water**	20,000
5/4/2005	Red Dog Mine	Process Water	13,500
2/16/2001	Red Dog Mine Port Road	Zinc Concentrate	12,000*
6/3/1996	Red Dog Mine	**Tailings**	10,000
6/6/2001	Red Dog Mine	**Reclaim Water**	10,000
6/11/2004	Red Dog Mine	Process Water	10,000
11/8/1999	Red Dog Mine	Process Water	6,500
1/29/2000	Red Dog Mine	Produced Water	5,000
5/14/2000	Red Dog Mine	**WTP Sludge**	5,000
10/2/2004	Red Dog Mine Port Site Tanker Diesel Spill	Diesel	4,075
6/9/1998	Red Dog Mine	**Magnesium Oxide (Slurry)**	3,500
10/24/1997	Red Dog Mine	Produced Water	3,000
12/2/2001	Red Dog Mine	Zinc	3,000
8/29/2002	Red Dog Mine	Process Water	3,000
8/11/2004	Red Dog Mine	Diesel	2,700
5/31/2001	Red Dog Mine	**Other**	2,204
6/7/1998	Red Dog Mine	**Process Water**	2,000
5/11/1998	Red Dog Mine	**Magnesium Oxide (Slurry)**	2,000
7/26/2000	Red Dog Mine	**Process Water**	2,000
5/20/2002	Red Dog Mine	Process Water	2,000
10/16/2000	Red Dog Mine	Produced Water	1,500
6/22/2001	Red Dog Mine	**Tailings**	1,500
2/25/2002	Red Dog Mine	Propylene Glycol	1,500
1/24/2004	Red Dog Mine	Propylene Glycol	1,200

Table 7.25. There were 128 recorded spills of at least 1,000 gallons (or pounds) from 1995-2020 at Red Dog (ADEC 2021). Quantities in pounds are indicated by an asterisk. Shaded rows indicate spills also listed in Table 7.24. Rows in bold occurred before July 2005 but were not listed in ADEC (2007). Spill names are from ADEC (2021) unless noted as "Responsible party:..."

Date	Spill name	Product	Gallons
8/12/2012	Red Dog Mine 250K lbs Zinc Concentrate	Zinc Concentrate	250,000*
5/31/1998	Red Dog Mine Zinc Slurry Spill	Zinc Slurry	200,000
7/19/1999	**Responsible party: COMINCO, RED DOG MINE**	**Other**	**160,000***
11/24/2003	Responsible party: TeckCominco	Zinc Slurry	158,398
11/22/2006	Teck Cominco Process Water 11/22/2006	Process Water	150,000
12/31/2016	Red Dog Mine MP 49 10000lbs Zinc Con.	Zinc Concentrate	145,200*
10/3/2015	Red Dog Port Rd Zn concentrate truck rollover	Zinc Concentrate	145,000*
2/7/1998	**Responsible party: COMINCO**	**Other**	**140,000***
5/7/2006	Red Dog Mine Reclaimed Water Release	Process Water	114,000
9/29/2008	Mine Site: Sand Filter Building 2023	Process Water	114,000
3/2/1999	Responsible party: COMINCO	Zinc Slurry	100,000
6/29/2010	Monthly	Process Water	80,640
12/28/2000	Responsible party: TeckCominco	Zinc Concentrate	80,000*
7/21/2007	Red Dog Operations	Produced Water	78,300
8/1/1998	**Responsible party: TeckCominco**	**Other**	**76,000***
8/5/1996	**Responsible party: COMINCO**	**Other**	**70,000***
8/19/1997	**35 Ton Zinc Concentrate Truck Rollover**	**Zinc Concentrate**	**70,000***
8/21/1997	**10 Ton Zinc Concentrate Truck Rollover**	**Zinc Concentrate**	**70,000***
11/21/1998	**Responsible party: RED DOG MINE (COMINCO)**	**Zinc Concentrate**	**70,000***
10/9/2000	Responsible party: TeckCominco	Lead	60,000*
1/21/1999	**Responsible party: COMINCO RED DOG MINE**	**Other**	**60,000***
9/21/2005	NANA/Lynden Logistics Truck Rollover	Zinc Concentrate	60,000*
1/6/1999	**Responsible party: COMINCO, RED DOG MINE**	**Other**	**50,000***
9/30/2020	Red Dog Mine 50k Lb Zinc Concentrate	Zinc Concentrate	50,000*
7/25/2017	Red Dog Mine, Unknown Creek 384cf Drill Shavings	Drilling Muds	46,000*
1/2/1997	40000 LB ZINC SPILL	Zinc Concentrate	40,000*
1/17/1998	Responsible party: COMINCO ALASKA	Other	37,760*
6/20/2019	Red Dog Mine 36k Lbs Zinc Concentrate	Zinc	36,900*
4/13/1998	Responsible party: COMINCO	Other	36,000
12/10/1996	**COMINCO 34000 LB ZINC SPILL**	**Zinc Concentrate**	**34,000***
6/2/2001	1st Red Dog Mine Reclaim Water Spill	Other	29,000

Table 7.25. (Continued.)

Date	Spill name	Product	Gallons
7/12/1998	**Responsible party: COMINCO**	**Zinc Concentrate**	**26,500***
2/9/2017	Teck Red Dog Kivalina Overburden Waste Water	Other	22,000
1/24/2004	Red Dog Process Water	Process Water	21,000
8/3/2000	Responsible party: COMINCO ALASKA INC.	Other	20,000
2/13/1999	Responsible party: COMINCO	Other	20,000
4/22/2020	Red Dog Mine Trench 20K+gal Process Water	Process Water	20,000
3/6/2000	Responsible party: COMINCO ALASKA	Produced Water	20,000
11/1/2017	Red Dog Mine Emulsion Plant 20K lbs. NH4NO3	Other	20,000*
3/20/2003	Responsible party: NANA LYNDEN LOGISTICS	Zinc Concentrate	20,000*
7/20/2001	Red Dog Mine Zinc Spill MP 38.3	Zinc Concentrate	20,000*
5/4/2005	Responsible party: TeckCominco	Process Water	13,500
2/16/2001	Red Dog Mine Zinc Concentrate Spill	Zinc Concentrate	12,000*
3/7/2009	MS 10: Teck NANA Lynden Rollover	Zinc	11,023*
6/6/2001	2nd Red Dog Mine Reclaim Water Spill	Other	10,000
6/3/1996	Responsible party: COMINCO	Zinc Slurry	10,000
5/9/2020	Red Dog Mine10k gal Water Treatment Sludge	Zinc Slurry	10,000
6/11/2004	Red Dog Mine Process Water Release	Process Water	10,000
10/21/2007	Responsible party: TeckCominco	Other	8,854
2/18/2018	Red Dog Mine, 7,200gal Acid Rock Drainage	Other	7,200
11/8/1999	Responsible party: COMINCO ALASKA	Process Water	6,500
7/4/2019	Teck Dry Flocculent Landfill Disposal	Other	6,000*
12/30/2020	DeLong Mtn Logistics 3 ton concentrate spill MP 21	Zinc	6,000*
2/27/1999	**Responsible party: COMINCO, ARROW TRANSPORT**	**Other**	**5,198***
5/14/2000	Responsible party: COMINCO ALASKA	Zinc Slurry	5,000
1/29/2000	Responsible party: COMINCO ALASKA	Produced Water	5,000
8/9/2005	Responsible party: TeckCominco	Process Water	4,800
4/17/2009	Mill Pad 4,200 gal slaked lime spill	Bases	4,200
10/2/2004	Red Dog Mine Port Site Tanker Diesel Spill	Diesel	4,075
4/7/2013	Mine Site- Under 2011 Module	Process Water	3,700
6/9/1998	Responsible party: COMINCO	Zinc Slurry	3,500
12/2/2001	Responsible party: TeckCominco	Zinc	3,000

Table 7.25. (Continued.)

Date	Spill name	Product	Gallons
3/29/2014	Red Dog Monthly-March	Zinc Concentrate	3,000
10/21/2007	3000 Gal Zinc Slurry Spill-Red Dog Mine	Zinc Slurry	3,000
8/29/2002	Responsible party: TeckCominco	Process Water	3,000
6/8/2012	Red Dog Monthly-June	Process Water	3,000
12/20/2016	Red Dog Mine, 3000gal Reclaimed Water	Process Water	3,000
10/24/1997	Responsible party: COMINCO	Produced Water	3,000
1/20/2014	Red Dog Mine Port Road MP3 zinc release	Zinc Concentrate	3,000*
8/11/2004	Nana-Lynden Red Dog Truck Rollover	Diesel	2,700
1/18/2011	Monthly report: Zinc thickener	Process Water	2,500
3/27/2017	Red Dog Mine, 1200gal Processed Water	Process Water	2,500
4/10/2016	Red Dog Mine, Mill 2011, 2328 gal Zinc Final Con.	Zinc Slurry	2,328
5/31/2001	Monthly	Zinc Slurry	2,204
11/14/2019	Red Dog Slurry Pumphouse station 3K lead sulfide	Mill Slurry	2,200
10/18/2006	Red Dog MP 14 Zinc Truck Rollover	Zinc Concentrate	2,088*
5/31/2020	Red Dog Mine 2000 gal mill feed	Mill Slurry	2,000
7/26/2000	Responsible party: COMINCO ALASKA INC.	Other	2,000
10/25/2017	Red Dog Mine, Mill 2011, 2,000gal Recalim water	Other	2,000
2/15/2012	Red Dog Zinc Slurry w/Lead Sulfied	Zinc Slurry	2,000
6/7/1998	Responsible party: TeckCominco	Zinc Slurry	2,000
5/11/1998	Responsible party: COMINCO	Zinc Slurry	2,000
1/20/2013	Red Dog Mine- Mill site	Process Water	2,000
5/20/2002	Responsible party: TeckCominco	Process Water	2,000
5/31/2007	Red Dog Operations	Process Water	2,000
5/2/2009	Millsite	Process Water	2,000
12/25/2011	Teck 2000-gal Produced Water Release	Process Water	2,000
12/29/2014	Teck/Red Dog ARD Pump House 6005 2000 gal pumpback	Process Water	2,000
12/13/2009	Mill 2021	Process Water	2,000
3/22/1998	**Responsible party: COMINCO**	**Other**	**2,000***
6/7/1996	**Responsible party: COMINCO**	**Other**	**2,000***
1/1/2010	Mill 2010	Mill Slurry	1,500
12/16/2012	Red Dog Mine Monthly- Mine Site	Mill Slurry	1,500
2/25/2002	Responsible party: TeckCominco	Propylene Glycol	1,500
6/22/2001	Responsible party: COMINCO ALASKA	Zinc Slurry	1,500
10/16/2000	Responsible party: COMINCO ALASKA	Produced Water	1,500
6/16/2015	Red Dog leaking propylene glycol pump	Propylene Glycol	1,300

Table 7.25. (Continued.)

Date	Spill name	Product	Gallons
1/24/2004	Red Dog Process Water	Propylene Glycol	1,200
5/24/1998	**Responsible party: COMINCO**	**Other**	**1,200***
5/20/1998	**Responsible party: RED DOG MINE (COMINCO)**	**Other**	**1,200***
10/11/2010	Mine Site 2030	Mill Slurry	1,000
5/31/2020	Red Dog Mine 1000 gal mill feed slurry	Mill Slurry	1,000
11/25/2007	Responsible party: TeckCominco	Other	1,000
8/21/2004	Responsible party: TeckCominco	Other	1,000
3/25/2000	Responsible party: COMINCO ALASKA	Other	1,000
5/2/1998	**Responsible party: COMINCO**	**Other**	**1,000**
1/31/1999	**Responsible party: COMINCO**	**Other**	**1,000**
2/26/1999	**Responsible party: COMINCO RED DOG MINE**	**Other**	**1,000**
4/28/1997	**Responsible party: COMINCO**	**Other**	**1,000**
7/27/1998	**Responsible party: RED DOG MINE**	**Other**	**1,000**
9/20/2002	**Responsible party: TeckCominco**	**Propylene Glycol**	**1,000**
1/13/2020	Red Dog Mine 1Kgal Ehtylene Glycol	Propylene Glycol	1,000
5/31/1998	**Responsible party: COMINCO**	**Zinc Slurry**	**1,000**
6/22/2005	**Responsible party: TeckCominco**	**Zinc Slurry**	**1,000**
3/30/2013	Mine Site- Under Module 2003	Process Water	1,000
1/8/2005	**Responsible party: TeckCominco**	**Process Water**	**1,000**
9/12/2010	Mine Site: Mill 2030	Process Water	1,000
10/7/2002	Responsible party: COMINCO RED DOG MINE	Process Water	1,000
4/29/1996	**PROCESS WATER SPILL**	**Process Water**	**1,000**
10/24/1997	**Responsible party: COMINCO**	**Produced Water**	**1,000**
7/20/2020	Red Dog 1000 gal processed water Module 6030	Produced Water	1,000
10/7/2000	**Responsible party: COMINCO ALASKA**	**Produced Water**	**1,000**
4/20/2000	**Responsible party: COMINCO ALASKA**	**Produced Water**	**1,000***
10/14/2012	Red Dog Mine, Port Dock 1,000lbs Ammonium Nitrate	Other	1,000*
12/25/2004	Responsible party: TeckCominco	Other	1,000*
10/8/2016	Red Dog Mine, Port Site, 1000# Ammonium Nitrate	Other	1,000*
11/9/2010	Mine Site: Prill Storage Area and Silo	Other	1,000*
10/17/2006	Nana-Lynden MP 34 Truck Rollover	Zinc Concentrate	1,000*

There has been an average of 113.5 spills per year at Red Dog from 1995-2020, with 59% of those from *non-crude oil* (Table 7.26). The highest number of recorded spill incidents was in 1998, when there were 213 spill incidents (Table 7.26, Figure 7.8). Spills are more common in May through October (Table 7.27, Figure 7.8), a period which overlaps when the port is open.

Table 7.26. Spills per year by substance type at Red Dog from July 1995-December 2020 based on ADEC (2021).

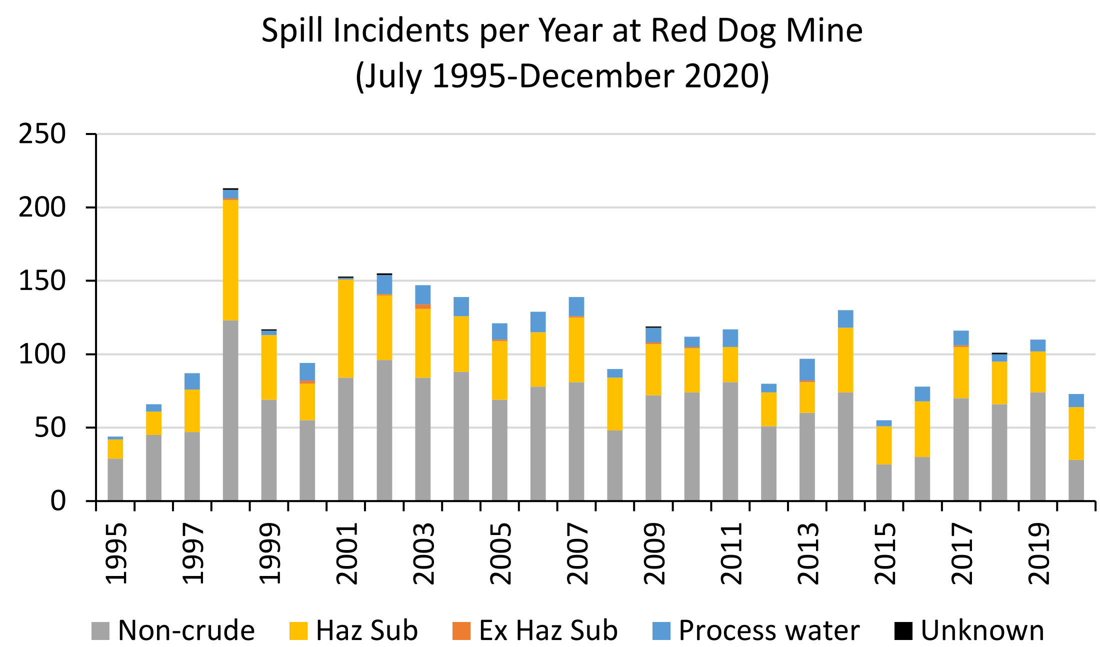
	Spills					
Year	Ex Haz Sub	Haz Sub	Non-crude	Process water	Unknown	Total
1995		13	29	2		44
1996		16	45	5		66
1997		29	47	11		87
1998	1	82	123	6	1	213
1999		44	69	3	1	117
2000	2	25	55	12		94
2001		67	84	1	1	153
2002	1	44	96	13	1	155
2003	3	47	84	13		147
2004		38	88	13		139
2005	1	40	69	11		121
2006		37	78	14		129
2007	1	44	81	13		139
2008		36	48	6		90
2009	1	35	72	10	1	119
2010	1	30	74	7		112
2011		24	81	12		117
2012		23	51	6		80
2013	1	21	60	15		97
2014		44	74	12		130
2015		26	25	4		55
2016		38	30	10		78
2017	1	35	70	10		116
2018		29	66	5	1	101
2019		28	74	8		110
2020		36	28	9		73
total	13	931	1,701	231	6	2,882
mean*	0.5	36.7	66.9	9.2	0.2	113.5
sd*	0.8	14.2	22.4	3.8	0.4	34.2

* for years with complete data (1996-2020)

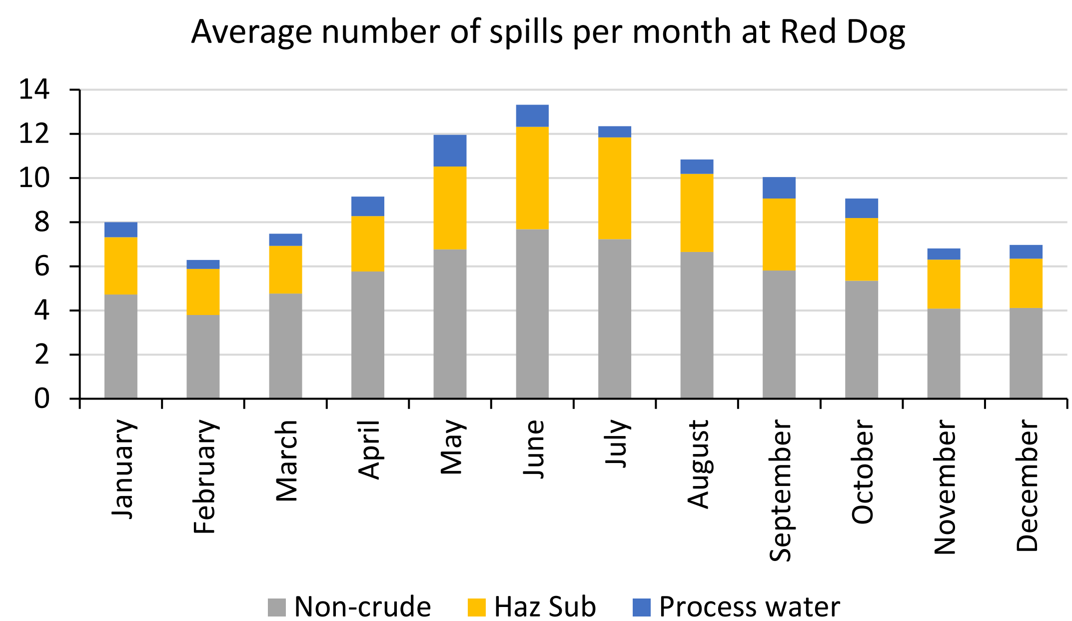
Table 7.27. Total spills per month by substance type at Red Dog from July 1995-December 2020 based on ADEC (2021).

Month	Number of spills per substance category					Total
	Ex Haz Sub	Haz Sub	Non-crude	Process water	Un-known	
January		65	118	17		200
February		52	95	10		157
March		54	119	14	1	188
April	1	63	144	22		230
May	1	94	169	36	1	301
June	1	116	192	25		334
July	1	120	188	13	2	324
August	2	92	173	17		284
September	2	85	151	25		263
October	3	74	139	23	1	240
November	1	58	106	13	1	179
December	1	58	107	16		182
Total	13	931	1,701	231	6	2,882

One of the Teck's goals for 2007 was to reduce the number of leaks and spills from the concentrator by 10% (<21 spills), a goal that was not attained (Teck, undated). Instead, they noted that there were 128 reportable spills in 2005, 130 in 2006, and 150 in 2007, although the number of spills specifically associated with the concentrator were not specified for any of those years. The numbers reported in Teck's 2007 Sustainability Report are slightly higher than the number of incidents I found in ADEC (2021) for those years (121 spills 2005, 129 spills in 2006, and 139 spills in 2007) (Table 7.26). According to Teck, the 2007 spills released 94,605 liters (24,992 gallons) and 9,539 kg (21,029.9 lb) of materials. According to ADEC (2021), in 2007 there were 127 spill incidents reported by volume which released a total of 87,395.25 gallons, and 12 spills reported by weight which released a total of 9,541.75 lbs.



a.



b.

Figure 7.8. Annual (a) and average monthly (b) spill incidents at Red Dog Mine based on ADEC records from July 1995-December 2020 and broken down by substance type. Average monthly spills are based on 25 years for January-June and 26 years for July-December.

The most common causes of the 741 *hazardous substances* spills given in gallons were *equipment failure* (211 spills), *line failure* (100 spills), *leaks* (93 spills), and *human error* (90 spills) (Table 7.28). Of the *non-crude oil* spills, there were 560 due to *equipment failure*, 376 from *line failures*, 221 from *leaks*, and 146 due to *human error*. For the 192 spills given in pounds, the most common causes were *human error* (49 spills), *cargo not secured* (28 spills), *rollover/capsize* (24 spills), and "*other*" (22 spills) (Table 7.29).

Table 7.28. Spills with quantities given in gallons associated with Red Dog Mine by cause sub-type and substance category.

Cause subtype	Extremely Hazardous Substances		Hazardous Substances		Non-crude oil		Process Water	
	n	volume range (gal)	*n*	volume range (gal)	*n*	volume range (gal)	*n*	volume range (gal)
Bilge discharge			1	1				
Cargo not secured	2	0.25-20	13	0.5-250	14	1.5-200	2	100
Collision/allision			6	3-45	7	1-90		
Containment overflow			45	0.25-100,000	8	1-60	17	2-150,000
Corrosion			5	1-200	2	1-10	2	25-250
Crack			12	1.5-22,000	16	1-40	2	2,000-13,000
Equipment failure	4	0.125-175	211	0-158,398	560	0.002-250	52	1-20,000
Erosion			1	2	4	1-15		
External factors			8	1-150	8	2-400	9	2-20,000
Gauge/site glass failure					7	1-20		
Hull failure			1	50	1	10	2	20-50
Human error	2	1-150	90	0.023-2,000	146	0.008-4,075	53	1-21,000
Intentional release							2	25-35
Leak	1	1	93	0.1-1,300	221	0.5-425	20	1-3,000
Line failure			100	0-29,000	376	1-175	25	1-114,000
Overfill	1	2	14	1-3,000	57	1-120	2	15-1,500
Puncture			14	1-300	19	1-49	2	200
Rollover/capsize	1	5	1	35	15	1-2,700		
Seal failure			27	1-1,000	84	1-160	16	1-80,640
Sinking					1	5		
Tank failure					6	2-20		
Valve failure			24	1-36,000	43	1-150	10	1-2,000
Vehicle leak, all			6	1-2	36	1-70		
Other	1	30	44	1-200,000	31	0.5-53	9	5-5,000
Unknown			25	0.5-2,000	38	0.01-700	6	10-3,000
Total spills and volume range (gal)	12	0.125-175	741	0-200,000	1,700	0.002-4,075	231	1-150,000

Table 7.29. Spills with quantities given in pounds associated with Red Dog Mine by cause sub-type and substance category.

Cause subtype	Extremely Hazardous Substances		Hazardous Substances		Non-crude oil	
	n	weight range (lb)	*n*	weight range (lb)	*n*	weight range (lb)
Cargo not secured			28	0.06-2,000		
Collision/allision			4	10-20,000		
Containment overflow			4	25-300		
Corrosion			1	50		
Crack			1	380		
Equipment failure			11	1-6,000		
Erosion			1	0.5		
External factors			7	1-300		
Human error	1	100	47	0.25-76,000	1	500
Intentional release			1	3		
Leak			11	1-1,200		
Line failure			1	10		
Overfill			3	45-500		
Puncture			9	0.3-100		
Rollover/capsize			24	800-250,000		
Seal failure			1	5		
Support structure failure			3	1-49		
Valve failure			2	8-12		
Other			22	1-5,198		
Unknown			9	2-50,000		
Total spills and weight range (lb)	1	100	190	0.06-250,000	1	500

Based on the *facility type*, *source type*, and *cause subtype*, I found there were 481 spills attributable to transportation at Red Dog, including at least 53 spills from *heavy equipment* (Table 7.30). There were 19 specified cause subtypes for transportation spills (Table 7.31). *Collision/allision* and *rollover/capsize* accounted for a combined 58 (12.1%) of the 481 transportation spills (Table 7.31). *Collision/allision* and *rollover/capsize* together represented 2% of the spills attributable to Red Dog Mine. At least 21 different substances were released due to transportation spills (Table 7.32). Of the 481 transportation spills, 29 were listed as being of lead, zinc, zinc concentrate, or zinc slurry. Even with the new truck configuration implemented in 2001, ore concentrate spills are still an issue (Table 7.33). As noted by ADEC DSPR (2021):

> On October 3, 2015 an estimated 144,000 pounds of concentrate spilled on to the tundra and shoulder of the road at a location between the mine and the port from a rollover of one of the trucks hauling concentrate from the mine.

Table 7.30. Transportation related spills from Red Dog Mine from June 1995-December 2020.

Facility type	Source type	Cause subtype	*n*
Maintenance yard	Trailer, other	Valve failure	1
Mining operation	Container, other	Cargo not secured	20
Mining operation	Drill	Rollover/capsize	5
Mining operation	Drum(s)	Cargo not secured	3
Mining operation	Heavy equipment	Cargo not secured	7
Mining operation	Heavy equipment	Collision/allision	6
Mining operation	Heavy equipment	Rollover/capsize	8
Mining operation	Heavy equipment	Vehicle leak, all	32
Mining operation	Hydraulic system	Cargo not secured	1
Mining operation	Hydraulic system	Vehicle leak, all	3
Mining operation	Other	Cargo not secured	5
Mining operation	Other	Rollover/capsize	1
Mining operation	Other	Vehicle leak, all	1
Mining operation	Pipe or line	Cargo not secured	3
Mining operation	Pipe or line	Collision/allision	1
Mining operation	Tank, other, aboveground	Cargo not secured	1
Mining operation	Tank, other, aboveground	Collision/allision	1
Mining operation	Trailer, other	Various	22
Mining operation	Trailer, tanker	Various	13
Mining operation	[Blank]	Bilge discharge	1
Mining operation	[Blank]	Cargo not secured	7
Mining operation	[Blank]	Collision/allision	1
Mining operation	[Blank]	Hull failure	4
Mining operation	[Blank]	Vehicle leak, all	2
Other	[Blank]	Cargo not secured	1
Vehicle	Various	Various	13
Vehicle	[Blank]	Various	315
Vessel	Various	Various	3
Total			481

Table 7.31. Transportation spills from Red Dog Mine from June 1995-December 2020 sorted by cause subtype.

Cause subtype	*n*	Cause subtype	*n*
Bilge discharge	1	Overfill	26
Cargo not secured	57	Puncture	7
Collision/allision	17	Rollover/capsize	41
Containment overflow	4	Seal failure	22
Equipment failure	20	Sinking	1
External factors	1	Tank failure	1
Gauge/site glass failure	2	Valve failure	13
Hull failure	4	Vehicle leak, all	42
Human error	15	Other	12
Leak	77	Unknown	4
Line failure	114		

Table 7.32. Transportation spills from Red Dog Mine from June 1995-2020 sorted by substance type and subtype.

Substance type		max quantity released in a single incident	
Substance subtype	*n* spills	lb	gal
Extremely hazardous			
Sulfuric acid	2		20
Hazardous			
Bases	4	100	
Emulsion breaker	2		15
Ethylene glycol	40		62
Lead	3	60,000	
Methanol	1		25
Mill slurry	1		1
Propylene glycol	3		5
Urea (solid)	1	700	
Zinc	3	36,900	
Zinc concentrate	22	250,000	250
Zinc slurry	1		2.5
Other	55	160,000	500
Total	136		
Non crude			
Aviation fuel	1		1
Diesel	82		4,075
Engine lube oil	50		15
Hydraulic oil	177		90
Transmission oil	17		90
Used oil (all types)	6		10
Other	3		55
	336		
Process water			
Process water	2		100
Produced water	4		5,000
Total	6		
Unknown	1		25

Table 7.33. Transportation spills of zinc (indicated with an asterisk) and zinc concentrate associated with Red Dog Mine from July 1995-December 2020 (ADEC 2021).

Spill date	Spill Name	Quantity released (lbs)	Source type	Cause subtype
12/10/1996	COMINCO 34000 LB ZINC SPILL	34,000	Trailer, Other	Rollover/Capsize
1/2/1997	40000 LB ZINC SPILL	40,000	Trailer, Other	Rollover/Capsize
8/19/1997	35 Ton Zinc Concentrate Truck Rollover	70,000	Trailer, Other	Rollover/Capsize
8/21/1997	10 Ton Zinc Concentrate Truck Rollover	70,000	Trailer, Other	Rollover/Capsize
3/10/1998		200		Cargo Not Secured
7/12/1998		26,500		Rollover/Capsize
11/21/1998		70,000		Rollover/Capsize
12/28/2000		80,000	Trailer, Tanker	Rollover/Capsize
2/16/2001	Red Dog Mine Zinc Concentrate Spill	12,000	Trailer, Other	Rollover/Capsize
7/20/2001	Red Dog Mine Zinc Spill MP 38.3	20,000	Trailer, Other	Collision/Allision
11/13/2001		250	Heavy Equipm't	Cargo Not Secured
12/15/2001		10	Trailer, Other	Unknown
3/20/2003		20,000	Trailer, Other	Human Error
9/21/2005	NANA/Lynden Logistics Truck Rollover	60,000	Trailer, Other	Rollover/Capsize
6/23/2006	Teck Cominco Lead and Zinc Concentrate 6/23/2006	125	Heavy Equipm't	Cargo Not Secured
10/17/2006	Nana-Lynden MP 34 Truck Rollover	1,000	Trailer, Other	Rollover/Capsize
10/18/2006	Red Dog MP 14 Zinc Truck Rollover	2,088	Trailer, Tanker	Rollover/Capsize
3/7/2009	MS 10: Teck NANA Lynden Rollover*	11,023	Heavy Equipm't	Collision/Allision
8/12/2012	Red Dog Mine 250K lbs Zinc Concentrate	250,000	Trailer, Tanker	Rollover/Capsize
1/20/2014	Red Dog Mine Port Road MP3 zinc release	3,000	Trailer, Tanker	Human Error
10/3/2015	Red Dog Port Rd Zn concentrate truck rollover	145,000	Heavy Equipm't	Rollover/Capsize
12/31/2016	Red Dog Mine MP 49 10000lbs Zinc Con.	145,200	Heavy Equipm't	Rollover/Capsize
6/20/2019	Red Dog Mine 36k Lbs Zinc Concentrate*	36,900	Heavy Equipm't	Rollover/Capsize
8/29/2020	Red Dog Zinc Con 10lbs Port Laydown	10	Trailer, Other	Human Error
12/30/2020	Delong Mtn Logistics 3 ton concentrate spill MP 21*	6,000	Trailer, Other	Rollover/Capsize

State and Federal compliance and enforcement

ADEC's Division of Spill Prevention and Response includes an active site report for Red Dog Mine (ADEC DSPR 2021c). Between 2008 and 2014, Red Dog Mine submitted plans for risk management, communications, dust emissions reduction, uncertainty reduction, and monitoring, and an updated Risk Management Plan was to be submitted in 2018 to address the plan modifications requested by ADEC. In addition to fugitive dust releases at Red Dog Mine dating back to 1991, there have been concerns about discrete spills and releases. As noted in Problems/Comments:

> The mine continues to monitor, assess the risks, and clean up past and ongoing spills and releases of ore concentrate. The ore concentrate collected as part of the cleanup is reprocessed at the mine. The mine continues to take steps to reduce the releases of ore concentrate during the transport of it from the mine to barges at the port. Ongoing site work includes cleanup of ore concentrate releases and spills on and along the road and at the port area... Ecological clean up levels have not yet been proposed by the mine or established for this site. Additional ecological studies and sampling is being conducted at this site to aid in assessment of the ecological risks for this site.

EPA's Enforcement and Compliance History Online (ECHO) contains a civil enforcement case report regarding Red Dog Mine (EPA ECHO 1997a). The case summary states:

> The most significant violations at the mine are NPDES Permit effluent violations, mostly heavy metals. The violations are based largely on DMRs. There are about 198 effluent limit violations at the mine. There are also about 611 violations of the CWA for unpermitted discharges from a Tent Camp used by contractors in the Summer. Cominco never requested an NPDES Permit for that site. There are also about 196 unpermitted Winter discharges. Cominco's NPDES Permit only authorizes discharges from May through October to Red Dog Creek. However, EPA program staff may have told the company it could discharge November through April, if it complied with a State-issued Winter discharge Permit. The company has been in almost constant violation of its NPDES Permit at the Port site since it began operations there in 1989. There are about 1186 BOD and TSS effluent violations shown on DMRs. There are also a number of lesser permit violations. The other major violation at the Port Site is diesel fuel spill that occured (*sic*) there in July 1993. This spill was of about 20,000 gallons of diesel fuel onto the tundra. There are also several SPCC violations related to the storage of fuel at the Port site.

The total compliance action cost was $3,540,000 with a total federal penalty of $1,700,000.

The current EPA detailed facility report for Red Dog Mine (EPA ECHO 2021a) shows that there have been high priority and federally reportable violations of the Clean Air Act from April 2019 to the present quarter (July-September 2021) for pollutants such as ammonia, nitrogen oxides, and carbon monoxide, and total particulate matter. Formal enforcement action in the last five years include an assessed penalty of $142,248 in October 2016, and informal enforcement actions include nine Warning Letters between December 2016 and March 2020 and three Notices of Violation between

February 2019 and July 2020. Additionally, there have been Clean Water Act permit schedule violations, effluent violations, management practice violations, and reporting violations. A monthly average cadmium concentration exceeding the discharge limit in 2018 resulted in a Letter of Violation/Warning Letter in October of that year. The compliance period of January-March 2021 showed 21 volatile organic chemicals, including toluene, benzene, and carbon tetrachloride, in violation of the Safe Drinking Water Act standards.

The detailed facility report for the Red Dog Mine port facility in Kivalina (EPA ECHO 2021d) shows high priority violations of the Clean Air Act total particulate matter standards from November 2019 to the present quarter. The port site initially included a 40-bed mancamp, which was increased to a 96-bed mancamp when annual production increased (AIDEA and Arcadis 2017). Warning letters were sent four times between December 2016 and December 2019, with a Notice of Violation sent in June 2020. Safe Drinking Water Act violations resulted in Boil Water Orders being issued by the state nine times between September 2018 and December 2020.

How well did the reported spills in EPA (2009) match ADEC records?

EPA (2009) reported that "Incidents of concentrate truck spills from 1990 to 2007 are summarized in Table 3.15-2", which is reproduced herein as Table 7.10. That summary listed 34 spills of concentrate, totaling to 1,152.35 tons (2,304,700 lbs) of concentrate spilled.

Table 7.34. Transportation spills from July 1995-December 2007 from ADEC (2021) for comparison to Table 7.10.

Year	Number of spills				Total quantity released		
	Ore concentrate (lead, zinc, and zinc concentrate)	Diesel	All other substances	Total	Ore concentrate		Diesel (gallons)
					lbs	tons	
1995	0	3	12	15	0	0	8
1996	1	12	21	34	34,000	17	85
1997	3	4	29	36	180,000	90	171
1998	3	21	76	100	96,700	48.35	102
1999	0	10	57	67	0	0	39
2000	2	10	44	56	140,000	70	247
2001	4	9	47	60	32,260	16.13	67
2002	0	4	6	10	0	0	220
2003	1	0	1	2	20,000	10	0
2004	0	2	5	7	0	0	6,775
2005	1	2	8	11	60,000	30	70
2006	4	2	8	14	3,338	1.67	163
2007	0	1	8	9	0	0	1
Total	19	80	322	421	566,298	283.15	7,948

Table 7.34 is based on the spills I extracted from ADEC (2021) and assigned to transportation (Appendix B5) and does not match Table 7.10 from EPA (2009) in the number of spills or the quantities released. EPA (2009) showed that there were 22 spills of ore concentrate and 705.35 tons of ore concentrate released from 1995-2007 (Table 7.10). My best approximation of transportation spills from 1995-2007 was 19 releases of ore concentrate accounting for 283.15 tons (Table 7.34). The change that truck configuration underwent in 2001 and the resultant decrease in ore concentrate spillage was more evident in Table 7.10 than in Table 7.34. Instead, Table 7.34 shows a more pronounced decrease in the number of diesel spills related to transportation incidents after 2001.

Based on data from ADEC (2021), while there were twice as many transportation spill incidents involving ore concentrate from 1995-2007 as there were from 2008-2020, the amount of ore concentrate spilled was higher from 2008-2020 (Tables 7.34 and 7.35). There was a decrease in transportation spill incidents involving diesel and other substances after 2001 (Tables 7.34 and 7.35).

Table 7.35. Transportation spills from 2008-2020 from ADEC (2021).

Year	Number of spills				Total quantity released		
	Ore concentrate (lead, zinc, and zinc concentrate)	Diesel	All other substances	Total	Ore concentrate		Diesel (gallons)
					lbs	tons	
2008	0	1	2	3	0	0	90
2009	2	0	3	5	11,223	5.61	0
2010	0	0	3	3	0	0	0
2011	0	0	5	5	0	0	0
2012	1	0	2	3	250,000	125	0
2013	0	0	5	5	0	0	0
2014	1	0	5	6	3,000	1.5	0
2015	1	0	3	4	145,000	72.5	0
2016	1	1	1	3	145,200	72.6	1
2017	0	0	1	1	0	0	0
2018	0	0	14	14	0	0	0
2019	1	0	1	2	36,900	18.45	0
2020	2	0	4	6	6,010	3.01	0
Total	9	2	49	60	597,333	298.67	91

While EPA (2009) may have been aiming to show that the safety record on the DMTS had improved since 2001, transportation accident spills are only a small fraction of the spill incidents. There were more spills of ore concentrate and diesel June 1995-December 2007 than reported in EPA (2009). Based on ADEC (2021), there were 54 spills of ore concentrate at Red Dog between 1995-2007. There were five spills of lead, with the largest incident being a 60,000 lb release from a rollover incident on October 9, 2000. There were also seven spills of zinc (up to 3,000 gallons) and 42 releases of zinc concentrate. Finally, there were 242 recorded incidents of diesel spills totaling to 10,972.5 gallons. These specific substances are a small fraction of the 1,604 recorded spill incidents from June 1995-December 2007 recorded for Red Dog (ADEC 2021).

How well were the recorded spills predicted?

If we use Harwood and Russell's (1990) transportation spill rate with the expected number of loads of diesel, ore concentrate, and reagents from EPA (2009) (Table 7.36) from 2008 to 2020, there would be an expected value of 1.8 transportation spills from truck accidents. The only quantitative spill rate in the original or supplemental EIS is for ore concentrate spills along the transportation corridor (EPA 2009). Based on the rate of 0.6 ore concentrate spills per year starting in the year 2001, there would be an estimate of

0.6 spills/year x 13 modeled years from 2008 to 2020 = 7.8 ore concentrate spills

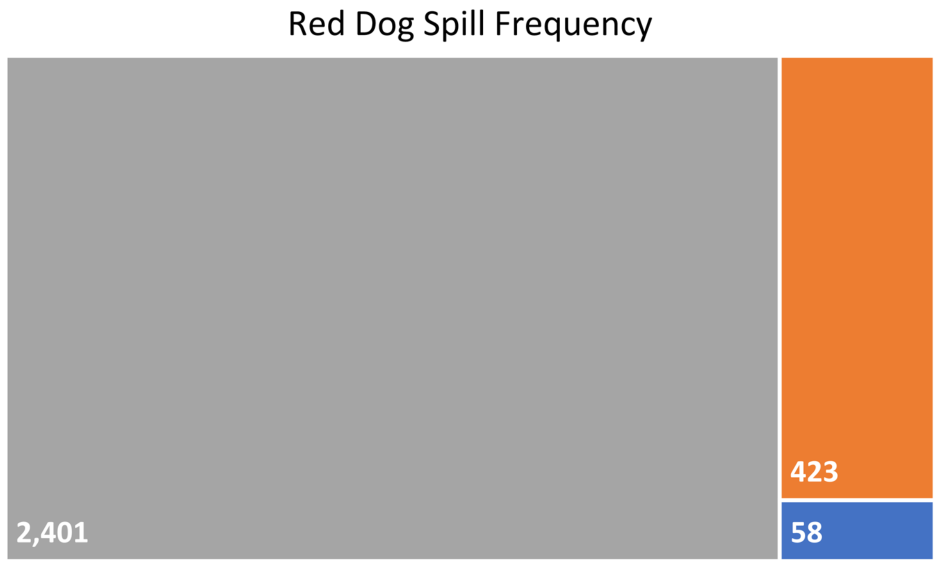
if the estimate of ore concentrate transportation spills rate from EPA (2009) is used.

Sixty of the 481 transportation spills extracted from ADEC (2021) occurred during 2008-2020. Among those, there was a 200 lb spill of lead on March 7, 2009, three spills of zinc totaling to 53,923 lbs, and five spills of zinc concentrate with a cumulative weight of 543,210 lb, for a total of nine ore concentrate spills due to transportation in that time. Two of those nine were due to *human error*, with the remaining seven due to *collision/allision* and *rollover/capsize*. The site-specific ore concentrate spill frequency is more accurate than using Harwood and Russell (1990), but it ignores all substances other than ore concentrates.

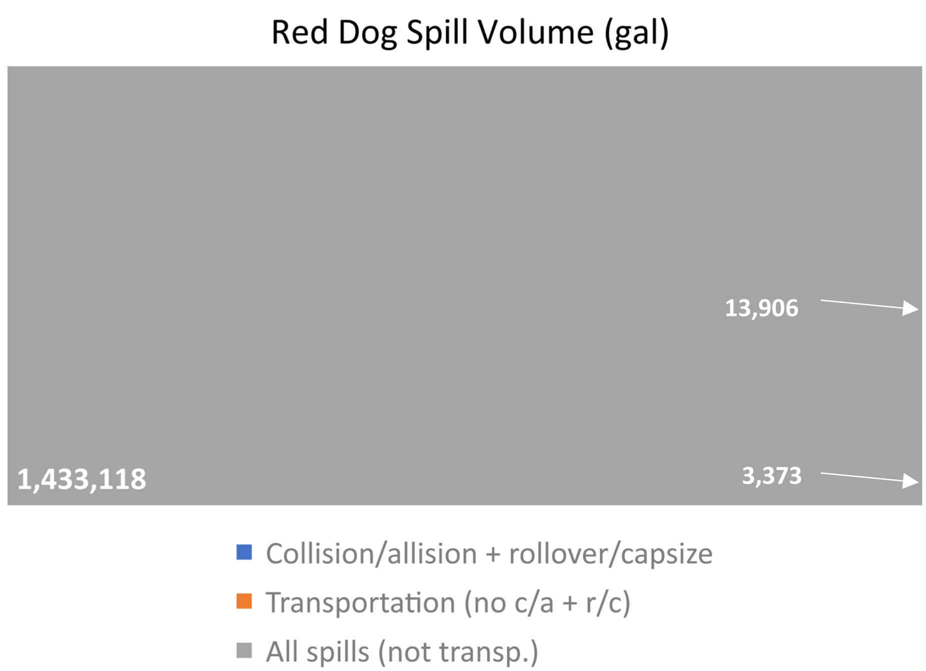
Table 7.36. Predictions for the number of transportation spills for Red Dog Mine from 2008-2020 compared to the observed transportation spills.

Substance (trip frequency)	Spills predicted to occur from 2008-2020 using spill rate from:		Actual spills 2008-2020
	Harwood and Russell (1990)	EPA (2009)	
Ore concentrate (36 trips/day)	1.69	7.8	9 spills of lead, zinc, and zinc concentrate
Fuel (1.7 trips/day)	0.08	not calculated	2 diesel spills; and 32 spills of other non-crude oil products
Reagents (1.2 trips/day)	0.06	not calculated	17 spills of all other hazardous materials
Total (38.9 trips/day)	1.82	>7.8	60

Considering the entire record for Red Dog Mine, from initial production rates to expanded rates and current rates, the $N = RT$ model would have estimated that there would have been 3.2 trucking accident spills expected from 1989-2020. This model was improved in the 2009 EIS (EPA 2009) for ore concentrate trucking accidents, which would have predicted 7.8 ore concentrate spills from 2009-2020 alone. In practice there have been 58 trucking accident (*collision/allision* + *rollover/capsize*) spills associated with Red Dog Mine from 1995-2020. The Harwood and Russell (1990) spill rate used in the $N = RT$ model produces an expected number of spills that is 20 times too small. The trucking accident spills represent only 58 of 481 transportation related spills (12.1%) (Figure 7.9). The total number of transportation spills are themselves only 16.7% of all 2,882 spills recorded at Red Dog Mine from July 1995-December 2020.



a.



b.

Figure 7.9. A comparison of the relative (a) number and (b) cumulative volume of (collision/allision and rollover/capsize spills) compared to the remaining transportation spills and non-transportation spills at Red Dog Mine from 1995-2020.

The permitting process for Red Dog Mine

The permitting process for Red Dog Mine has been described from two different perspectives that were separated by 25 years. The earlier work was an examination of Red Dog Mine as a case study of the metal mine permitting process in Alaska (Cocklan-Vendl and Hemming 1992). The later report is a review of the DMTS as a financial asset (AIDEA and Arcadis 2017). Among the topics discussed are how to establish good will within communities, how to think long term and strategically in the Alaskan legislature and with the regional corporations, how to minimize opposition based on environmental concerns, how environmental baseline data were collected, how the project Alternatives were framed in the EIS process, and how changing environmental regulations may affect this mine and other future mines.

The importance of good community relations was stressed beginning from the exploration phase of the project, because creating the appearance that the developer was environmentally responsible set the stage for future community support of the project and then in the permitting process (Cocklan-Vendl and Hemming 1992). It was noted that Cominco, on the advice of consultants, "proceeded to garner support for their project by 'working from the bottom up' rather than from the top down" (Cocklan-Vendl and Hemming 1992). Current Red Dog Mine strategies include "contributing strategic donations" to Kivalina (Teck undated) and entering into payment in lieu of taxes (PILT) agreements which support local infrastructure, including schools (AIDEA and Arcadis 2017).

Long term planning for Red Dog Mine's permits involved corporate strategies as well as political ones. According to AIDEA and Arcadis (2017):

> The initial go-ahead for Red Dog required significant early coordination and planning. Early-on, NANA and Teck cooperatively established key relationships with the Alaska Legislature, Governor Sheffield's administration, and federal representatives/ stakeholders.

Prior to the publication of the EIS in 1984, Cominco developed an agreement with the landowners "to make the mine project a joint endeavor" in 1981-1982 (Cocklan-Vendl and Hemming 1992). This was part of the patient pursuit of the right set of circumstances for permit approval, a process which "which required several years and two Legislative sessions" (AIDEA and Arcadis 2017).

The project proponents worked to minimize environmental opposition to the mine. One of Cominco's early goals in the exploration phase was to establish a reputation as an environmentally responsible developer to reduce local opposition to the mine, especially fears that it could impact subsistence (Cocklan-Vendl and Hemming 1992). It has been acknowledged that "Operating a mine and road/port come with inherent environmental risks" and that "The mining industry has a generally negative public perception" (AIDEA and Arcadis 2017). The business strategy of consolidating the village corporations in the region "also facilitated early project approvals by minimizing potential non-supportive factions" (AIDEA and Arcadis 2017). Finally, "The remote location of Red Dog and the DMTS limits NIMBY (not in my backyard) influences" (AIDEA and Arcadis 2017).

Unlike the planning for getting community and political support, the collection of baseline data for Red Dog was done over a relatively short period of time of three years, even though there was very little baseline data available prior to starting the EIS process (Cocklan-Vendl and Hemming 1992). Furthermore,

> The initial group stated that their concern was to expend the least amount of effort on baseline data collection until they knew whether the project would actually proceed … The questions in their minds in the early stages were "What can be done to make this mine become a profitable project? What do we need to do to get the basic operating permits? What are the minimum expenditures to accomplish this goal?" The first priority was to secure an approved right-of-way. The Company was unwilling to fund extensive baseline studies until the issue of access was resolved. This did not happen until long after designs were completed. (Cocklan-Vendl and Hemming 1992)

Indeed, "The early project managers were motivated to pare down the issues to the bare minimum" (Cocklan-Vendl and Hemming 1992).

Not only was the baseline evaluation for the EIS done with an eye more on the budget than on the completeness and robustness of the analysis, but the Alternatives presented in the EIS were deliberately chosen to have the worst environmental consequences so that when there were mitigations requested in the permitting process, the company would have a ready answer for the permitting agencies and to show the public that they were complying with environmental policies:

> While the EIS was being prepared, a number of project designs were still evolving.Whenever the Company was unsure about which design alternative to use, they usually chose the worst case scenario with regard to environmental impacts to include in the EIS. As such, subsequent changes in project design generally resulted in lower impacts to the environment. Since the changes made actually reduced potential impacts, agencies usually approved the changes rather than require the Company to re-do their EIS. As such, continued open communications enhanced regulatory and public trust in the Company's operations and facilitated permit approvals despite numerous changes in project design throughout the development phase of the project. (Cocklan-Vendl and Hemming 1992)

As noted, "For a reviewer to assess the effects of a project on the environment, the EIS should include detailed information of the existing environmental conditions of the potentially affected area" (Cocklan-Vendl and Hemming 1992). Such data are necessary for the project proponents, too, as they provide invaluable site-specific information which can affect project siting, design, and engineering (Cocklan-Vendl and Hemming 1992). The EIS prepared for Red Dog did not have adequate detail to avoid some expensive problems and design changes. Red Dog Mine ran into issues with water and air quality very early:

> [D]esign of the mine tailings impoundment did not include a number of critical design issues due to a lack of adequate hydrologic, geologic, and climatologic baseline information, … site-specific precipitation data and runoff considerations associated with mine development in arctic conditions was not adequately addressed….. As a result the mine tailings impoundment filled with water runoff at a much faster rate than expected, thus necessitating the acceleration of impoundment development and engineering design changes. (Cocklan-Vendl and Hemming 1992)

and

> [Cominco] decided to collect only air quality data which they felt was necessary for the [Prevention of Significant Deterioration] PSD permit application. As a result only limited ambient air quality data was collected. Particulate matter (PM-10) data was not collected at all, resulting in little information on naturally occurring particulates and the effect of wind on the distribution of mineral oxides which were common on the undisturbed surface of the mineral deposit prior to mining. As with [Cominco's] other mine development projects, they attempted to keep the layout of the mine facilities compact...No special provisions were made in siting or designing mine facilities to minimize air health risks to mine personnel as these potential risks were not known at the time due to limited baseline data. (Cocklan-Vendl and Hemming 1992)

In fact

> The Company permit coordinator found that most of the problems encountered were the result of the Company changing their mind after the permitting process had begun and not collecting enough baseline data ... By early 1991, the Company had pursued over 12 modifications of the COE permit for the road, and 6 modifications of the mine permit. When a change was made and the permit process was started, the Company would find that the alternative was not feasible and there was insufficient baseline data to indicate that ahead of time. .... The inadequacy of the baseline information, specifically in the areas of water and air quality data, cost the project during construction and operation phases. (Cocklan-Vendl and Hemming 1992)

Moving forward, changing political landscapes and more stringent mine permitting and environmental monitoring requirements are issues for mines in Alaska (Cocklan-Vendl and Hemming 1992, AIDEA and Arcadis 2017), especially as those changes increase costs and the times for issuing permits as compared to third world countries (AIDEA and Arcadis 2017). More specifically to Red Dog, concerns about lead and lead concentrates, their toxicity, transportation, and continued demand could have impacts on the mine (AIDEA and Arcadis 2017). Once the ore body is exhausted, AIDEA and Arcadis (2017) are looking to how the DMTS would be used:

> Port and road infrastructure will be needed to support post-mine closure environmental activities, however without a user, the full DMTS port infrastructure will not be needed (such as the bulk fuel tanks, mancamp, CSBs, and conveyors/shiploader). ...
>
> The DMTS infrastructure can provide support to numerous opportunities into the future. Some of these include:
>
> - *Regional fuel distribution...*
> - *The "Opening of the Arctic"...*
> - *Regional material receipt and staging...*
> - *On-going mining activities.*

but it is also admitted that "The aging port and mine/mill infrastructure will begin to require significant maintenance/repairs" (AIDEA and Arcadis 2017).

Red Dog Mine Summary

Red Dog Mine is an open pit lead and zinc mine, roughly 82 miles north of Kotzebue and 47 miles inland from the coast of the Chukchi Sea (EPA 1984, 2009). Red Dog has a current annual output of 1,000,000 pounds of zinc concentrate. While many of the mine components (mine, mill, tailings pond, housing, and water supply facilities) are on private land owned by the NANA Regional Corporation, the transportation corridor goes through Cape Krusenstern National Monument (EPA 1984, 2009). Red Dog Mine began ore processing 1989 (EPA 2009), followed by an expansion into the Aqqaluk ore deposit. The initial estimates of the ore deposit were that >85 million tons of ore were present (EPA 1984). The expected life of the mine was at least 40 years but is now expected to last until 2031 or longer.

The Delong Mountain Transportation System (DMTS) includes a 30-foot wide gravel industrial haul road that is 52 miles long and port infrastructure. The road has nine bridges for crossing creeks. Pipelines to transport ore slurry, tailings impoundment water, and diesel to or from the port were considered but never built.

The expected initial ore concentrate production amounts were 479,000 tons/yr in the first five years and 754,000 tons/year in years six and later (EPA 1984). Production has since increased to 1.5 million tons of ore concentrate shipped from the port site annually (EPA 2009).

Red Dog uses zinc sulfate, copper sulfate, sodium cyanide, and MIBC, among other reagents. Reagent use increased from an estimated 5,530 tons per year during initial production to 11,731 tons per year in expanded production (EPA 1984) to 15,841 tons per year by 2009 (EPA 2009). In addition, Red Dog consumed an average of 16,710,880 gallons of diesel annually between 2000 and 2006. Approximately 39 one-way truck trips per day were averaged for ore concentrate, fuel and supplies (EPA 2009). The initial EIS left the transportation corridor risks as “undetermined probabilit[ies]” (EPA 1984). The supplemental EIS stated that “Traffic statistics using accident and spill data will be used to assess the effects of changes in transportation among the alternatives” (EPA 2009). The EPA (2009) estimated that 0.6 ore concentrate spills per year could be expected along the road from the mine to the port but did not then calculate the number of expected spills over the remaining life of the project or estimate spill rates for any other hazardous materials.

Based on production levels estimated for initial production (1989-1993), expanded production (1994-2002) and current production (2003-2020), the number of annual trips with hazardous materials (ore concentrate, reagents, diesel, and ammonium nitrate) increased from ~3,700/year, to ~5,600/year, to ~14,000/year. With more than 320,000 truckloads transporting hazardous materials 52 miles, 3.2 spills would have been expected from transportation accidents from 1989-2020 under the $N = RT$ model with Harwood and Russell’s (1990) value for R and the probability of at least one such spill would have been 95.8%.

Based on records from ADEC (2021), *collision/allision* and *rollover/capsize* accounted for a combined 58 (12.1%) of the 481 transportation spills associated with Red Dog Mine from 1995-2020. The most common cause subtypes associated with transportation-related spills at Red Dog were *line failure* (114 spills), *leaks* (77 spills), and *cargo not secured* (57 spills). There were 25 spills of zinc or zinc concentrate from transportation-related incidents between 1995 and 2020, with 7 of those between 2012 and 2020.

Based on records from ADEC (2021), there were 2,882 spills attributable to Red Dog Mine from 1995-2020. There were 192 incidents with quantities in pounds, and the remaining 2,690 spill amounts were in gallons. Transportation spills (including all subcauses) were 16.7% of the total spills, with (*collision/allision* + *rollover/capsize*) spills as 2% of all spills associated with Red Dog. *Non-crude oil* and *hazardous substance* spills accounted for 2,441 out of 2,690 spills listed in gallons, with more than 1,000 spills of hydraulic oil. The *hazardous* and *extremely hazardous substances* spilled included cyanide, sulfuric acid, and glycols, as well as ore concentrates and slurry. While 56% of the spills were less than 10 gallons, the relative infrequency of larger spills was overshadowed by their contribution the overall volume of hazardous materials released. The 10% of the spills that were of 100 gallons or more amassed 98% of the total volume accidentally released. More than 20% of the spills listed by weight were of at least 1,000 pounds; those spills accounted for 99% of the materials released listed by weight. ADEC (2021) shows there were 128 spills of ≥1,000 gallons or pounds associated with Red Dog Mine from 1995-2020.

There were 1,048 hydraulic oil spills totaling to 11,363 gallons at Red Dog Mine. While those spills represent 39% of the number of spills listed by volume, they only account for 0.8% of the 1,450,397 gallons spilled. *Hazardous substances* (719,118 gallons) and *process water* (699,924 gallons) were 49.6% and 48.3% of the total spills given by volume, respectively.

CHAPTER 8
Summary of the case studies

All five of the case study mines had spill reports due to more than just *mining operations* as a facility type (Table 8.1 and Appendix B). *Mining operations* spills were the most common classification for spills associated with the mines, accounting for 89.7% of the incidents. The next most common facility types were *vehicle*, *other,* and *maintenance yard/shop.*

Table 8.1. Percent of spills at each mine listed as "mining operation" spills.

Facility type	Underground			Open pit		Total
Mine	Pogo	Kensing-ton	Greens Creek	Fort Knox/ True North	Red Dog	
[blank]	1	1		1	4	7
Air transportation	1			2	3	6
Bulk fuel terminal				3	1	4
Chemical manufacturing and storage				2		2
Commercial/retail/ office				2		2
Crude oil terminal		1		2		3
Gas station			7	11	2	20
Harbor/port/marina			1		1	2
Maintenance yard/shop	3		2	36	7	48
Military operation	1					1
Mining operation	1,476	278	1,464	1,636	2,462	7,316
Other	8	7	3	40	28	86
Power generation	2	1	2		2	7
Railroad operation				1		1
Refinery operation				1		1
School	1					1
Transmission pipeline				1	13	14
Vehicle	10	18	34	204	328	594
Vessel			2		3	5
Water/wastewater facility		1			7	8
Unknown		1		7	21	29
Total	1,503	308	1,515	1,949	2,882	8,157
Percent of spill records attributable to *Mining operation*	98.2%	90.3%	96.6%	83.9%	85.4%	89.7%

None of the mines had quantitative spill predictions for anything other than transportation spills, and the transportation spill risks calculated were limited to single substances spilled via truck accidents or pipelines. Other forms of transportation spills and composite totals of spill risks were not calculated.

The math for implementing the *N* = *RT* model used as a unifying structure in this report is straightforward, but it cannot work unless the EIS or EA has enough specificity about what hazardous materials will be transported, how much of each, and in what size loads to calculate the number of trips. Table 8.2 shows the results of attempting to model a fuller picture of truck accident spills for each of the five case studies based only on the information in their respective EIS/EAs. Most of those data were incomplete or had to be based on inference in the EISs examined in this report (Table 8.2). Even if the *N* = *RT* model was sophisticated enough to capture the risks of spills due to transportation accidents at large Alaskan mines, the adage "Garbage in, garbage out" applies. Not only were there few details about quantities, load sizes, and trip frequencies, but the lists of hazardous materials were often incomplete, as most mines did not include explicit information about blasting agents, spill mitigation chemicals, water treatment chemicals, and any hazardous waste that would have to be hauled off site in their consideration of transportation spill risks.

The calculated spill probability of at least one trucking accident spill varied from 2.3% for Kensington to 94.4% for Red Dog when all hazardous materials described in the EIS/EAs were included (Table 8.2). Only two of the EISs, Pogo and Kensington, included quantitative spill probabilities. Pogo estimated 1% risk of a diesel spill if diesel were not trucked in for power generation, but the full set of hazardous materials had a 7.2% chance of a spill based on the estimations from the *N* = *RT* model. Kensington's EIS also had an estimate for the probability of a diesel spill, but the <0.4% chance did not capture the full set of hazardous materials, which would have led to an estimate of a 2.3% chance. For both mines, there was a 6 to 7-fold discrepancy between considering just diesel and including all hazardous materials in the trucking accident risk estimates. The supplemental EIS for Red Dog included an annual spill rate estimate for ore concentrate from trucks but did not extend that to either an expected number of spills or a spill probability.

Table 8.2. Summary of transportation spill modeling and data for the five mines based on data available in their EISs or EAs. Some loads/year value are averages over varying annual production levels estimated in early permitting documents and may not reflect current production. Color coding follows table.

Trucking risks	Pogo	Kensington	Greens Creek	Fort Knox/True North	Red Dog
Loads/year					
Explosives					
Ammonium nitrate	60	40		365	30
Diesel	130				95
Diesel		492	300	100	548
Reagents	240	115	5,110	1,235	125
Ore concentrate		1,825	4,015		8,500
Other hazardous materials	300		8,400		
Total annual trips = *t*	730	2,472	17,825	1,700	9,298
Road length (miles) = *l*	50	5	8.5, 7.5	26	52
Years of production = *y*	11	10	28	16	32
Total exposure = *T* = *t* x *l* x *y* miles	401,500	123,600	4,077,710	707,200	15,471,872
Number of expected spills = *N* = *RT* (lifetime)	0.075	0.023	0.76	0.13	2.89
P(≥1 spills) (%)	7.2%	2.3%	53.2%	12.2%	94.4%
Any estimates of spill rate, E(*N*), or *P*(≥1 spill) given in the mine permitting documents	1% (diesel spill risk if no on-site power generation)	<0.4% for spills of 6,500 gal diesel			0.6 ore concentrate spills per year (EPA 2009)

(green)	given explicitly in the permitting document
(yellow)	found by inference or arithmetic
(orange)	calculated based on outside information

I was able to create a more complete picture of the expected transportation accident risks for the mines from the outset of construction and operations through 2020, considering any changes in ore production over time and creating a fuller picture of the years of operation that were not part of the initial EISs (Table 8.3). The probabilities of truck accident spills ranged from 3.4% for Kensington to 95.8% for Red Dog, and reflected a combination of years of operation, number of truck trips, and transportation corridor length. Kensington and Pogo have been in operation for nearly the same amount of time, but Pogo was expected to have roughly three times as many spills. This difference is because while Pogo's transportation corridor is 10 times longer, Kensington had approximately three times as many loads of hazardous substances because Kensington transports ore concentrate from the mill to the port.

The number of expected truck accident spills depends on many factors, including road length, number of annual trips, and number of years materials are transported. Although Red Dog and Pogo have similar road lengths, the number of annual trips at Red Dog is more than an order of magnitude higher and it has been in production for longer (Tables 8.2 and 8.3). Those two factors mean that Red Dog was predicted to have ~30 times as many truck accident spills as Pogo based on the $N = RT$ model. In practice, Pogo had 11 truck accident spills between 2006-2020 and Red Dog had 58 from 1989-2020. Both mines had more truck accident spills than were predicted. True North had the second most truck accident spills (31 from 1994-2020) with a transportation corridor half the length of Pogo's or Red Dog's. Greens Creek and Pogo had nearly the same number of truck accidents (10 and 11, respectively) even though Pogo has a 50-mile road and Greens Creeks has road lengths of 7.5 and 8.5 miles (depending on what's being transported). In short, while road length alone is not enough to predict the number of spills, it is literally a factor in the equation for determining how many spills are expected.

In practice, the number of truck accidents observed exceeded the predicted number from the $N = RT$ model for all five mines, and the predictions were often orders of magnitude too low (Fifure 8.1, Table 8.3). Considering the expected number of miles traveled for all five mines through 2020, the $N = RT$ model would have predicted that there would have been four or five truck accidents. Based on the records from ADEC (2021) there were 114 *collision/allision* and *rollover/capsize* accidents, which is 26.5 times as many as would have been predicted. These 114 accidents spilled nearly 6,000 gallons and 1,660,000 pounds of hazardous materials. The truck accident spills only represent 11.4% of all 1,004 transportation-related releases from the five mines considered.

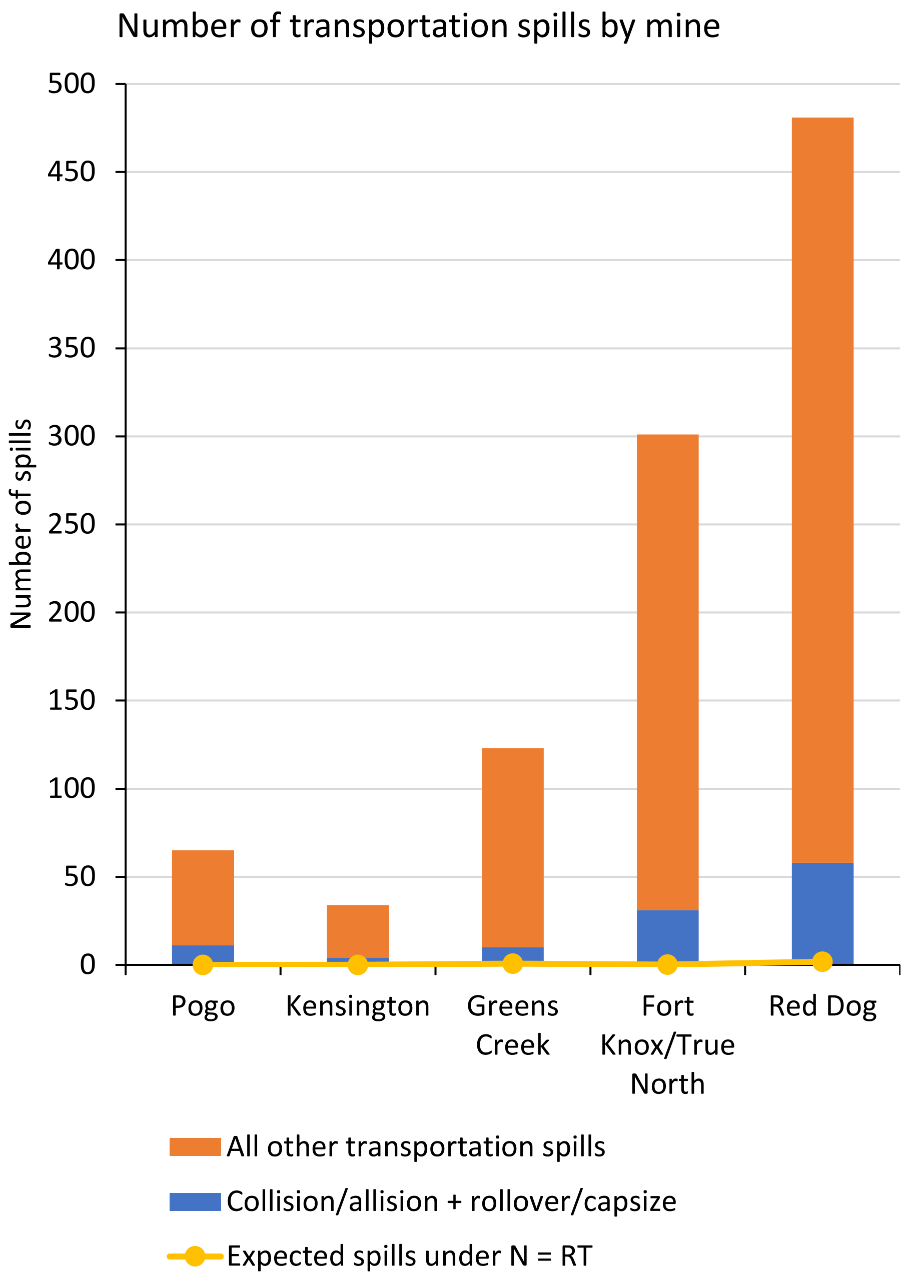


Figure 8.1. Expected and actual spills from accidents and all other transportation spills for the five mines through 2020. The dotted yellow line is used to predict the spills shown in blue and the expected number of spills from the N = RT model are shown in Table 8.4.

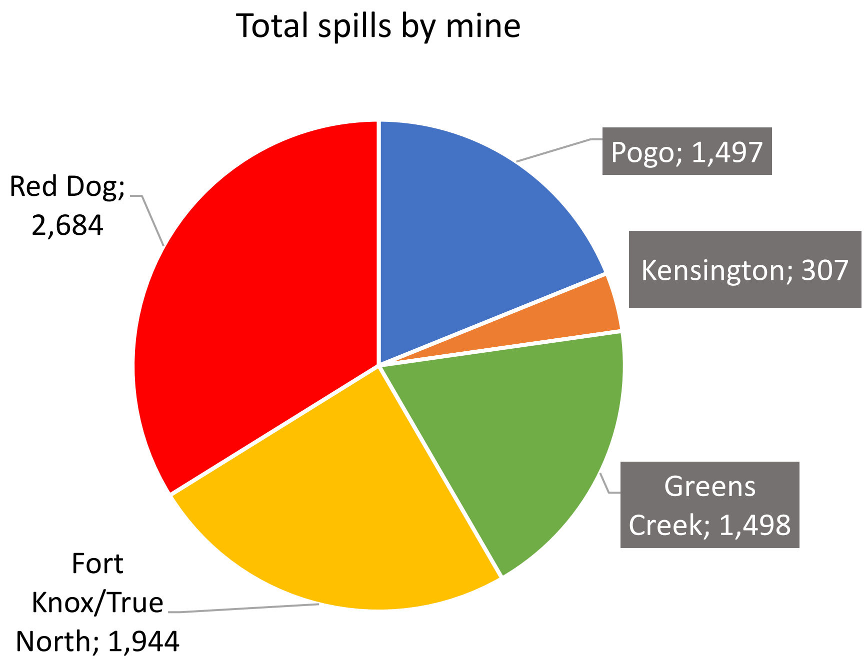
Table 8.3. Comparison of the factors determining transportation accident spill risk predictions using N = RT for the five mines and the observed spill record for transportation-associated spills.

Mine	Pogo	Kensing-ton	Greens Creek	Fort Knox/ True North	Red Dog	Total
Mine type	Underground			Open pit		
Product	dore/bars	ore con-centrate	ore con-centrate	dore/bars	ore con-centrate	
Years in operation	2006-2020	2005-2020	1989-2020	1994-2020	1989-2020	
Road length (mi)	50	5	8.5, 7.5	26	52	
Ore production (tpd)	2,500-3,500	2,000	800-2,300	36,000	3,000-10,000	
Expected number of spills *N* = *RT* with Harwood and Russell (1990) estimate of *R* through 2020						
	0.10	0.035	0.76	0.21	3.2	4.3
Probability of at least one spill based on *N* = *RT* expected number (Poisson model) (%)						
	9.7%	3.4%	53.2%	18.9%	95.8%	98.6%
(Collision/allision + rollover/capsize) spills through 2020 (volume in gal; weight in lbs)						
Number	11	4	10	31	58	114
Cumulative volume	952	332.5	89	1,177	3,373	5,924
Cumulative weight	0	0	0	0	1,658,481	1,658,481
Transportation spills (all causes) through 2020 (volume in gal; weight in lbs)						
Number	65	34	123	301	481	1,004
Cumulative volume	1,603	495	2,396	11,631	17,279	33,404
Cumulative weight	0.5	2	0	10	1,771,064	1,771,077
(Collision/allision + rollover/capsize) spills as a percentage of all transportation spills						
Number	16.92%	11.76%	8.13%	10.30%	12.06%	11.35%
Cumulative volume	59.39%	67.17%	3.71%	10.12%	19.52%	17.73%
Cumulative weight	0.00%	0.00%	-	0.00%	93.64%	93.64%

While truck accident and pipeline spills are the only spills with quantitative representation in any of the EIS/EAs examined, they are only a small portion all the transportation spills or of the overall number of spills. The five mines considered here had more than 8,150 spill incidents, releasing >2,360,000 gallons and >1,930,000 pounds of *hazardous substances* since July 1995 (Table 8.4, Figure 8.2). Fort Knox/True North and Red Dog mines accounted for both the highest numbers of spill incidents and the largest spill quantities by volume. If overall spill were risk were directly proportional to ore production, Fort Knox/True North, which produces 36,000 tons of ore per day, would be expected to have more spills than Red Dog, which has a 10,000 tons of ore per day production rate. In a very general sense, the underground mines (Pogo, Kensington, and Greens Creek) seem to have fewer and smaller spills than the open pit mines (Fort Knox/True North and Red Dog), but several other factors (operating lifetime, scale of production, exported product) could also be at play in those differences.

Table 8.4. Total spills, and transportation spills, and transportation accident spills by number, cumulative volume, and cumulative weight as percentages of the total spills for the five mines.

Mine	Pogo	Kensing-ton	Greens Creek	Fort Knox/ True North	Red Dog	Total
Observed number of spills, all sources through 2020						
Number	1,503	308	1,515	1,949	2,882	8,157
Cumulative volume	267,710	6,272	111,333	527,533	1,450,397	2,363,245
Cumulative weight	29.5	4	13,899	5,024	1,919,563	1,938,520
Transportation spills (all causes) through 2020 as a percentage of all spills						
Number	4.32%	11.04%	8.12%	15.44%	16.69%	12.31%
Cumulative volume	0.60%	7.89%	2.15%	2.20%	1.19%	1.41%
Cumulative weight	1.69%	50.00%	0.00%	0.20%	92.26%	91.36%
(Collision/allision + rollover/capsize) spills through 2020 as a percentage of all spills						
Number	0.73%	1.30%	0.66%	1.59%	2.01%	1.40%
Cumulative volume	0.36%	5.30%	0.08%	0.22%	0.23%	0.25%
Cumulative weight	0.00%	0.00%	0.00%	0.00%	86.40%	85.55%



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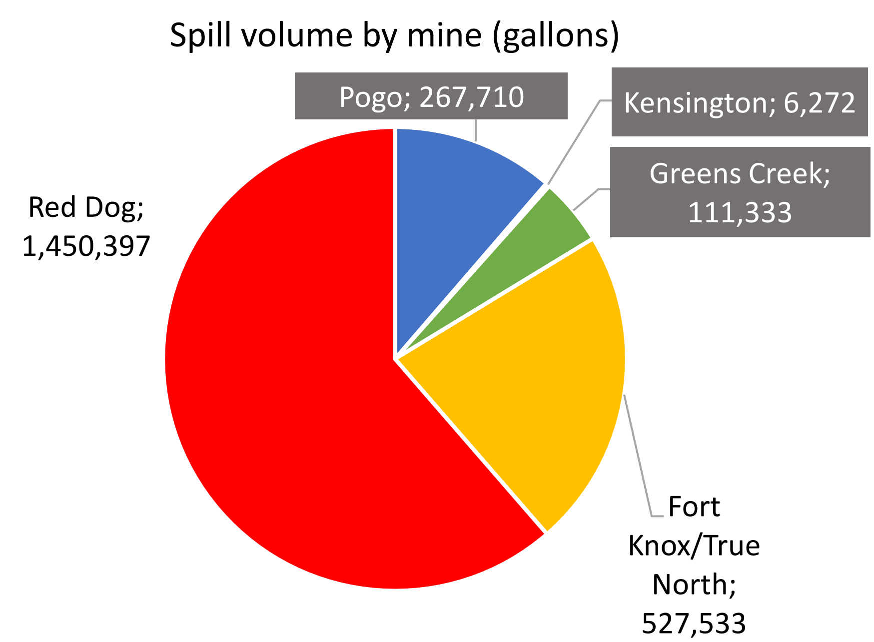

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Figure 8.2. Relative proportions of total spills and cumulative volume for the five mines. Mine names in dark boxes indicate underground mines rather than open pit mines.

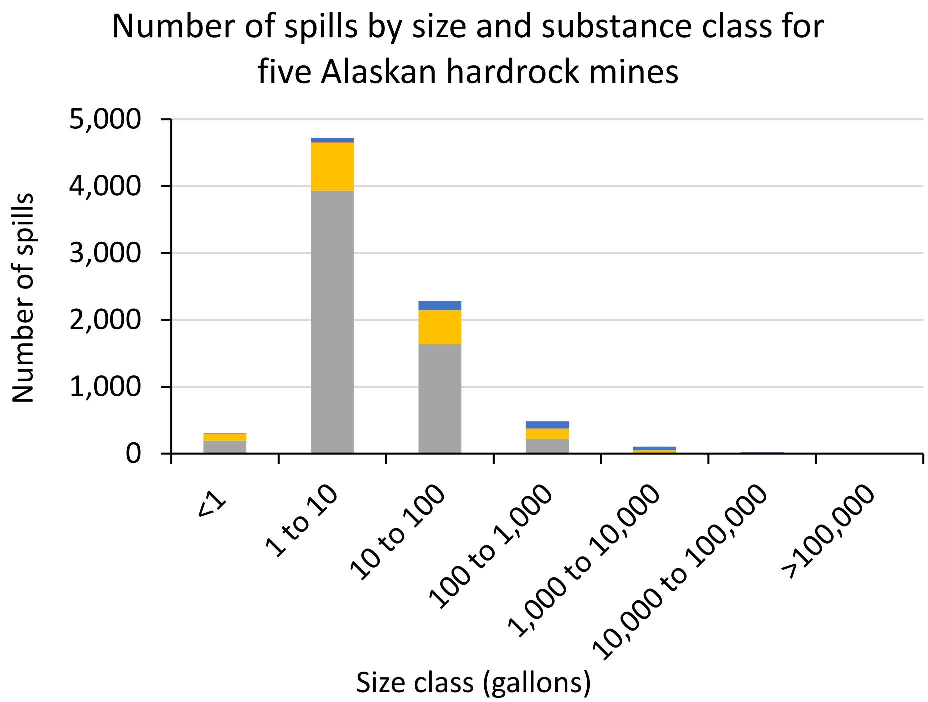
Seventy-five percent of the spill incidents at all five large mines involved *non-crude oil*, but *non-crude oil* spills only accounted for 5.2% of the volume spilled (Tables 8.5, 8.6, and 8.7, Figures 8.3 and 8.4). Most of the spill volume was from releases of *hazardous substances* and *process water*, which together represented 94.7% of the volume released, even if they were only 24% of the incidents (Table 8.5 and 8.6, Figure 8.3). More than 92% of the spills were in quantities <100 gallons and had total volume of almost 75,000 gallons; the remaining 7.8% of the incidents released 2,288,361 gallons (Table 8.5 and 8.6, Figure 8.3).

Table 8.5. Combined counts of spills with quantities given in gallons from July 1995-December 2020 by substance class and size category from the five hardrock mines in the case studies (ADEC 2021).

Size class (gallons)	Substance type				Total	Percent
	Non-crude	Extremely Hazardous	Hazardous	Process water		
<1	193	6	100	3	302	3.8%
1 to <10	3,933	13	714	64	4,724	59.6%
10 to <100	1,634	5	510	135	2,284	28.8%
100 to <1,000	217	9	151	105	482	6.1%
1,000 to <10,000	10	0	44	52	106	1.3%
10,000 to <100,000	0	0	11	13	24	0.3%
≥100,000	0	0	4	4	8	0.1%
Total	5,987	33	1,534	376	7,930	100.0%
Percent	75.5%	0.4%	19.3%	4.7%	100.0%	

Table 8.6. Total volume of spills with quantities given in gallons from July 1995-December 2020 by substance class and size category from the five hardrock mines in the case studies (ADEC 2021).

Size class (gallons)	Substance Type				Total	Percent
	Non-crude	Extremely Hazardous	Hazardous	Process water		
<1	51.2	1.7	30.4	1.5	84.8	0.0%
1 to <10	13,010	39	2,277.3	213	15,539.3	0.7%
10 to <100	41,678.5	90	13,272	4,221	59,261.5	2.5%
100 to <1,000	50,078	2,168	37,497	30,284	120,027	5.1%
1,000 to <10,000	17,375	0	106,409	117,950	241,734	10.2%
10,000 to <100,000	0	0	224,000	425,832	649,832	27.5%
≥100,000	0	0	593,398	683,370	1,276,768	54.0%
Total	122,191.7	2,298.3	976,883	1,261,871	2,363,244	100.0%
Percent	5.2%	0.1%	41.3%	53.4%	100.0%	



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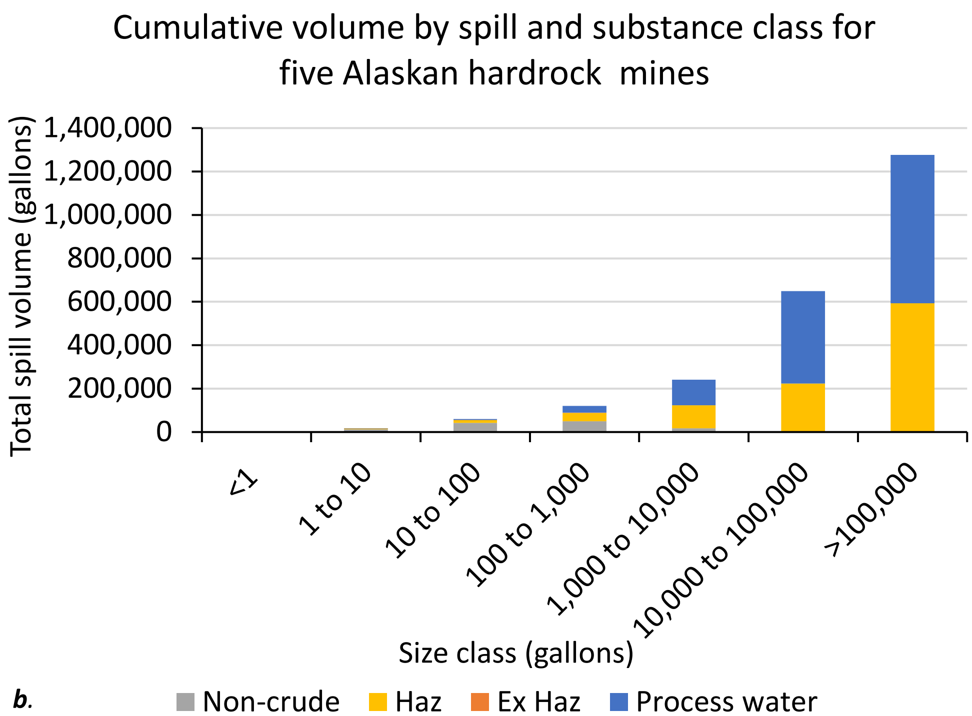

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Figure 8.3. Number of spill incidents (a) and cumulative gallons spilled (b) for non-crude oil, hazardous substances, extremely hazardous substances, and process water in different spill size classes for five Alaska hardrock mines from July 1995-December 2020 based on ADEC (2021).

While diesel was the substance used in modeling spill risks, diesel spills only represented 15.8% of *non-crude oil* spill incidents and 11.9% of all spill incidents given by volume in ADEC (2021) (Table 8.7, Figure 8.4). Spills of *hazardous* and *extremely hazardous substances* accounted for 19.8% of spill incidents, 41.4% of the volume released (Tables 8.5 and 8.6), and nearly all of the weight spilled.

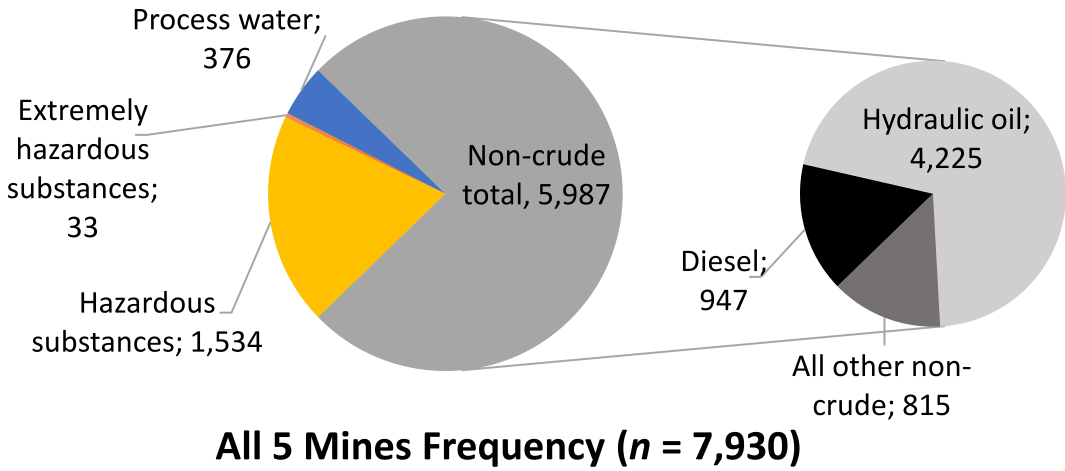
Table 8.7. Comparison of the relative number of spills and quantities released by substance class for the five mines.

Mine	Pogo	Kensing-ton	Greens Creek	Fort Knox/ True North	Red Dog	Total
Number of spills given by volume						
Diesel	80	72	206	249	340	947
Hydraulic oil	1,122	170	1,039	846	1,048	4,225
Other non-crude	89	36	153	225	312	815
Non-crude total	1,291	278	1,398	1,320	1,700	5,987
Hazardous substances	143	27	90	533	741	1,534
Extr. Haz. substances	5	1	2	13	12	33
Process water	58	1	8	78	231	376
Total	1,497	307	1,498	1,944	2,684	7,930
Cumulative volume of spills (gallons)						
Diesel	4,174	2,218	8,020	8,891	15,929	39,232
Hydraulic oil	4,066	1,609	7,196	42,443	11,363	66,677
Other non-crude	391	524	3,879	7,813	3,677	16,284
Non-crude total	8,631	4,351	19,095	59,147	30,969	122,193
Hazardous substances	240,136	921	2,038	14,670	719,118	976,883
Extr. Haz. substances	27	200	650	1,035	386	2,298
Process water	18,916	800	89,550	452,681	699,924	1,261,871
Total	267,710	6,272	111,333	527,533	1,450,397	2,363,245
Spills given by weight (pounds)						
Number	4	1	16	5	192	218
Cumulative weight	29.5	4	13,899	5,024	1,919,563	1,938,520

A closer examination of the *non-crude oil* spills shows that hydraulic oil accounted for 61.2 to 86.96% of the spill incidents at the mines, averaging 70.6% (Table 8.8, Figure 8.4). While hydraulic oil spills cumulatively released nearly 67,000 gallons, this is only 2.8% of the volume spilled associate with these five mines.

Table 8.8. Comparison of the relative number of spills and quantities released of hydraulic oil in relation to other non-crude oil spills at the five mines.

Mine	Pogo	Kensing-ton	Greens Creek	Fort Knox/ True North	Red Dog	Total
Hydraulic oil as a percentage of non-crude oil spills						
Number of spills	86.9%	61.2%	74.3%	64.1%	61.6%	70.6%
Spill volume	47.1%	37.0%	37.7%	71.8%	36.7%	54.6%
Hydraulic oil as a percentage of all spills given by volume						
Number of spills	74.9%	55.4%	69.4%	43.5%	39.0%	53.3%
Spill volume	1.5%	25.7%	6.5%	8.0%	0.8%	2.8%



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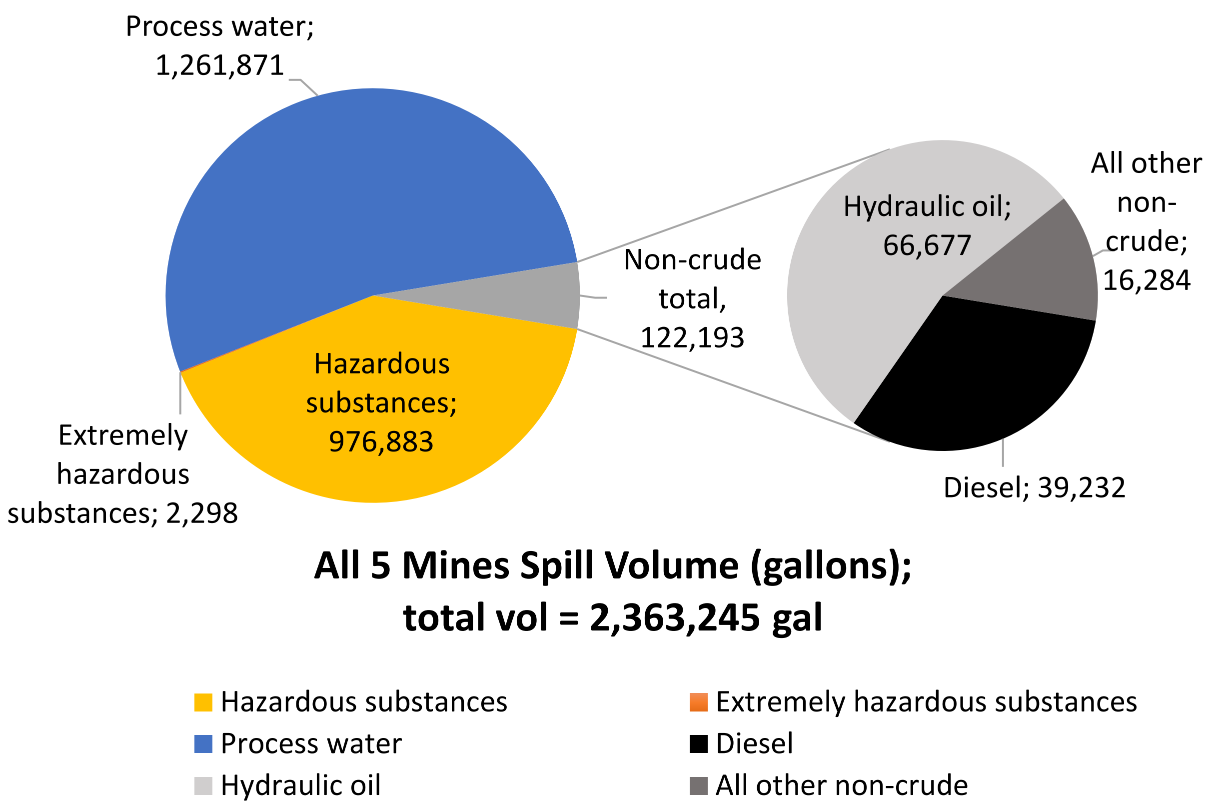

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Figure 8.4. Relative proportions of substance classes with further detail about hydraulic oil and diesel as components of non-crude oil spills by frequency and volume for the aggregated spills from the five mines.

At least 49 different hazardous substances were spilled at the five mines studied in this report (Table 8.9). That number is an undercount due to spills of "other" or "unknown" substances that were not otherwise specified. All five of the mines had recorded spills of more substances than were discussed in their EIS/EAs. Relatively few of the listed substances had recorded spills, but sodium cyanide, sulfuric acid, hydrochloric acid, copper sulfate, ore concentrate, diesel, and gasoline were all mentioned in EIS/EAs and had recorded spill instances. Most (between 80 and 88%) of the substances spilled were not discussed in the EIS/EAs. (The spill frequencies and quantities of the listed and unlisted substances should also be considered.) All five mines at least mentioned the possibilities of tailings spills, which are listed as *process water* in Table 8.9 and occurred at all five mines in the case studies. Although ≥49 materials were spilled, quantitative modeling was only attempted for diesel, ore concentrate, and mill slurry.

Many of the unlisted spill substances are *non-crude oil* (hydraulic oil, transmission oil, used oil, etc.), as well as antifreezes such as ethylene glycol, propylene glycol, and other glycols. While these chemicals were not listed among the reagents associated with milling, they are essential to running the heavy equipment at the mines and are used in sufficient quantities to result in more than 5,100 spills and nearly 85,000 gallons released (Table 8.10).

Another unlisted substance that is regularly spilled at least three of the mines considered in this report is sewage/wastewater. These spills were reported for Pogo, Kensington, and Greens Creek Mines; Red Dog has also had violations of the Safe Drinking Water Act resulting in Boil Water Orders. These spills are not tracked in ADEC (2021), but records are available through detailed facility reports showing enforcement and compliance and civil enforcement case reports on EPA's Environmental Compliance History Online (ECHO) website.

Table 8.9. Hazardous materials used or produced at the five case study mines that are mentioned in the EIS/EAs. L = listed among hazardous materials in the EIS/EAs; S = substance spilled; M in a shaded cell = substance had modeled spill risk in an EIS.

Reagents and hazardous materials listed	Pogo	Kensington	Greens Creek	Fort Knox/ True North	Red Dog
Extremely hazardous substances					
Anhydrous ammonia					S
Chlordane				S	
Formaldehyde				S	
Hydrochloric acid		S	S	L, S	
Hydrogen cyanide	S			S	
Hydrogen peroxide			S		
Nitric acid	L				
Phosphoric acid, dimethyl 4- (methylthio)				S	
Sodium cyanide	L, S		L	L, S	L, S
Sulfur dioxide				L	
Sulfuric acid	L, S		L	S	L, S
Hazardous substances					
Acid, other	S			S	S
Activated carbon	L			L	
Aero Promoter 208	L				
Ammonium bisulfite				L	
Antiscalant					L
Bases					S
Caustic alkali liquids		S		S	S
Copper sulfate	L		L, S	L	L
Corrosion inhibitor			S		S
Dextrin					L
Emulsion breaker				S	S
Ethyl alcohol				S	S
Ethylene glycol	S	S	S	S	S
Explosives (ammonium nitrate)	L			L	S
Ferric chloride	S	S			
Flocculant	L	L		L	L
Flotation scale inhibitor		L			

Table 8.9. (Continued.)

Reagents and hazardous materials listed	Pogo	Kensington	Greens Creek	Fort Knox/ True North	Red Dog
Hazardous substances (continued)					
Glycol, other	S	S	S	S	S
Lead				S	S
Lead nitrate				L	
Lime	L	L	L	L	L
Magnafloc					L, S
Magnesium oxide slurry					S
Methyl alcohol				S	S
MIBC	L	L	L		L
Mill slurry	S	M		S	S
Ore concentrate		L	L		L, S, M
Permanganate		S			
Perol 351			L		
Polymer		L			
Potassium amyl xanthate	L	L			
Potassium ethyl xanthate					L
Potassium hydroxide		S			
Propylene glycol	S			S	S
SIPX			L		L
Sodium cetylsulfonate					L
Sodium hydroxide	L		L	L	
Sodium hypochlorite		S		S	S
Sodium isobutyl xanthate					L
Sodium metabisulfite	L				L
Sodium sulfide					L
Solvent				S	S
Surfactant		L			
Tetrachloroethene				S	
Urea (solid)		S			
Zinc					S
Zinc slurry	S				
Zinc sulphate					L

Table 8.9. (Continued.)

Reagents and hazardous materials listed	Pogo	Kensington	Greens Creek	Fort Knox/ True North	Red Dog
Non-crude oil					
Aviation fuel			S	S	S
Creosote			S		
Diesel	L, S, M	L, S, M	L, S	L, S	L, S
Engine lube oil		S	S	S	S
Engine lubricant	S				
Gasoline	S		S	L, S	S
Grease	S		S	S	S
Heating oil				L	
Hydraulic oil	S	S	S	S	S
Kerosene		S	S		
Propane	L				
Synthetic oil			S	S	S
Transformer oil		S			S
Transmission oil	S	S	S	S	S
Used oil	S		S	S	S
Process water					
Process water	L, S	L, S	L, S	L, S	L, S
Produced water	S				S
Source water	S		S	S	S
Number of listed substances	15	9	10	14	18
Number of substances spilled	20	16	19	31	34
Number of listed substances spilled	4	2	3	5	5
Number of unlisted substances spilled	16	14	16	26	29
Percent of spilled substances not discussed in the EIS/EAs	80.0%	87.5%	84.2%	83.9%	85.3%

Table 8.10. Number and volume of spills of selected hazardous materials that were not discussed in the mine permitting documents.

Substance	Pogo	Kensington	Greens Creek	Fort Knox/ True North	Red Dog	Total
Hydraulic oil						
number of spills	1,122	170	1,039	846	1,048	4,225
total volume (gal)	4,066	1,609	7,196	42,443	11,363	66,677
Ethylene glycol						
number of spills	51	14	43	439	223	770
total volume (gal)	246	37	1,165	7,175	1,560	10,183
Propylene glycol						
number of spills	4			17	35	56
total volume (gal)	41			609	6,497	7,147
Other glycols						
number of spills	12	1	37	21	8	79
total volume (gal)	70	15	492	210	109	896

Summary

Mining operations spills were the most common classification for spills associated with the mines, accounting for 89.7% of the incidents at the five mines in the case studies.

None of the mines had quantitative spill predictions for anything other than transportation spills, and the transportation spill risks calculated were limited to single substances spilled via truck accidents or pipelines. The math for implementing the $N = RT$ model is straightforward, but it cannot work unless the EIS or EA has enough specificity about what hazardous materials will be transported, how much of each, and in what size loads to calculate the number of trips. Most of those data were incomplete or had to be based on inference in the EISs examined in this report.

Based on the expected number of spills from the $N = RT$ model and using a Poisson distribution to estimate the probability of at least one truck accident spill from the beginning of the projects through 2020, the probabilities of truck accident spills ranged from 3.4% for Kensington to 95.8% for Red Dog. Considering the expected number of miles traveled for all five mines through 2020, the $N = RT$ model would have predicted that there would have been 4.3 trucks accident spills. Based on the records from ADEC (2021) there were 114 *collision/allision* and *rollover/capsize* accidents, which is 26.5 times as many as would have been predicted. These 114 accidents spilled nearly 6,000 gallons and 1,660,000 pounds of hazardous materials. The truck accident spills only represent 11.4% of all 1,004 transportation-related releases from the five mines considered.

While truck accident and pipeline spills are the only spills with quantitative representation in any of the EIS/EAs examined, they are only a small portion all the transportation spills or of the overall number of spills. The five mines considered here had more than 8,150 spill incidents, releasing >2,360,000 gallons and >1,930,000 pounds of hazardous substance since July 1995.

CHAPTER 9
Other *mining operations* spills in Alaska

There are many other mines in Alaska in addition to the five considered in detail in these case studies. To get a sense of proportion for the five large active mines as compared to the other mining operations in Alaska, I searched for *mining operations* spills for all 10 subareas from 1995-2020, looking at the number of responsible parties and spill incidents (Table 9.1) (Appendix C). This search is only an approximation of the full number of mining entities and incidents. Mines may progress through multiple owners and many contractors may play roles at each site. Further, ADEC (2021) often has single companies that are listed in the *responsible party* field with many variations of their names. Also, as seen in the case studies, *mining operations* captured ~90% of the spill incidents related to the five large mines of interest, and the *mining operations* spills may miss some spills that were more indirectly related to mines.

Table 9.1. Number of mining operation responsible parties and spill counts by subarea.

Subarea	Responsible parties (approxi-mate)	Mining operation spills	Mining operation spills from the mines of interest	*Mining operation* spills from other responsible parties
Aleutian Islands	1	2	0	2
Bristol Bay	4	28	0	28
Cook Inlet	19	25	0	25
Interior Alaska	46+	3,799	1,636 (Fort Knox) + 1,476 (Pogo) 3,112	687
Kodiak Island	2	3	0	3
North Slope	7	20	0	20
Northwest Arctic	35+	2,556	2,462 (Red Dog)	94
Prince William Sound	5	12	0	12
Southeast Alaska	24+	1,765	1,464 (Greens Creek) + 278 (Kensington) 1,742	23
Western Alaska	18	131	0	131
Total	161+	8,341	7,316	1,025

Mining operation spills are most frequent in the three subareas where the five large mines are sited, and the five large mines are responsible for 87.7% of all the *mining operations* spills in ADEC (2021) (Table 9.1). Four of the five mines considered in detail each had more spills than the combined 1,025 spill incidents from all the other Alaskan mines. I found six mines or entities that each had at least 20 spills incidents among the other Alaskan mines (Table 9.2). Usibelli Coal Mine was responsible for more than half of the mining operations spills not caused by the five largest hard rock mines.

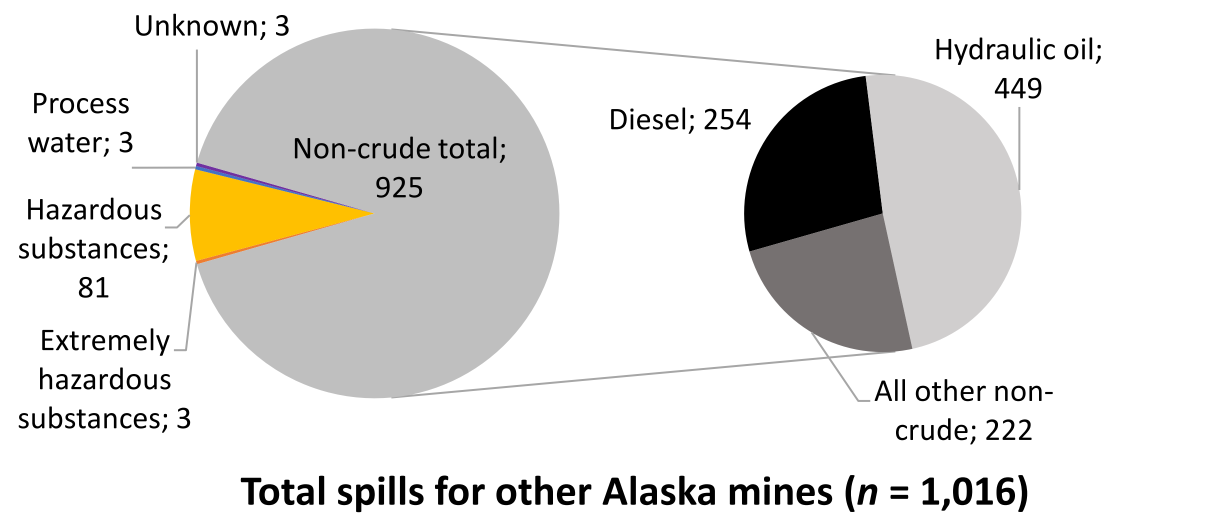
Table 9.2. There were six major contributors (at least 20 spill incidents) to the mining operations spills in ADEC (2021) other than the five case study mines:

Responsible party	Subarea	Number of incidents (est.)
Barrick/Donlin Creek	Western Alaska	82
Northern Dynasty/Pebble Mine	Bristol Bay	25
Nova Copper and Nova Gold	Northwest Arctic	21
Talon Gold	Interior	59
Tower Hill Mines	Interior	53
Usibelli Coal Mine	Interior	515

Most of the spill incidents were described by the volume released (Table 9.3), but there were also nine spills listed in pounds. Nearly 60,000 gallons of *non-crude oil*, *hazardous materials*, *extremely hazardous materials*, and *process water* were spilled, as well as three spills of *unknown* substances. *Non-crude oil* spills, often of diesel or hydraulic oil, made up the bulk of the spill incidents and spill volume (Figure 9.1, Tables 9.4 and 9.5). The largest single incident was classified as a *non-crude oil: other* spill that was from drums of tar that corroded, releasing 27,500 gallons of tar at a NovaGold Resources site in Nome in June 2000. Most of the *hazardous substances* spill instances were of glycols (ethylene, propylene, and other).

Table 9.3. Spills associated with mining operations from other mines in Alaska by substance, number of spills, volume range, and total volume.

	n	Volume (gallons)	
		Range	Total
Extremely hazardous substances			
Hydrochloric Acid	1	0	0
Sodium Cyanide (Solution)	1	0.1	0.1
Sulfuric Acid	1	0.063	0.063
Total	3		0.163
Hazardous substances			
Acid, Other	2	1-2	3
Drilling Muds	3	20-126	189
Ethylene Glycol (Antifreeze)	56	0-60	597.5
Glycol, Other	5	2-50	122
Propylene Glycol	8	0.13-55	90.01
Other	7	2-710	748
Total	81		1,749.51
Non-crude oil			
Aviation Fuel	19	0.264-53	223.26
Bunker	2	1-10	11
Diesel	254	0-1,070	10,701.455
Engine lube oil	91	0-150	987.351
Engine Lube/Gear Oil	1	3	3
Gasoline	12	0-75	100.264
Grease	5	1-90	96
Hydraulic oil	449	0-500	13,356.75
Synthetic Oil	2	7-17	24
Transformer Oil	1	3	3
Transmission Oil	47	0.5-225	818
Turbine Fuel	2	2-20	22
Used Oil (all types)	31	0.25-700	1,326.25
Other	9	2-27,500	27,690
Total	925		55,362.3
Process water	3	1-1,500	2,601
Unknown	3	0-5	7



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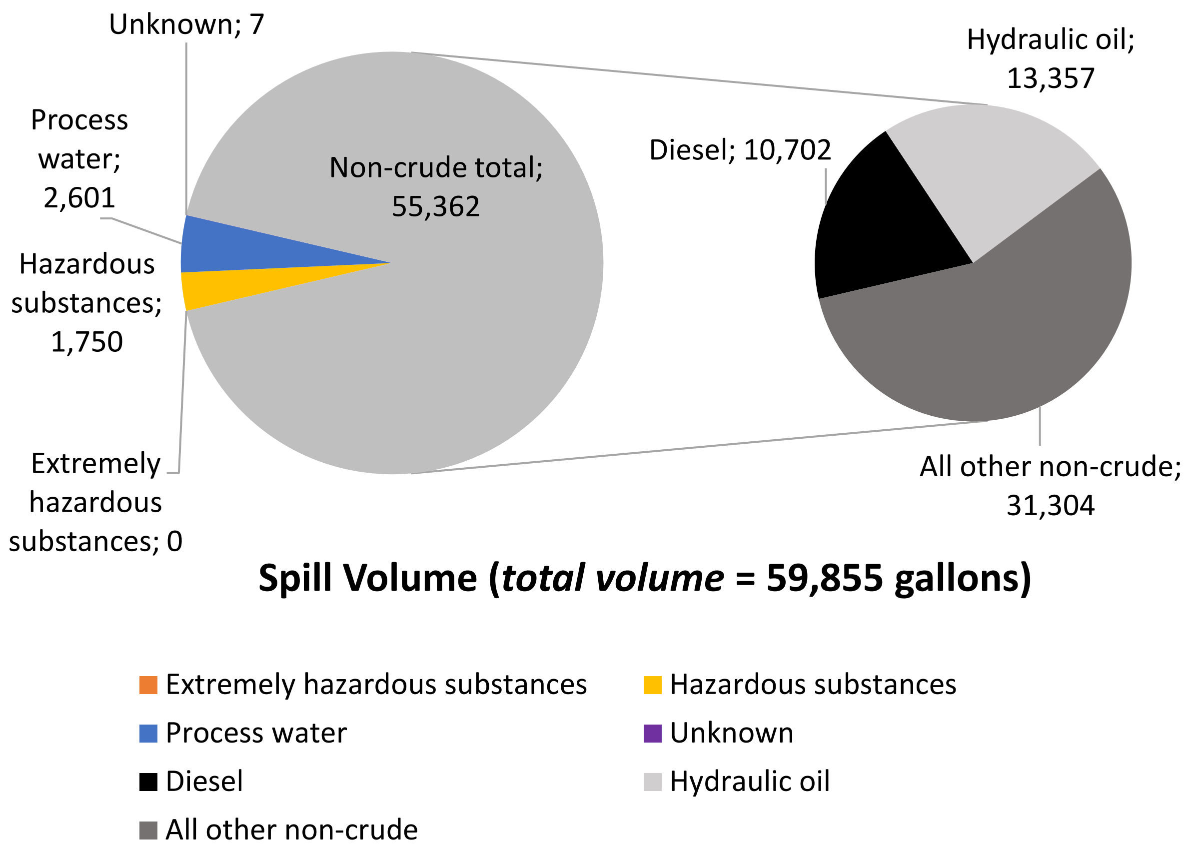

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Figure 9.1. Relative proportions of (a) number and (b) volume from different substance classes from mining operations spills from 1995-2020 from other Alaskan mines with non-crude oil spills further broken down to show the amounts due to diesel and hydraulic oil spills.

More than 90% of the spills from the smaller mines were <100 gallons (Table 9.4, Figure 9.2), but those incidents only accounted for 20.4% of the spill volume (Table 9.5, Figure 9.2).

Table 9.4. Spill size class frequency by substance class for mining operations for other Alaskan mines.

	Spill size class by volume (gallons)						Total	Percent
	<1	1-9	10-99	100-999	1,000-9,999	≥10,000		
Ex Haz Sub	3						3	0.30%
Haz Sub	6	40	33	2			81	7.97%
Non-crude oil	29	492	327	75	2	1	926	91.14%
Process water		1			2		3	0.30%
Unknown	1	2					3	0.30%
Total	39	535	360	77	4	1	1,016	
Percent	3.8%	52.7%	35.4%	7.6%	0.4%	0.1%		

Table 9.5. Spill size class total volume by substance class for Mining operations for other Alaskan mines.

	Spill size class by volume (gallons)						Total	Percent
	<1	1-9	10-99	100-999	1,000-9,999	≥10,000		
Ex Haz Sub	0.163						0.163	0.00%
Haz Sub	1.26	148	764.25	836			1,749.51	2.92%
Non-crude oil	7.834	1,776	9,522.5	14,621	2,070	27,500	55,497.3	92.72%
Process water		1			2,600		2,601	4.35%
Unknown	0	7					7	0.01%
Total	9.257	1,932	10,286.75	15,457	4,670	27,500	59,855	
Percent	0.02%	3.23%	17.19%	25.82%	7.80%	45.94%		

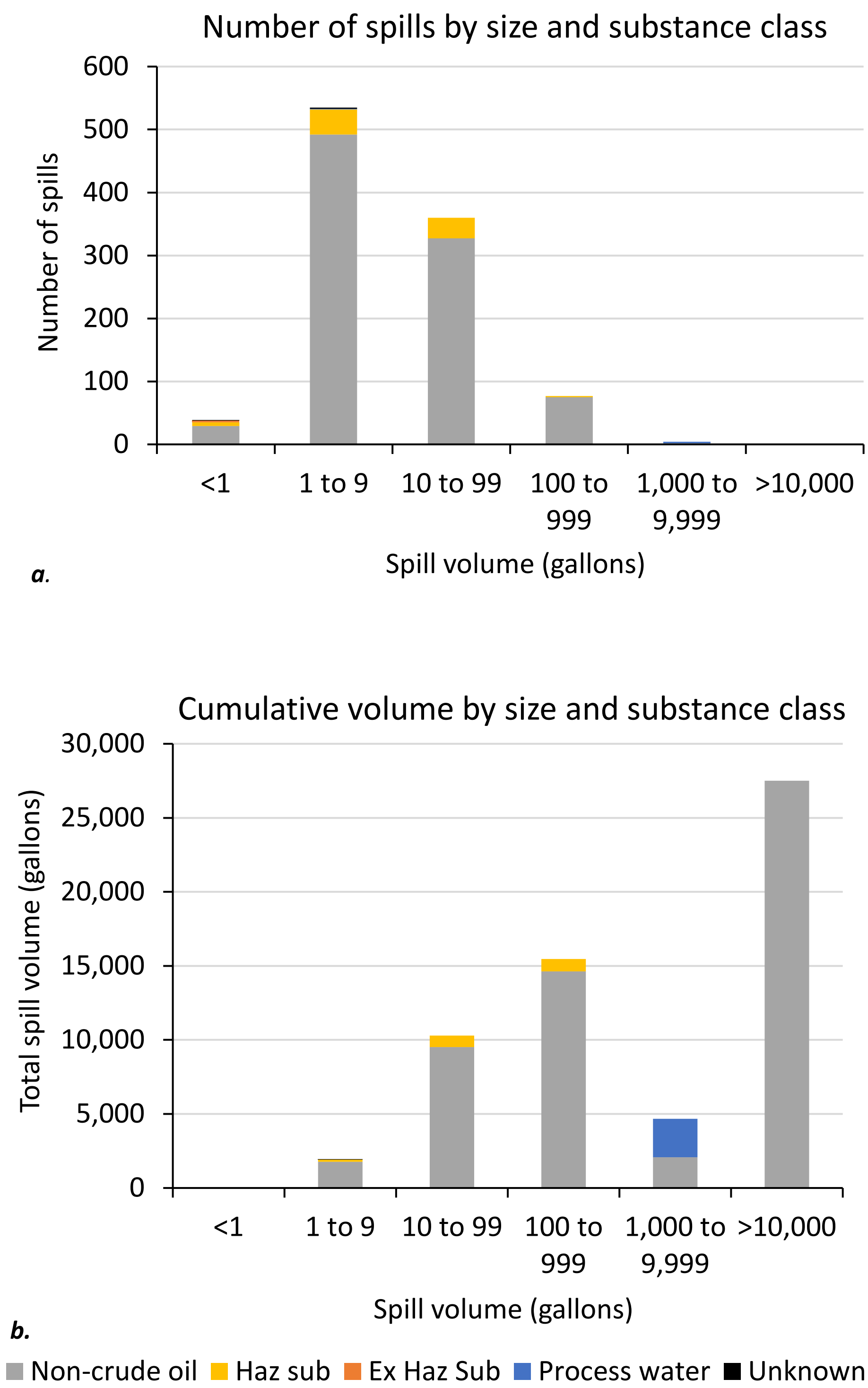


Figure 9.2. Number of spill incidents (a) and cumulative gallons spilled (b) for non-crude oil, hazardous substances, extremely hazardous substances, and process water in different spill size classes for Mining operations spills for all other Alaskan mines from July 1995-December 2020 based on ADEC (2021).

Summary

The five large mines considered in this report are responsible for 7,316 of 8,341 (87.7%) of *mining operations* spills in ADEC (2021). Usibelli Coal Mine was responsible for more than half of the mining operations spills not caused by the five largest hard rock mines (515 out of 1,025 of the remaining *mining operation* spills).

Non-crude oil spills, often of diesel or hydraulic oil, made up the bulk of the spill incidents and spill volume. More than 90% of the spills (of all substances) from the smaller mines were <100 gallons.

CHAPTER 10
NRC and PHMSA spill records

NRC records

The United States Coast Guard National Response Center (https://nrc.uscg.mil/) has annual records of reported spills from 1990-202 but noted that:

> The National Response Center (NRC) is not a response agency. It serves as an emergency call center that fields INITIAL reports for pollution and railroad incidents and forwards that information to appropriate federal/state agencies for response. The spreadsheets posted to the NRC website contain INITIAL incident data that has not been validated or investigated by a federal/state response agency.

The NRC page includes annual reports from 1990-2021. I downloaded those from 1990-2020. There were 10 sheets associated with each year's report, each with a different number of fields (Table 10.1).

Table 10.1. Summary of data available through the NRC website for spills reported from 1990-2020.

Sheet name	Number of fields	Sheet name	Number of fields
Calls	11	Material involved CR (continuous release)	7
Incident commons	29	Trains detail	11
Incident details	78	Derailed units	6
Incidents	80	Vessels detail	17
Material involved	10	Mobile detail	13

I downloaded those records to compare with the records from ADEC, searching for Alaskan spills only. The NRC lists 15,474 spills in Alaska from 1990-2020. I collected 18 characteristics for all 15,474 recorded Alaskan spill incidents (Table 10.2) (Appendix D). Two of the spills were from prior to 1990: one was a vessel sinking in 1952 or 1953, and one was a spill from 1989. (Note: ADEC (2007) lists 23,009 spills in Alaska from July 1, 1995-June 30, 2005.) The *unit of measure* category ranged from ounces to tons for weights and teaspoons to barrels for volumes. I converted all weights to pounds and volumes to gallons.

Table 10.2. Spill data from Alaskan spills in the NRC database obtained in this analysis.

Field	Description
SeqNos	Unique Identifier assigned to each report
Description of Incident	Detailed explanation of the incident
Type of Incident	Specific type of incident being reported
Incident Cause	Cause of the Incident
Incident Date Time	Date and Time incident occurred, was discovered, or planned
Incident DTG	Date Time Group - **Discovered, Occurred** or **Planned**
Incident Location	Descriptive explanation for the location of the incident
Location Address	Complete street address of the incident location
Location City	City or Town nearest to the incident location
Location State	State where incident occurred
Responsible Company	Name of Suspected Responsible Company
Responsible Org Type	Organization Type of the Suspected Responsible party
Amount of Material	Amount of Material Released
Unit of Measure	Unit of Measure for Amount Released
Name of Material	Name of material released
If reached water	Indicates if material reached a body of water
Amount in water	Amount of material that reached water
Unit of measure reach water	Unit of Measure for Amount in Water

Based on the information under *Responsible Company*, location fields, the description of the incident, and the substances spilled, I estimate that as many as 197 incidents in the NRC database were attributable to the five mines considered in this report, although I did not assign any of the NRC Alaska mining spills to Pogo Mine. There were three incidents included that had no listing for *Responsible Company*. One incident was a spill of 1,200 pounds of zinc sulfate on Admiralty Island and one was a 200-gallon spill of hydraulic oil at the Hawk Inlet Cannery on Admiralty Island, both of which I attributed to Greens Creek Mine. The third was a 0.5-gallon spill of ethylene glycol in Kotzebue at the Red Dog port site, which I attributed to Red Dog Mine. There were six spills attributed to Lynden Transport that were not obviously tied to any of the five mines and have been categorized as *unknown* under "mine" in Tables 10.3 to 10.7 and Figures 10.1 and 10.2. They occurred in Anchorage, Salcha (one incident with two substances released), Ninilchik, Fairbanks, and Juneau and involved releases of hydraulic oil, nitric acid, sodium hypochlorite, sulfur, tetrachloroethylene, and diesel.

As recorded in the NRC database, the substances released vary by mine (Table 10.3). The NRC database does not have broad substance classes corresponding to the ones in the ADEC database. I have categorized the spill substances to match ADEC's substance classes. Tailings and slurries are categorized here under *hazardous substances* rather than as *process water*. One water spill at Greens Creek was described as "Washdown water line in concentrate storage building froze/broke overfilling sump which overflowed out doors (sic) and down rip/rap to Hawk Inlet. Approx. 100 gallons of water was released. No sheen observed." Because the origin of the water was the washdown water line, I have not categorized this spill as *process water*, but if the sump contents contained other chemicals, this may understate the contaminants that were released, even if in trace concentrations.

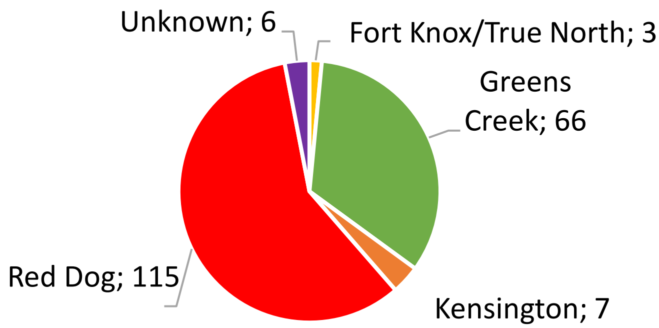
Red Dog and Greens Creek mines had the most extensive lists of substances spilled (Table 10.3), the most spill incidents, the largest cumulative spill volume, and the largest cumulative spill weights (Figure 10.1). Kensington Mine had one diesel spill of an unknown amount which is included in Table 10.3 but not in Tables 10.4 and 10.5. Approximately 94% of the spills measured by volume were <1,000 gallons, and they accounted for 19% of the total volume released (Tables 10.4 and 10.5, Figures 10.2 and 10.3). Spills measured by weight occurred across a broad range of spill size classes and 97.5% of the cumulative weight spilled was the result of spills of ≥10,000 pounds (Tables 10.6 and 10.7).

Table 10.3. Substances recorded and number of spills in the NRC spill database for Alaska mines.

Greens Creek	Kensington	Fort Knox/ True North	Red Dog	Unknown
Non-crude oil (*n*)				
Diesel (9)	Diesel (3)	Lubricating oil (1)	Diesel (4)	Diesel (1)
Fuel oil (10)	Hydraulic oil (2)		Diesel exhaust fluid (1)	Hydraulic oil (1)
Gear oil (1)	Jet fuel (1)		Fuel oil (5)	
Hydraulic oil (18)			Gasoline (1)	
Jet fuel (2)			Hydraulic oil (13)	
Lubricating oil (5)			Jet fuel (5)	
Motor oil (1)			Motor oil (1)	
Waste oil (2)			Unknown oil (5)	
Hazardous and extremely hazardous substances (*n*)				
Copper sulfate (1)	Ferric chloride solution (1)	Blend of synthetic, ester, polyolefin and additives (1)	Ammonium nitrate (1)	Nitric acid (1)
Drilling mud (1)		Sodium cyanide solution (1)	Drilling mud (1)	Sodium hypochlorite (1)
Ethylene glycol (5)			Emulsion product (1)	Sulfur (1)
Hydrogen peroxide solution (1)			Epoxy paint (1)	Tetrachloro-ethylene (1)
Lead (1)			Ethylene glycol (1)	
Lead concentrate (3)			Lead (2)	
Tailings (1)			Lead and zinc sulfide (1)	
Zinc concentrate (2)			Lead concentrate (3)	
Zinc sulfate (1)			Lead sulfate (2)	
			Lead sulfide (15)	

Table 10.3. (Continued.)

Greens Creek	Kensington	Fort Knox/ True North	Red Dog	Unknown
Hazardous and extremely hazardous substances (continued) (*n*)				
			Lead sulfide concentrate (1)	
			Lime and water mixture (1)	
			Mill feed (1)	
			Mine waste (1)	
			Ore slurry (1)	
			Process slurry (containing lead) (1)	
			Slurry (2)	
			Sodium metabisulfite (2)	
			Zinc (1)	
			Zinc column tails containing lead (1)	
			Zinc concentrate (and variations, some containing lead and/or cadmium) (22)	
			Zinc slurry (2)	
			Zinc sulfide (5)	
			Zinc sulfate (3)	
Process water (*n*)				
			Mine drainage water (1)	
			Processed water (1)	
Other (*n*)				
Crude oil (1)			Raw sewage (3)	
Water (1)			Sewage (3)	



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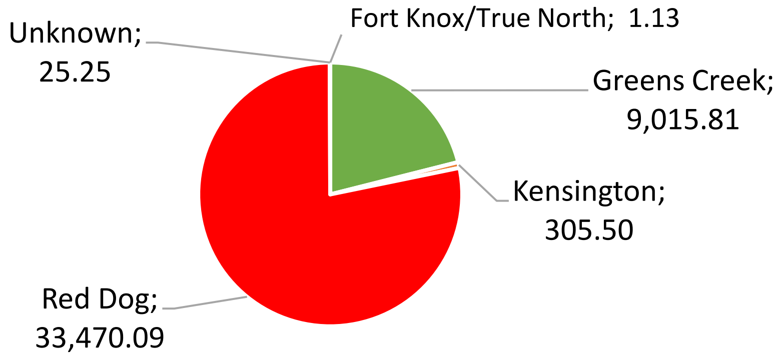

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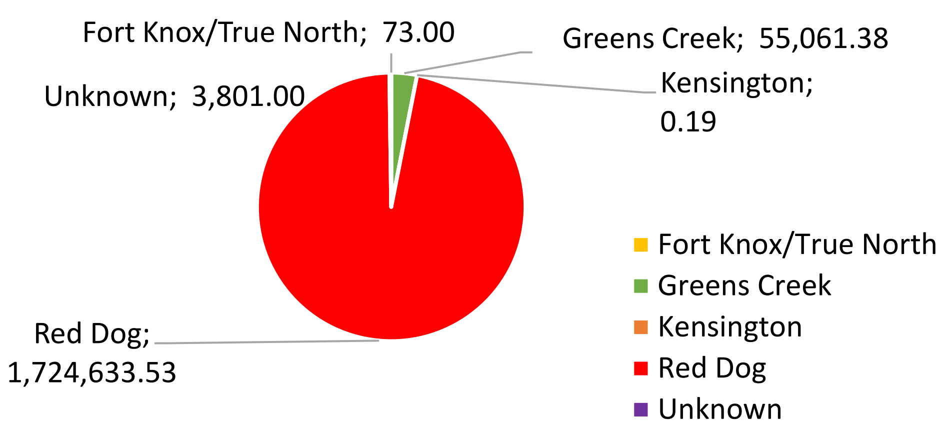


c.

Figure 10.1. The relative proportions of (a) number of spills out of 197; (b) cumulative volume out of 42,817.8 gallons, and (c) cumulative weight out of 1,783,569.1 pounds attributable to each mine based on the NRC spill database.

Table 10.4. Spill counts by size class and mine for NRC Alaska mining spills given by volume.

Volume range (gallons)	Greens Creek	Kensing-ton	Fort Knox/ True North	Red Dog	Unknown	Total	Percent
<1	3		1	12	1	17	15.2%
1 to <10	9	3	1	8		21	18.8%
10 to <100	26	1		9	1	37	33.0%
100 to <1,000	14	1		15		30	26.8%
1,000 to <10,000	1			4		5	4.5%
10,000 to <100,000				2		2	1.8%
Total	53	5	2	50	2	112	
Percent	47.3%	4.5%	1.8%	44.6%	1.8%		

Table 10.5. Cumulative volume by size class and mine for NRC Alaska mining spills given by volume.

Volume range (gallons)	Greens Creek	Kensing-ton	Fort Knox/ True North	Red Dog	Unknown	Total	Percent
<1	0.3		0.1	2.1	0.25	2.8	0.0%
1 to <10	30.5	5.5	1	23		60	0.1%
10 to<100	810	20		320	25	1,175	2.7%
100 to <1,000	2,975	300		3,605		6,880	16.1%
1,000 to <10,000	5,200			6,000		11,200	26.2%
10,000 to <100,000				23,500		23,500	54.9%
Total	9,015.8	325.5	1.1	33,450.1	25.25	42,817.8	
Percent	21.1%	0.8%	0.0%	78.1%	0.1%		

Table 10.6. Spill counts by size class and mine for NRC Alaska mining spills given by weight.

Weight range (pounds)	Greens Creek	Kensington	Fort Knox/ True North	Red Dog	Unknown	Total	Percent
<1	1	1		1		3	4.7%
1 to <10						0	0.0%
10 to <100	2		1	13		16	25.0%
100 to <1,000	2			5	2	9	14.1%
1,000 to <10,000	3			12	1	16	25.0%
10,000 to <100,000	2			11		13	20.3%
≥100,000				7		7	10.9%
Total	10	1	1	49	3	64	
Percent	15.6%	1.6%	1.6%	76.6%	4.7%		

Table 10.7. Cumulative weight by size class and mine for NRC Alaska mining spills given by weight.

Weight range (pounds)	Greens Creek	Kens-ington	Fort Knox/ True North	Red Dog	Unknown	Total	Per-cent
<1	0.4	0.2		0.1		0.6	0.0%
1 to <10						0	0.0%
10 to <100	36		73	498.8		607.8	0.0%
100 to <1,000	425			1,394	351	2,170	0.1%
1,000 to <10,000	12,200			25,840.7	3,500	41,540.7	2.3%
10,000 to <100,000	42,400			534,900		577,300	32.4%
≥100,000				1,162,000		1,162,000	65.1%
Total	55,061.4	0.2	73	1,724,633.5	3,851	1,783,618	
Percent	3.1%	0.0%	0.0%	96.7%	0.2%		

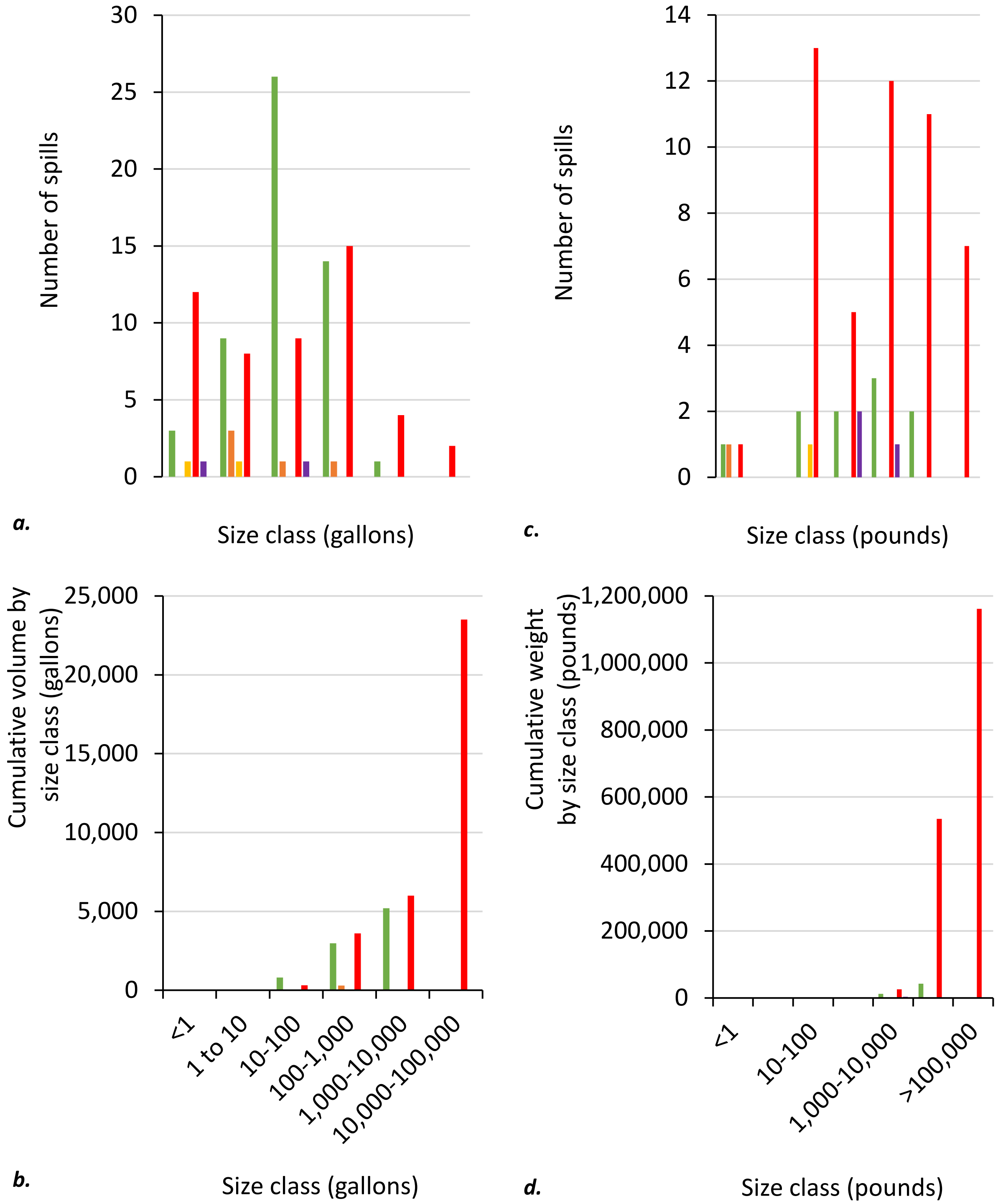


Figure 10.2. Spill frequency (a) and cumulative volume (b) for spill quantities given by volume, and spill frequency (c) and cumulative weight (d) for spill quantities given by weight for the Alaskan mines represented in the NRC database broken down by mine (NRC 2021). Color coding for the induvial mines follows Figure 10.1. Subfigures (a) and (b) share the same x-axes. Subfigures (c) and (d) share the same x-axes.

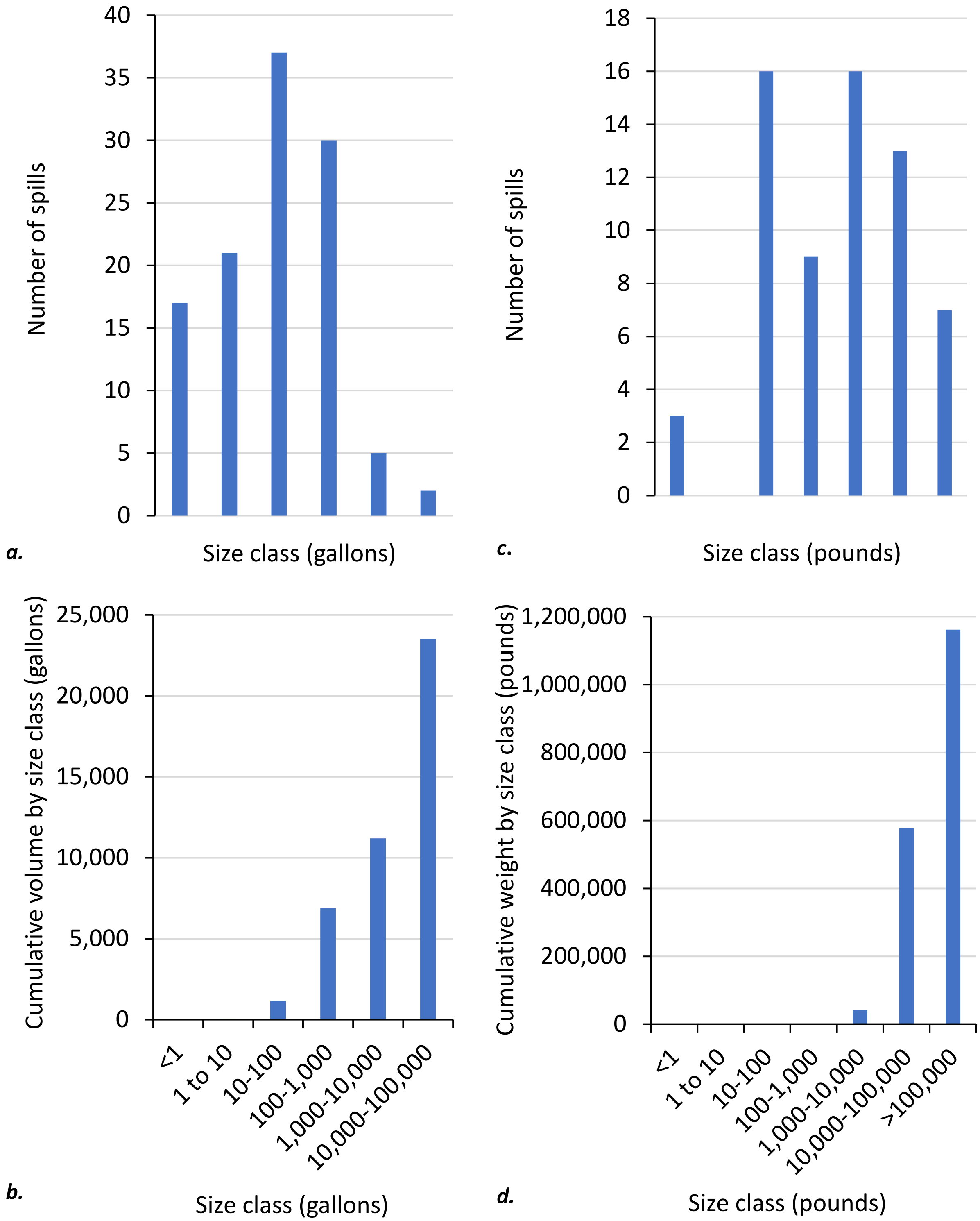


Figure 10.3. Spill frequency (a) and cumulative volume (b) for spill quantities given by volume, and spill frequency (c) and cumulative weight (d) for spill quantities given by weight for the Alaskan mines represented in the NRC database aggregated across all the mines (NRC 2021). Subfigures (a) and (b) share the same x-axes. Subfigures (c) and (d) share the same x-axes.

PHMSA records

Two of the mines considered in the case studies, Red Dog and Kensington, explored transporting diesel, ore slurry, and/or wastewater by pipeline. Kensington Mine provided a quantitative estimate of the percent chance of having a pipeline spill, although the details of the calculation were not shown (USFS 2004). Spill incidents from pipes and lines are common at all the mines considered herein, and I searched the Pipeline and Hazardous Materials Safety Administration (PHMSA) records for mine related spills from pipes or lines. PHMSA has a mission of "protect[ing] people and the environment by advancing the safe transportation of energy and other hazardous materials that are essential to our daily lives" (https://www.phmsa.dot.gov/about-phmsa/phmsas-mission). PHMSA tracks pipeline failures, incidents, and accidents (https://www.phmsa.dot.gov/data-and-statistics/pipeline/national-pipeline-performance-measures). The original regulation for pipeline facility incident reporting criteria dates back to 1970 and has undergone several modifications in the ensuing five decades (PHMSA 2021b). See:

> https://www.phmsa.dot.gov/data-and-statistics/pipeline/pipeline-facility-incident-report-criteria-history

PHMSA maintains a database of reported incidents (PHMSA 2021c), which can be found at:

> https://www.phmsa.dot.gov/data-and-statistics/pipeline/distribution-transmission-gathering-lng-and-liquid-accident-and-incident-data

The PHMSA release database is downloadable in four time periods: pre-1986, 1986-2001, 2002-2009, and 2010-present (Appendix D). Each of those sets of data has a different set of fields for the incident records (Table 10.8). All but three of the 36 pipeline spills recorded in Alaska were crude oil spills (data not shown), and none of the spills were related to mining.

Table 10.8. Summary of the information available from the PHMSA data and statistics database by time period.

Period	Number of incidents	Number of data fields	Number of Alaska pipeline accidents
Pre-1986	4,733	61	3
1986-Jan 2002	3,094	63	13
Jan 2002-Dec 2009	3,030	243	6
Jan 2010-present	4,470	588	14
Total			36

PHMSA also has a portal for searching for spills (PHMSA 2021a). It is searchable by state for the years 2001-2020:

> https://portal.phmsa.dot.gov/analytics/saw.dll?Portalpages&PortalPath=%2Fshared%2FPDM%20Public%20Website%2F_portal%2FSC%20Incident%20Trend&Page=All%20Reported

I searched for spills in Alaska by year from 2001-2020 and found 96 pipeline spills (Appendix D). The two methods for searching for Alaskan spills do not yield the same results, either for the number of spills listed in any given year or the total number that occurred (Table 10.9).

Table 10.9. Pipeline spills in Alaska by year (all responsible parties) from two different PHMSA data sources (PHMSA 2021a, c).

Year	Recorded Spills phmsa.dot.gov/data-and-statistics PHMSA 2021c	Year	Recorded Spills portal.phmsa.dot.gov PHMSA 2021a	Recorded Spills phmsa.dot.gov/data-and-statistics PHMSA 2021c
1977	2	2001	10	5
		2002	13	
1979	1	2003	8	
		2004	7	1
		2004	4	
1986		2006	6	1
1987		2007	7	2
1988		2008	4	
1989		2009	11	2
1990	1	2010	3	2
1991		2011	1	1
1992		2012	4	2
1993	3	2013	1	1
1994	2	2014	2	1
1995		2015	4	2
1996	2	2016	3	2
1997		2017	2	0
1998		2018	2	1
1999		2019	3	1
2000		2020	1	1

The portal searches show incident causes, fatalities, injuries, costs associated with the spills, and the amount of oil spilled and net amount lost. While some of the cause information (Table 10.10) might be interesting if there were further exploration or the pipe and line failures associated with mining, especially for pipelines carrying diesel, ore slurry or tailings over miles of terrain, the PHMSA data do not appear to reflect spills attributed to pipes or lines in Alaskan mines.

Table 10.10. Number of spills based on the data available for Alaskan pipelines (PHMSA 2021a).

Year	Cause							Annual total
	Corrosion	Excavation damage	Incorrect operation	Material/weld/ equipment failure	Natural force damage	Other outside force damage	All other causes	
2001	1	2	2			3	2	10
2002						10	3	13
2003		1		1		5	1	8
2004						7		7
2005						4		4
2006				1		2	3	6
2007						3	4	7
2008						4		4
2009				2	1	8		11
2010			1	1		1		3
2011	1							1
2012				2	1	1		4
2013					1			1
2014				1		1		2
2015				2	1	1		4
2016				2	1			3
2017		1			1			2
2018		1		1				2
2019	1	1		1				3
2020				1				1
Total	3	6	3	15	6	50	13	96

The lack of records of Alaskan mining spills in either the NRC or PHMSA databases compared to ADEC (2021), is perhaps less surprising given that

> Questions were raised in 2009 Congressional hearings about the completeness of reporting of (non-pipeline) hazardous materials incidents. One estimate quoted was that 60-90% of all such incidents were unreported. If these estimates apply equally to serious incidents, then the number of serious road and railway hazardous material incidents presented in this section could be too low by a factor of 10 (some cases were cited of non-pipeline incidents involving fatalities or injuries that went unreported). (PHMSA 2010)

Summary

The United States Coast Guard National Response Center (https://nrc.uscg.mil/) has annual records of reported spills from 1990-2021. The NRC lists 15,474 spills in Alaska from 1990-2020. Based on the information under *Responsible Company*, location fields, the description of the incident, and the substances spilled, I estimate that as many as 197 incidents in the NRC database were attributable to the five mines considered in this report, although I did not assign any of the NRC Alaska mining spills to Pogo Mine.

PHMSA is the Pipeline and Hazardous Materials Safety Administration. The PHMSA pipeline release database contained 36 records related to Alaska from prior or 1986 through 2020. All but three of the 36 pipeline spills recorded in Alaska were crude oil spills, and none of the spills were related to mining. PHMSA also has a portal that allows for searching for spills by state that had 96 records for Alaskan spills between 2001 and 2020. The PHMSA data are primarily focused on petroleum products and natural gas and do not appear to reflect spills attributed to pipes or lines in Alaskan mines.

There is concern that underreporting of spills may mean that national databases might only show a tenth of the actual spills that occur.

CHAPTER 11
Reconsidering the *N* = *RT* model

The *N* = *RT* model has several positive attributes. It is intuitive, with larger estimated numbers of spills arising when the number of miles traveled increases. It is straightforward to calculate when given the appropriate information about the number of loads transported and length of roads traveled. It has precedent in several EISs and other governmental impact assessments of environmental risks. Finally, there is a ready estimate of *R* to use from Harwood and Russell (1990) that has been cited in several of those precedent documents. Unfortunately, as has been shown in the case studies for the five mines in this report, *N* = *RT* fails to accurately predict spills from transportation accidents on Alaskan haul roads when *R* = 1.87×10^{-7} spills per mile. This section explores what other estimates of *R* are available or derivable from existing data about hazardous material transportation, what factors might affect *R* for specific roads or stretches of roads, and what other methods for calculating transportation accident risk are in the peer reviewed literature.

How *R* may be estimated from nationally available hazardous materials transport data

Spill frequency may be estimated using local, regional, or national data, depending on which are most appropriate, reliable, and/or available. Data gaps and reporting inconsistencies across states make deriving widely applicable rates problematic (Kazantzi et al. 2011). National data are available in the *Pocket Guide to Large Truck and Bus Statistics*, which is published annually by the Federal Motor Carrier Safety Administration (FMCSA). The data presented in each guide cited here (FMCSA 2014, 2015, 2018, and 2020) cover a four-year time frame, with the most recent twenty-two months in each guide considered preliminary data.

I concatenated data from the guides to assess the number of large trucks registered in the United States (Table 1-1 from FMCSA 2014, 2015, 2018, and 2020), the number of vehicle miles traveled by large trucks in the United States (Table 1-2 from FMCSA 2014, 2015, 2018, and 2020), the total number of crashes by vehicle type (Table 4-1 from FMCSA 2014, 2015, 2018, and 2020), fatal crashes by vehicle type (Table 4-2 from FMCSA 2014, 2015, 2018, and 2020), injury crashes (Table 4-3 from FMCSA 2014, 2015, 2018, and 2020), and crashes involving trucks with hazardous material placards, both with and without known releases (Table 4-15 from FMCSA 2014, 2015, 2018, and 2020) (Table 11.1). Collectively, the data span from 2009-2018, but the data from 2017 and 2018 were considered provisional when the most recent guide (FMCSA 2020) was published. I used the most recently published for each year in Table 11.1, which may supersede a value from a previous Pocket Guide. For example, FMCSA (2018) lists 522 large truck crashes with known releases in 2016, which is the number cited in USFS (2020). The most recent guide (FMCSA 2020) had updated that to 551 large truck crashes with releases of hazardous materials in 2016, which is the value shown in Table 11.1.

Table 11.1. Data extracted from Pocket Guides to Large Truck and Bus Statistics (FMSCA 2014, 2015, 2018, 2020) for large trucks from 2009-2017. Column letters are used in Table 11.2 to show how the rate calculations were performed.

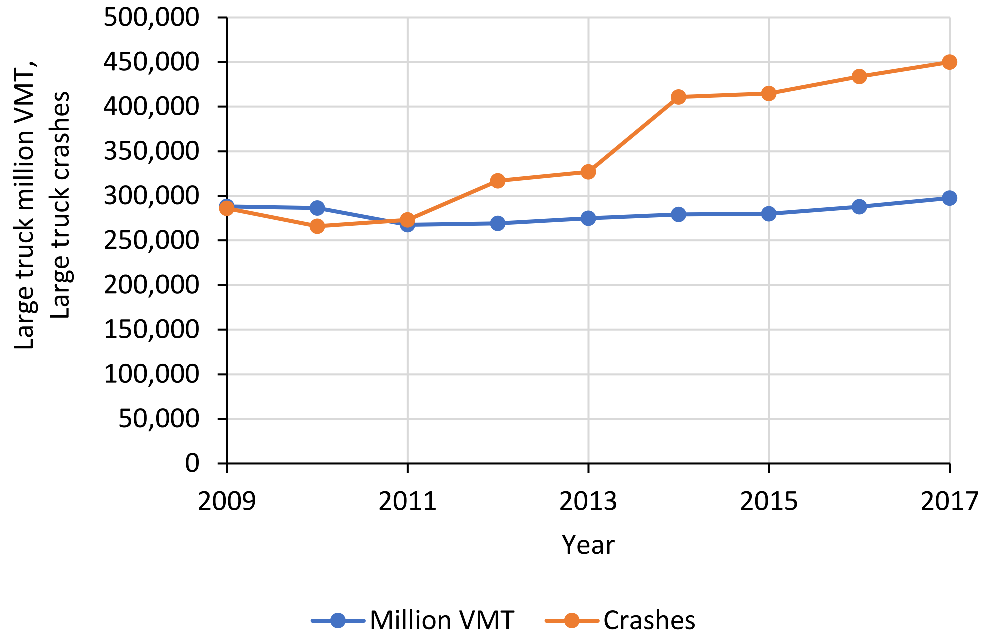
Year	Large trucks registered	Millions of vehicle miles traveled (VMT)	Crashes	Fatal crashes	Hazardous materials crashes	Hazardous materials crashes with known release	Hazardous materials crashes with known release or possible release
	A	B	C	D	E	F	G
2009	10,973,610	288,306	286,000	2,983	2,462	270	772
2010	10,770,054	286,527	266,000	3,271	2,579	281	763
2011	10,270,693	267,594	273,000	3,365	2,892	311	881
2012	10,659,380	269,207	317,000	3,486	2,775	371	812
2013	10,597,356	275,018	327,000	3,554	3,244	385	824
2014	10,905,956	279,131	411,000	3,429	3,619	434	1,161
2015	11,203,184	279,843	415,000	3,622	3,712	483	1,062
2016	11,498,561	287,895	434,000	3,896	3,557	551	1,071
2017	12,229,216	297,592	450,000	4,237	3,881	606	1,096
2009-2017		2,531,113	3,179,000	31,843	28,721	3,692	8,442

Ideally, the rate of hazardous materials releases would be calculated based on the number of vehicle miles traveled (VMT) that large trucks transported hazardous materials, but those data are unavailable. Instead, I will assume that the rate of crashes per million VMT for large trucks carrying hazardous materials is the same as a crash rate per million VMT for all large trucks (Figure 11.1).

The annual number of truck-miles amassed by heavy vehicles remained relatively constant from 2009-2017, but the number of heavy vehicle crashes generally increased over that period (Figure 11.1a), leading to an increase in the estimated number of crashes per truck-mile traveled by heavy vehicles (Figure 11.1b). Not all crashes involving large trucks with hazardous materials placards result in spills. The rate of spills per million VMT is found by taking the large truck crash rate per million VMT and multiplying it by the proportion of crashes that results in spills. The number of known spills has generally been less than half the number of possible spills (Figure 11.2a). From 2009-2017, the rate of potential spills from heavy vehicles has remained near 30% of crashes (Table 11.2, column G/E) and the number of known spills has been between 10-16% of crashes annually and showing a slight upward trend (Figure 11.2b and Table 11.2, column F/E). (With only 9 years of data, I did not check if this trend was statistically significant.) The percent of crashes involving large trucks potentially carrying hazardous materials that may have had releases ranged from 25.4-32.1% from 2009-2017

(Figure 11.2b). The percent of potential releases is consistent with other estimates. For trucks that were involved in fatal crashes from 1991-2000, Craft (2004) found that and average of 31.2% of those carrying hazardous materials had releases, compared to 20.9% of the trucks carrying non-hazardous materials.

Based on the crash rate per million VMT and proportion of crashes that resulted in known spills of hazardous materials, the rate of hazardous materials spills per VMT by large trucks ranged from 1.01 x 10^{-7} spills per mile traveled in 2010 to 2.36 x 10^{-7} spills per mile traveled in 2017 (Table 11.2, shaded column, and Figure 11.3). The known spill rate per number of miles traveled by heavy vehicles increased from 2009-2017, with all rates based on data from an individual year falling between 0.10-0.25 spills per million VMT, and had an average value of 1.615 x 10^{-7} spills per vehicle mile (Figure 11.3 and Table 11.2, shaded column).



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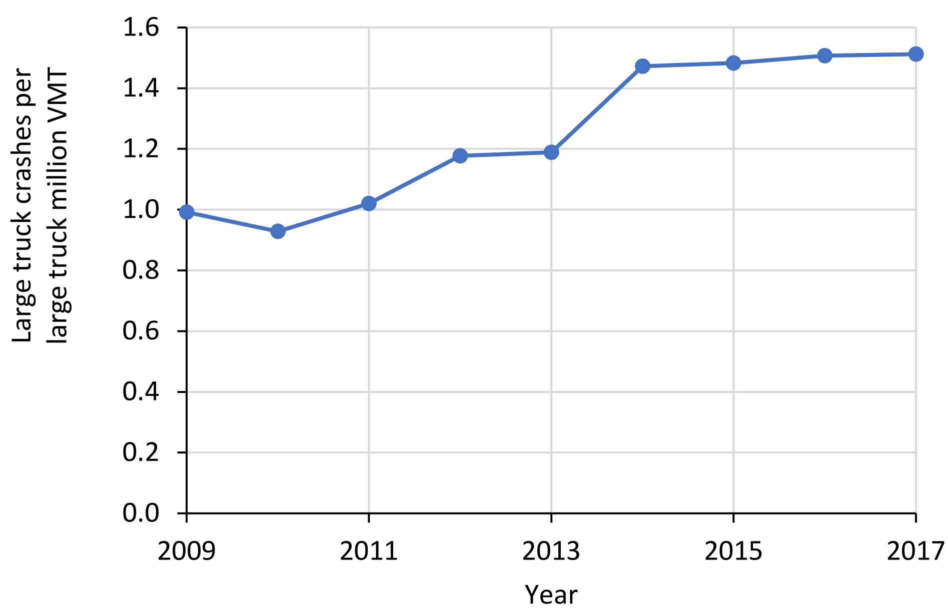

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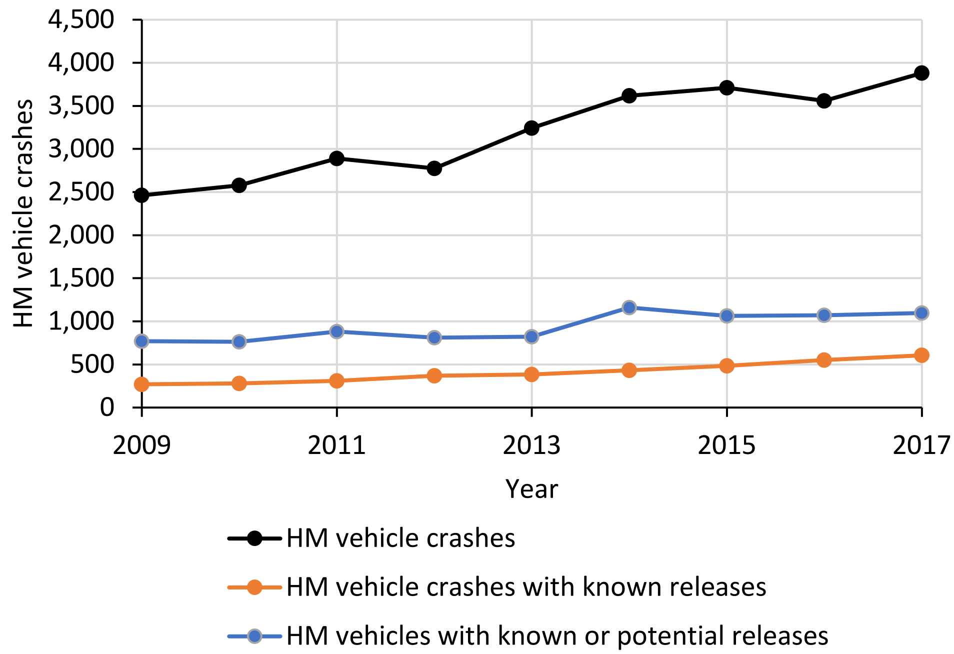
Figure 11.1. (a) Millions of vehicle miles traveled by large trucks (blue line) and number of large truck crashes (orange line) from 2009-2017; (b) Number of large truck crashes per million vehicle miles traveled from 2009-2017. Data from FMCSA (2014, 2015, 2018, 2020).

Table 11.2. Rates of crashes and hazardous materials releases from large trucks per year from 2009-2017 based on FMCSA (2014, 2015, 2018, and 2020). The minimum spill rate of hazardous materials per million VMT is in the shaded column. See appropriate columns in Table for data used to calculate each rate.

Year	Crash rate per million VMT	Fatal crash rate per million VMT	Hazardous material crashes per million VMT	Percent of hazardous materials crashes with known releases	Hazardous materials crashes with known releases per million VMT	Percent of hazardous materials with potential releases per million VMT	Hazardous material crashes with potential releases per million VMT
	C/B	D/B	E/B	F/E	(C/B) x (F/E)	G/E	(C/B) x (G/E)
2009	0.992	0.0103	0.0085	11.0%	0.1088	31.4%	0.3111
2010	0.928	0.0114	0.0090	10.9%	0.1012	29.6%	0.2747
2011	1.020	0.0126	0.0108	10.8%	0.1097	30.5%	0.3108
2012	1.178	0.0129	0.0103	13.4%	0.1574	29.3%	0.3446
2013	1.189	0.0129	0.0118	11.9%	0.1411	25.4%	0.3020
2014	1.472	0.0123	0.0130	12.0%	0.1766	32.1%	0.4724
2015	1.483	0.0129	0.0133	13.0%	0.1930	28.6%	0.4243
2016	1.507	0.0135	0.0124	15.5%	0.2335	30.1%	0.4539
2017	1.512	0.0142	0.0130	15.6%	0.2361	28.2%	0.4270
2009-2017	1.256	0.0126	0.0113	12.9%	0.1615	29.4%	0.3692



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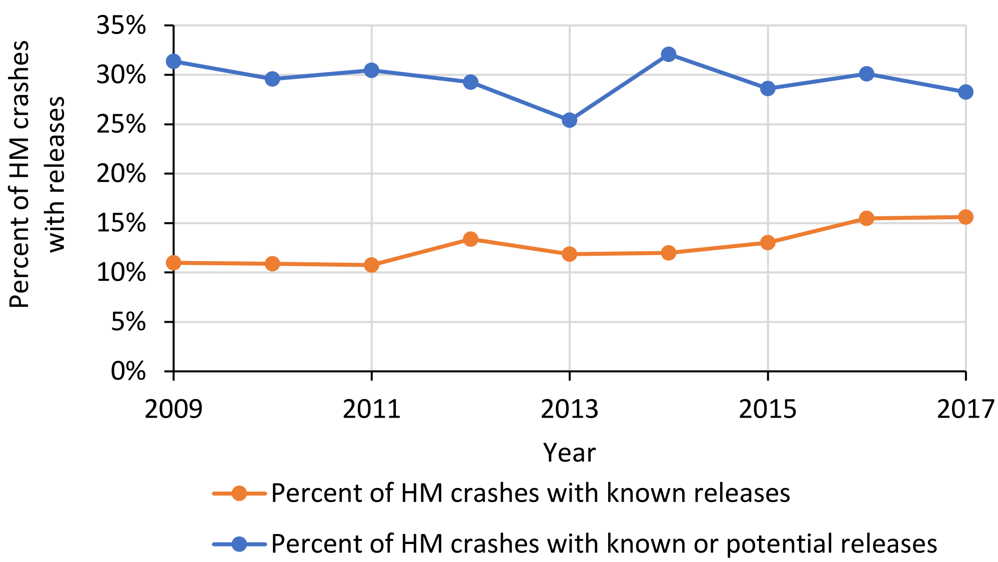

b.

Figure 11.2. (a) Crashes involving large trucks with hazardous materials placards (black line) and the number of known releases of hazardous materials in those crashes (orange line) and known and potential releases of hazardous materials (blue line) from 2009-2017; (b) Percent of crashes from large trucks with hazardous materials with known releases (orange line) and percent of crashes from large trucks with hazardous materials with known or potential releases (blue line) from 2009-2017. Data from FMCSA (2014, 2015, 2018, 2020).

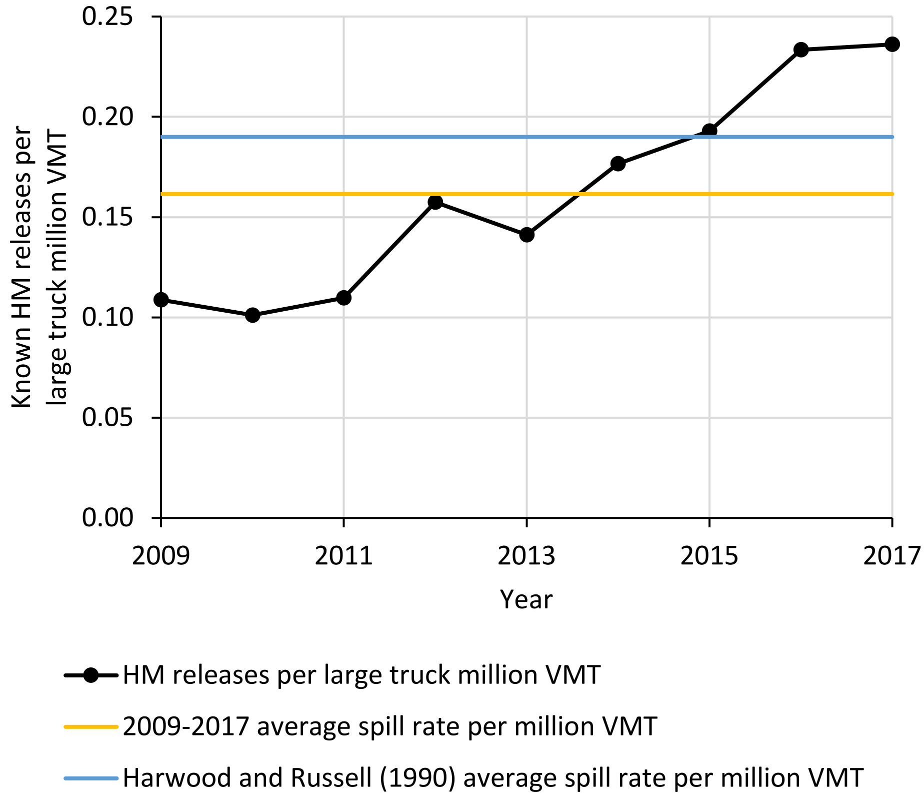

Figure 11.3. Estimated rate of known hazardous materials releases per million vehicles miles traveled by large trucks with hazardous materials placards from 2009-2017. Data from FMCSA (2014, 2015, 2018, 2020).

For comparison, recall that when estimating the risks of spills of hazardous materials from trucks for the Pogo and Pebble Mines, EPA (2003, 2014) used a risk rate per mile of 1.9 x 10^{-7} spills per truck-mile, citing statistics from Harwood and Russell (1990). Although Harwood and Russell (1990) used data from California, Michigan, and Illinois that are now at least 30 years old, their estimate of *R* is similar to recent annual spill rates per VMT and a little higher than the average rate based on national data from 2009-2017 (Figure 11.3).

The national data described above do not consider any differences in spill rates between types of hazardous materials. Battelle (2001) examined the miles traveled, number of accidents, and number of leaks for hazardous materials vehicles transporting 12 types of hazardous materials (Table 11.3). Battelle (2001) found that the average hazardous material accident rate was 3.2 x 10^{-7} spill per vehicle mile, based on estimated mileage figures from the 1997 Commodity Flow Survey. The rate varies by hazardous material class:

> Risk of an accident per mile ranges from 1.3E-07 for Division 2.2 [non-flammable gases] to 7.2E-07 for Class 9 [miscellaneous dangerous goods]. The average accident rate for HM is 3.2E-07. If enroute incidents are included, as shown in Table 25, the risk increases to an average risk of 5.0E-07. Thus, without including enroute incidents, the accident/incident rate for accidents on the road declines by about 37 percent. (Battelle 2001)

The number of leaks per mile traveled were generally lower than accidents per mile, with the exceptions of *toxic materials and infectious substances* and *corrosive materials*. Combining leaks and accidents with releases yields the total spills per mile for the various hazardous materials classes. *Non-flammable gases* have the lowest combined release rate of 0.32 x 10^{-7} per mile, while *toxic materials* and *miscellaneous dangerous goods* have combined release rates of 6.4 x 10^{-7} and 6.2 x 10^{-7} per truck-mile, respectively (Table 11.3).

Table 11.3. Spill probabilities (given an accident) may vary by substance type. See Battelle (2001), Table 6 (p. 3-9), and Tables 24 and 25 (p. 4-13).

Hazardous material classes and divisions, with descriptions	HazMat Miles	Total HazMat Accidents	Leaks en route	Accidents per mile	Leaks per mile	Fraction of accidents with releases	Accidents with releases per mile	Leaks and accidents with releases per mile
1.1, 1.2, and 1.3: Explosives with the potential for mass detonation	23,000,000	14.2	1	6.2×10^{-7}	0.43×10^{-7}	0.155	0.96×10^{-7}	1.4×10^{-7}
1.4, 1.5, and 1.6: Explosives with characteristics making mass detonation extremely unlikely	46,000,000	32.101	3	7.0×10^{-7}	0.65×10^{-7}	0.284	2.0×10^{-7}	2.6×10^{-7}
2.1: Flammable gases	805,000,000	276	15	3.4×10^{-7}	0.19×10^{-7}	0.170	0.58×10^{-7}	0.77×10^{-7}
2.2: Non-flammable gases	1,400,000,000	178	19	1.3×10^{-7}	0.14×10^{-7}	0.146	0.19×10^{-7}	0.32×10^{-7}
2.3: Poisonous gases	50,000,000	12.02	5	2.4×10^{-7}	1.0×10^{-7}	-	-	$\geq 1.0 \times 10^{-7}$
3: Flammable liquids and combustible liquids	2,800,000,000	1,379.021	587	4.9×10^{-7}	2.1×10^{-7}	0.355	1.7×10^{-7}	3.8×10^{-7}
4.1, 4.2, and 4.3: Flammable solids; spontaneously combustible materials and dangerous when wet materials	48,000,000	33	13	6.9×10^{-7}	2.7×10^{-7}	0.242	1.7×10^{-7}	4.4×10^{-7}
5.1, 5.2: Oxidizers and organic peroxides	201,000,000	61	50	3.0×10^{-7}	2.5×10^{-7}	0.475	1.4×10^{-7}	3.9×10^{-7}
6.1, 6.2: Toxic (poison) materials and infectious substances	218,000,000	50	125	2.3×10^{-7}	5.7×10^{-7}	0.300	0.69×10^{-7}	6.4×10^{-7}
7: Radioactive materials	30,000,000	12.001	4	4.0×10^{-7}	1.3×10^{-7}	-	-	$\geq 1.3 \times 10^{-7}$
8: Corrosive materials	1,900,000,000	257	539	1.4×10^{-7}	2.8×10^{-7}	0.284	0.38×10^{-7}	3.2×10^{-7}
9: Miscellaneous dangerous goods	250,000,000	179.3	94	7.2×10^{-7}	3.8×10^{-7}	0.336	2.4×10^{-7}	6.2×10^{-7}

This still does not describe all vehicle spills because “[t]he accidental releases of hazardous materials occur not only during transport, but also at fixed locations during loading and unloading activities (US DOT 2010)” (Inanloo et al. 2015). Furthermore, these risk calculations likely underestimate the actual risk due to underreporting of spills. Not only does the national database of hazardous materials spills, the Hazardous Material Information System, not record accidents occurring on intrastate roads and accidents not resulting in a spill (Qiao et al. 2009), but one estimate prepared for a Congressional hearing on PHMSA’s effectiveness suggested that spill estimates based on national data could be up to an order of magnitude too small:

> Questions were raised in 2009 Congressional hearings about the completeness of reporting of (non-pipeline) hazardous materials incidents. One estimate quoted was that 60-90% of all such incidents were unreported. If these estimates apply equally to serious incidents, then the number of serious road and railway hazardous material incidents presented in this section could be too low by a factor of 10 (some cases were cited of non-pipeline incidents involving fatalities or injuries that went unreported). (PHMSA 2010)

Location specific road hazards that may impact *R*

With the exceptions of the rate of ore concentrate spills for Red Dog Mine, the hazardous spill risk rates in the case studies are based on national data. The average the rates given do not reflect the variability and localization of spill probabilities, a fact which is acknowledged by both EPA and PHMSA.

EPA 2003b:

> The probability of truck accidents and release was reported as 1.9×10^{-7} spills per mile of travel for rural two-lane roads (Harwood and Russell, 1990). … This frequency provides an order-of-magnitude estimate because the conditions on the Pogo mine road would be different from those for which the statistics were developed (more difficult driving and road conditions).

PHMSA 2010, p. 24:

> The rate of serious incidents per mile in a specific location in any specific community may vary considerably, based on the specific characteristics of the transportation infrastructure at the location (pipeline, roadway, and railway) and characteristics of the surrounding community. The expected rate of incidents involving different hazardous material transportation modes in a specific community will depend on the degree of exposure to each mode, namely, the number of miles of road, railway, and pipeline. The higher the pipeline, road, and railway mileage in a community, the higher is the community's level of exposure to potential incidents. However, the characteristics of the area (e.g., rural versus urban; density, pattern, and type of structures; topography) could decrease or increase the risk to the area surrounding the transportation infrastructure.

While in an ideal world (from a statistical standpoint) there would be sufficient data to characterize each region specifically, with up-to-date, accurate, and detailed records of accidents, spills, and truck-miles, the reality is that hazardous spill rates are low and data are often collected in different formats by different agencies around the country, incomplete, or inaccurate (Erkut et al. 2007, Kazantzi et al. 2011) and different researchers can present conflicting numbers (Erkut et al. 2007), potentially in part due to varying methodologies and assumptions (Kazantzi et al. 2011). Furthermore, from the standpoint of preparing EISs with transportation corridors that involve the potential of newly constructed roads or significant changes in traffic and materials being moved, the relevant site-specific data may not exist. Nonetheless, the national statistics offer a consistent starting point which could then be used with location-specific details to modify the estimate of spill rate per mile traveled. (For new roads, an examination of roads from similar terrain and use would be a good starting point.)

Detailed models of spill probability per mile can incorporate area-specific risks that more generalized ones do not (Table 11.4). The general procedure is to first find the base (average) accident frequency by dividing the number of accidents by the number of miles traveled and then modify it based on factors that make a significant change to the rate for the specified scenario (Qiao 2009). Potential factors that can affect the accident rate have been studied in mathematical modeling contexts (Qiao et al. 2009, Kazantzi et al., 2011), in governmental guidelines (AASHTO 2018), and suggested by examination of specific road corridors (USGS 2020) (Table 11.4). Factors may be important singly or have compounding effects (Kazantzi et al. 2011). The roadways for all the Alaska mines considered in this report would have some significant risks (road grade and quality, weather and climate, earthquakes, etc.) that would be expected to increase the spill rate above the national average rate if a detailed model were used. It is beyond the scope of this report to model these for their transportation corridors.

Table 11.4. Some potential factors that may affect spill probabilities for trucks carrying hazardous materials.

Reference	Factors that may affect spill risk
Erkut and Verter 1998	substance being transported road network characteristics, such as road type and population, along the chosen route
Erkut et al. 2007	hot spots such as road intersections, highway ramps, and bridges intrinsic factors such as tunnels, rail bridges, road geometry, weather conditions, and human factors factors correlated to traffic conditions, such as traffic volume and frequency of hazmat shipment
Qiao et al. 2009	nature of the roads, characteristics of the trucks, environmental factors, and driver conditions urban versus rural and divided versus undivided highway location specific conditions, such as vehicle speed limit, topographical conditions, excessive grade, obstructions to vision, poorly designed intersections weather conditions, such as rain, fog, storms, icing, wind, or tornado conditions driver training programs, fleet maintenance, speed monitoring, driver stress level, driver drinking habits
Kazantzi et al. 2011	material type, mode of transportation, container type, meteorological and weather conditions, geographical location, season, time of the day, road conditions, management of the transportation, age, training and condition of the driver, operations performed, and equipment used
AASHTO 2018	type of terrain (level, rolling, mountainous); straight or winding grade, cross slope, width, medians, number of lanes, speed, rural vs. urban, traffic volumes, sight distances, lighting, drainage
USFS 2020b	road surface or substrate; landslide, rockfall and avalanche risk; fires; flash floods; earthquakes; road condition and maintenance level; previous disturbances to the area

Hazardous materials risk modeling peer-reviewed literature

There are decades of study and peer-reviewed models in the field of operations research for quantifying the risks of transporting hazardous materials because it "is an important decision problem that is of interest to hazmat producers and consumers, hazmat carriers, local governments, insurance companies, and the people exposed to the risks from the shipments" and a complicated problem that is mathematically interesting (Erkut and Verter 1998). Other transportation problems differ from hazardous materials routing because of the element of risk (Erkut et al. 2007) associated with the cargo and because it is "an important, complex, socially and environmentally sensitive problem; involving a plethora of parameters: economic, social and environmental" (Barilla et al. 2009). Unlike other transportation problems, where the main objective is to minimize the costs or time associated with shipping, hazardous materials transportation requires minimization of hazards exposures from accidents (Erkut and Verter 1998, Barilla et al. 2009), which is an important consideration for not just researchers, but also for government bodies, regulatory authorities, and the public in general (Kazantzi et al. 2011).

Definition of risk

Risk models in the peer-reviewed literature are nearly always a function that represents both the probability of an incident, such as a spill, occurring and the consequences of such an event. There are many ways to model risk, as explained by Erkut and Verter (1998) (italicized emphasis added):

> [T]here is no agreement among researchers on the proper representation of the associated transport risks… Although risk is a popular term in the media, and a popular topic with many authors, there is no universally accepted definition of risk. *Most people would agree that risk has to do with the probability and the consequence of an undesirable event*. Although some authors define risk as only one of these terms (i.e., probability or consequence), *it is more common to define risk as the product of both the probability of and the consequence of the undesirable event (*Covello and Merkhofer 1993). Note that this is an "expected consequence" definition, and it is the definition that we refer to as "traditional risk" in this paper (primarily for the reason that it is the definition used in the U.S. Department of Transportation 1989 guidelines for transporting hazmats, which have influenced many researchers in this area). We emphasize that*, depending on the circumstances, it might make sense to use other definitions of risk*.

In various forms, probability, frequency, and consequences of accidents are all components of measuring risk. For example, Etkin (2006) stated (italicized emphasis in the original):

> Risk assessment incorporates an evaluation of both the *probability* and *consequences* of particular events. Wtih (*sic*) oil spills, risk assessment requires looking at the *frequency* of spill incidents from historical spill rates, as well as measuring the *consequences* or *potential impacts* (costs and damages) of spill incidents. Impacts vary with oil type, spill magnitude, and a variety of location-related factors (*e.g*., sensitive natural and socioeconomic resources, waterway type).

Similarly, Qiao et al.'s (2009) definition of risk was "a combination of two parameters: frequency and the magnitude of the consequence" and Barilla et al.'s (2009) was "the expected consequences associated with a given activity."

Qualitative vs. quantitative risk analysis

Risk assessment can be qualitative, dealing with identifying possible accident scenarios and attempting to estimate the resulting impacts and consequences (Erkut et al. 2007), and there are frequent examples of such qualitative assessments in the EISs and EAs for the mines in this report. Quantitative risk assessment (QRA), on the other hand, "results in a numerical assessment of risks involved, for example, an expected number of individuals impacted per year" (Erkut et al. 2007). QRA has three component steps: 1. Estimation of the probability (and frequency) of an incident; 2. Identifying the hazard impacts associated with an incident and the relative levels of exposure (to people or the environment) along various route segments; and 3. Modeling the magnitude of the consequences (Erkut et al. 2007, Kazantzi et al. 2011). Particularly in EISs which include several options for transportation corridors, QRA allows for objective measurement and comparison of potential impacts from spills of hazardous materials.

Frequency analysis

Deriving an estimate of spill probability (or frequency) is an essential first step (Qiao et al. 2009). Models for spill probability range from very simple to very specialized and detailed. As we have seen with the *N* = *RT* model, simple (and therefore popular) models may only take a few factors into consideration, but other factors such as different types of roads, truck configurations, operating conditions, environmental factors, and road conditions (Qiao et al. 2009) add to the list of parameters to consider individually and in combination. As the calculations shown in the section detailing how to find *R* from national transportation data showed,

> Accident frequency can be defined as the number of accidents per unit of road (mile, kilometer, etc.). The frequency can be computed by dividing the number of accidents by the number of vehicle miles, which is the corresponding exposure measure of opportunities for an accident to occur. There are three basic options to assess accident frequency with reasonable accuracy. The first is to obtain at least one database and analyze both accident data and travel data for the specific conditions under investigation (assuming that the dataset is structured to support distinctions between the desired variables). The second option is to access state databases for specific routes. Frequently, states have accident data and travel data for major state highways. A third option is to use an existing limited analysis of databases and apply the results to a specific route of interest. (Qiao et al. 2009)

Not all accidents result in spills, not all trucks carry the same types of hazardous materials in the same load sizes, and not all spills release the same amounts of hazardous substances. Therefore, a more detailed frequency analysis requires more data which can be used to not only determine the probability of an undesirable event but also assess how severe the events are and how such events affect their surroundings (Erkut et al. 2007).

Impacts and consequences to consider and model

Fatalities are an obvious harm to avoid in transporting hazardous materials, and so population density measures around routes are important measures to have (Erkut and Verter 1998). Additional costs and risks to minimize include travel distance, population exposure, societal risk, traditional risk, accident probability, and incident probability (Erkut and Verter 1998). Other potential consequences include health effects, such as death, injury, or long-term exposure effects, property loss, environmental effects, or interruptions in routines such as population evacuations or traffic stoppages along the route (Erkut et al. 2007). Not all spills are created equal, and the "[i]mpacts of hazardous material releases during transport depend on the characteristics of the cargo, incident location and time, weather conditions (i.e., wind direction and speed), and land use" (Inanloo et al. 2015).

Models of risk

Models vary in how they incorporate consequences into the math, depending on the priorities of the specific application. Erkut and Verter (1998) identified five models for quantifying risk along different potential routes that hazardous materials might travel: traditional risk, population exposure, incident probability, perceived risk, and conditional risk. Erkut et al. (2007) expanded the list to nine models by adding maximum population exposure, expected disutility, mean-variance, and demand satisfaction models. Only one of these formulations, the population exposure model, did not include some form of p, the probability of an incident along a route segment (Table 11.5).

Erkut et al. (2007) categorized hazardous materials transportation models in the peer reviewed literature from 1973-2004 in four general classes: 1. risk assessment; 2) routing; 3) combined facility location and routing; and 4) network design, but also noted that many problems intersect multiple classes. See Table 2a (Erkut et al. 2007) for a list of peer-reviewed papers on the topic of risk assessment for hazardous materials transportation and Table 2b (Erkut et al. 2007) for hazardous materials transportation routing models for transport by road, rail, marine, and/or air.

Table 11.5. Various models of path risk shown in Erkut et al. (2007). In these models p_i is the probability of an incident along segment i, and c_i is a measure of the consequence (e.g., population size that would be affected) along segment i for path segments 1 to n.

Model	Approximation formula	Notes
Traditional risk	$\sum_{i=1}^{n} p_i c_i$	Used by the Department of Transportation
Population exposure	$\sum_{i=1}^{n} c_i$	Measures the total consequence along the entire route
Incident probability	$\sum_{i=1}^{n} p_i$	Measures the total probability along the entire route
Perceived risk	$\sum_{i=1}^{n} p_i {c_i}^{\alpha}$	a > 0; allows the modeler to increase the importance of the consequence as it gets larger
Conditional risk	$\frac{\sum_{i=1}^{n} p_i c_i}{\sum_{i=1}^{n} p_i}$	Addresses the size of the consequence if it known that an event will occur
Maximum population exposure	$\max e_i \in pc_i$	Finds the largest consequence along the route
Expected disutility	$\sum_{i=1}^{n} p_i \left(\exp\left(\alpha c_i\right) - 1\right)$	α > 0; "incorporates the risk aversion of the society toward hazmat incidents, especially incidents with very large consequences"
Mean-variance	$\sum_{i=1}^{n} (p_i c_i + \beta p_i {c_i}^2)^4$	β > 0; "identifies the least expected length path subject to the constraint that the variance of the path length is within a pre-specified threshold"
Demand satisfaction	$\sum_{i=1}^{n} (1 - \exp(-p_i)) c_i \prod_{j=1}^{n} \exp(p_i)$	Considers that additional shipments will be necessary following an incident to fill the demand that went unmet due to the event

Choosing a risk model is not straightforward and using different criteria can lead to defining different routes as optimal. For example, Erkut and Verter (1998) compared five different models of risk:

> [We] searched for answers to the following two questions: "How similar are the paths found by different objectives for a given origin-destination pair?" and "How does the optimal solution for one objective perform under the other objectives?" Our analysis was performed using a professional decision-support system for hazmat route selection. … We found that the optimal paths with respect to the three fundamental risk models— namely, minimizing the traditional definition of risk, minimizing total incident probability, and minimizing total population exposed—do not exhibit strong similarities…. Based on our analysis, we conclude that considerable attention should be paid to the modeling of risk for hazmat transport since the different objectives that are suggested in the literature cannot be used interchangeably. Different models result in different paths, and the models do not tolerate one another very well. (Erkut and Verter 1998)

Fortunately, it is not necessary to force those optimization criteria into agreement. Barilla et al. (2009) demonstrated how to consider several risk measures to minimize (travel time, travel distance, risk for the population, risk for the urban environment, and risk related to a natural hazard) coupled with a matrix describing the relative weight each of those metrics. Barilla et al. (2009) note that "The objectives are not fixed; they reflect the interests of stakeholders in the decision-making process." Considering many types of impacts for specific spill substances and circumstances is complicated, but oversimplified models can miss important differences in spill impacts. As described by Inanloo et al. (2015) from a modeling exercise with two chemicals and different atmospheric conditions:

> [I]mpact zones can be significantly different for different types of hazardous cargo. …. The overlay of the toxic threat zone plots over the GIS map of the accident location provided an effective tool to visualize the geographical domain affected by the release (number of people exposed, age distribution of the exposed population, potential secondary exposure routes such as water and soil). …. The health risks estimated based on the area and population at risk showed the significance of the consequences of the accidental releases. The analyses showed that the risk which is quantified for a specific consequence can be different from the risk quantified based upon another type of consequence (e.g., impacted area vs. population). … Therefore, a great consideration should be focused on the selecting of the consequences of accidents. The results vary depending on the released chemical, atmospheric condition, location, traffic volume, and crash rate data. … Considering uncertainties and lack of data, risk assessments similar to the proposed approach can help to decrease the accidental release risks of hazardous chemicals during transport by avoiding densely populated areas or segments with high crash rates, as well as selecting specific paths or road segments based on their level of accident risks. The multilevel analysis of impacts after hazardous material releases during transport (i.e., type of material, geographical data, dispersion profile, meteorological information, population density, and traffic data) can be used for planning and implementing appropriate response and mitigation measures for hazardous cargo releases to atmosphere. The insights provided by this research can aid decision makers for routing and scheduling of hazardous material cargos and developing strategies which avoid high-risk and vulnerable regions for transporting hazardous materials.

Summary

EISs, including those for Pogo and Kensington mines, often use an estimate of 1.9×10^{-7} spills per truck-mile (Harwood and Russell 1990). I calculated an average spill rate of 1.62×10^{-7} spills per truck-mile for the period of 2009-2017 based on data from the FMSCA. PHMSA estimated that there were an average 3.2×10^{-7} accidents per truck-mile of hazardous material transport, and found the rate of accidents, releases, and leaks varied by class of hazardous material. Due to underreporting, it is likely that all these estimated rates are too low, perhaps by as much as a factor of ten.

Estimates of spill risk per truck-mile based on data collected nationwide are generalized and miss factors that may be relevant to individual hazardous material transportation scenarios. Some risks are dependent on the route chosen (road grade, number of lanes, weather, etc.) and some are route independent (driver experience level, material type, truck configuration, etc.). Alaskan mines would have some significant risks (road grade and quality, climate and weather, etc.) that would be expected to increase the spill rate if a detailed model were used. While road improvement and speed limits might help abate some of the risks inherent in the analysis area, developing a project-specific spill risks per truck-mile for one or more segments of the transportation corridors would be complicated, even if enough data were available, and would likely result in an estimated rate that is higher than the national average spill rate per truck-mile.

Even though the spill probability for a single trip with hazardous materials is low, spills can be extremely harmful to human health and the environment, and the full measure of risks and impacts need "to be assessed and characterized even in the absence of sufficient data for the quantification of all parameters involved" (Kazantzi et al. 2011). Quantitative measures of risk, singly or in combination, can be used in an absolute sense to inform stakeholders or comparatively to select an optimal route, including one associated with a No Action Alternative in an EIS (Barilla et al. 2009, Kazantzi et al. 2011).

CHAPTER 12
NEPA process overview and EPA modeling guidelines

The National Environmental Policy Act (NEPA) was enacted in 1969. Under the Act, Federal agencies are required to “engage in an environmental review process that integrates the consideration of the environment in Federal agency decision-making” (Council on Environmental Quality (CEQ) 2021). The CEQ (2021) continues

> In NEPA, Congress recognized that the Federal Government’s actions may cause significant environmental effects. Using the NEPA process, agencies must determine if their proposed actions will have significant environmental effects and consider the reasonably foreseeable environmental and related social and economic effects of their proposed actions that have a reasonably close causal relationship to the proposed actions.

NEPA is not the National Environmental Protection Act, and therefore

> NEPA does not require particular results or outcomes. Rather, NEPA encourages better decisions by requiring agencies to consider the environmental effects of their proposed actions in making their decisions. This environmental review process has two major purposes: ensuring that agencies consider the significant environmental consequences of their proposed actions and informing the public about their decision making. (CEQ 2021)

Cocklan-Vendl and Hemming (1992) summarized the NEPA process for EISs:

> NEPA requires that an EIS be "included in every recommendation or report on proposals for legislation and other major federal actions significantly affecting the quality of the human environment." Federal actions include a federal agency's decision on whether to grant its required permission for activities of others, such as private businesses or state or local governments.
>
> The EIS review process is designed to assure that all viable project alternatives have been considered in order to minimize the possibility of damage to the environment. As such, EPA uses a multiple-disciplinary review system for each of the impact statements submitted to the regional office for review. Impact statements are examined by specialists with expertise in air quality, water quality, engineering, biology, land use management, noise abatement, solid waste disposal, toxic substances, economics, and radiation health. Each person with an interest in the proposal has an opportunity to comment.

An EIS must contain the following:

1. A description of primary and secondary impacts on the environment including impacts on aesthetics, and aquatic and terrestrial ecosystems.
2. A description of any probable impact on the environment, including impact on ecological systems such as wildlife, fish, and marine life. The individual proposing the action must

consider and report all alterations to existing conditions whether or not they are deemed beneficial or detrimental.

3. An evaluation of appropriate alternatives to recommended courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resources.
4. An assessment of the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term environmental productivity.
5. A description of any irreversible and unretrievable commitment of resources.
6. A discussion of problems and objections raised by local entities in the review process, where appropriate.

Additionally, recall that 40 CFR, Section 1508.27 (cited in CH2M Hill 1993) included that among the considerations in its definition of intensity was "[w]hether the action is related to other actions with individually insignificant but cumulatively significant impacts. *Significance exists if it is reasonable to anticipate a cumulatively significant impact on the environment*. *Significance cannot be avoided* by terming an action temporary or *by breaking it down into small component parts*." (emphasis added).

EPA's guidelines about mathematical modeling should be applied to spill impacts, for transportation spills from accidents, other transportation spills such as leaks, and other spills associated with mining. The guidelines for model use (EPA 2012) include

- Predictions used in the analysis must have sufficient detail to support long term planning.
- Explanations of the model and assumptions must be provided.
- The probability that predictions are accurate should be disclosed.
- Uncertainties or gaps in data should be identified.
- The level of confidence in predicted outcomes should be provided so that reasonable decisions about management, monitoring, and mitigation will be made.
- Disclosure of the uncertainty and sensitivity analysis is a key component in interpreting predictions.

CHAPTER 13
Synthesis and recommendations

Synthesis

The objectives of this report were report to:

- Assess what spill risks are addressed in the permitting documents for five large hardrock mines in Alaska
- Use a consistent quantitative model for estimating the number of spills expected and probability of at least one spill
- Compare observed spills to predicted numbers
- Compare the spill histories of the five case study mines to those of the other mines in Alaska
- Offer model critiques
- Identify data gaps
- Synthesize the findings and make recommendations for the EIS/NEPA process for proposed new mines and mine expansions

Of the five mines studied, only two, Pogo and Kensington, attempted quantitative spill predictions at the initial EIS phase and only one, Red Dog, examined mine specific spill rates in a supplemental EIS. The modeling of spill risks was restricted to trucking accidents of single materials such as ore concentrate or diesel and spills related to pipelines.

The truck accident spill model of $N = RT$ has some precedent in other environmental permitting for large mines and has used a value of $R = 1.87 \times 10^{-7}$ spills per mile (Harwood and Russell 1990). The $N = RT$ model only applies to trucking accidents, such as *collisions/allisions* and *rollovers/capsizes*. Other types of transportation spills, such as *leaks*, *cargo not being secured*, or *overfilling of tanks*, are not considered in this model. The $N = RT$ model requires an estimate of T, the total vehicle miles traveled with hazardous materials. The EIS/EAs did not apply the model to any substances other than diesel or ore concentrate, although other hazardous substances from cyanide and lime to ammonium nitrate and sulfuric acid are also transported to the mine in quantities up to hundreds of tons each year. Even with incomplete information about the substances, quantities, load sizes, and total loads, I was able to estimate a minimum value of how many truck accidents would have been expected across all five mines. I found that 4.3 such spills would have been predicted to occur through 2020. In practice, the five mines had a combined total of 114 truck accidents spills which released 5,924 gallons and 1,658,481 pounds of hazardous materials.

The total number of transportation spills was 1,004, resulting in 33,404 gallons and 1,771,077 pounds released. The trucking accident spills were not only inadequately modeled, but the model also only addressed a small fraction (11.35%) of the transportation spill frequency. The trucking accident spills account for 17.73% of the overall transportation spill volume released and 93.64% of the weight released, mostly due to ore concentrate spills along the 50-mile DMTS from Red Dog Mine to the port facility. In turn, the transportation spills from all causes represented only 12.31% of 8,157 recorded spill incidents for these five mines from July 1995-December 2020.

Within EISs, spill impacts are usually only addressed qualitatively. Spills of individual substances, such as diesel, from specific sources, such as tanker trailers, and certain events, like accidents or fuel transfers, are described as low probability events, but the aggregate, cumulative risks and impacts of all the hazardous material spills from all sources and causes are not addressed. There were more than 35 hazardous materials specified for use at the five mines. At least 49 hazardous materials are listed in the ADEC spill database associated with these five mines. Only 12-20% of them were mentioned in the EISs as part of reagent lists, fuels, or tailings that could be released. While there were references to material safety data sheets in Spill Prevention Containment and Countermeasure Plans, the EA/EISs documents themselves gave only cursory descriptions, if any, of the properties of reagents such as sodium cyanide and sulfuric acid, non-crude oil products and antifreezes that are spilled frequently, ore concentrate, tailings/process water, and other mine wastes. EA/EISs are prospective documents; later SEISs and plans of operations gave more detailed lists of reagents than were available at the initial permitting stages (see Pogo, Greens Creek, Fort Knox/True North and Red Dog reagents lists).

Spill modeling only addressed diesel, ore concentrate, ore slurry, tailings, and wastewater. Although spill probabilities at mines are often characterized as low in permitting documents, especially for individual hazardous materials from specific sources, from July 1995-December 2020, there were 8,157 spill incidents that released 2,363,245 gallons and 1,938,520 pounds of hazardous materials at the five hardrock mines in these case studies. In short, few EISs quantitatively addressed any spill risks, those that did only considered some of the hazardous materials singly, and the $N = RT$ model was inadequate to predict a subset of spills which comprised 1.4% (114 of 8,157) of all the spills recorded at the five mines.

The $N = RT$ model used to estimate transportation corridor risks was the only example implemented in any of the EISs examined, and even then, it was done poorly. The prospective descriptions in the EIS have several serious flaws. EIS/EAs lack explicit, complete, and quantitative reagents lists, as well specifications of other chemicals for blasting, water treatment, and spill mitigation, that would be considered as hazardous materials being transported to or from the mine or used on-site. Other hazardous materials, such as hydraulic oil and antifreeze, which are essential to the mining process are also not mentioned but form a significant portion of the spill incidents. The EIS/EAs also lack complete descriptions of the transportation method, load size, and frequency for the hazardous materials that would be essential for calculating the number of road miles traveled as part of quantitative risk assessment. The few EISs that included quantitative transportation spill risk estimates computed them for individual substances, such as diesel or ore concentrate, and not for the aggregated total of trips, thus underrepresenting the number of trips and potential for accidents and spills for the whole mine operation's hazardous materials spill risk.

Not only was there incomplete information about the hazardous materials brought to and from and used at the mines, the risk assessment for accidents on the transportation corridor are flawed. The $N = RT$ model uses a value of R from Harwood and Russell (1990) based on data from California, Michigan, and Illinois that are now at least 30 years old to estimate hazardous material spill rates per vehicle mile. The model assumes that every mile has the same spill rate and does not account for any differences for Alaskan locations from the national data the estimate of *R* was based on. Even if the model is good, if *R* or *T* is wrong, then *N* will be, too. More comprehensive models of hazardous material trucking accident risks are plentiful in the peer-reviewed literature. Even if the trucking accident release rates and probabilities are successfully modeled, spills and releases along the transportation corridor from accidents (i.e. *collisions/allisions* and *rollover/capsizes*) are only a fraction of transportation incidents, and transportation incidents are only small fraction of all spills. Likewise, spills are only a small portion of environmental impacts from mining. It is possible that other impact descriptions in EIS/EAs are as inadequate as those for spill risks.

It may be difficult to estimate spill risks for new mines on new roads, but site-specific information can be used to improve risk and impact prediction. The mines in this case study were often expanded and/or their project lives extended beyond the scope shown in the initial permitting documents, sometimes with the production of supplemental EISs. Those later documents should reflect the expanded or extended spill risks, which would be possible to compute based on site specific data and experience. Only the ore concentrate spill rate from trucks along the DMTS from Red Dog to the port was calculated based on observed incidents, but that spill rate per year was not then used to estimate the number of expected spills if the project were to be extended until 2031. (Again, this was only done for a single hazardous material, ore concentrate, and the same kind of analysis was not undertaken for any other transportation spill risks or other spill risks.)

ADEC (2021) has lots of information describing spill incidents. Unfortunately, data about whether a spill breaks containment, reaches the environment, and what sorts of clean up occurred are not readily available among them. Such data are necessary for a full understanding of the environmental impacts at the mine sites, along the transportation corridors, or in assessing the quantity of hazardous materials and waste produced by the mines. The oil spill history from Greens Creek Mine showed that 80 out of 139 spills (57.6%) were not contained (Hecla Greens Creek Mining Company 2020). At Fort Knox, roughly 20% of spills since 2012 are characterized as out-of-pit (SRK Consulting 2019). These two characterizations, which are from environmental audits for an underground mine and an open pit mine, respectively, are insufficient to describe how much spilled material reaches the environment.

Recommendations

Recall from the Pogo EIS that the metrics for rating the impact levels of accidental or unplanned chemical or fuel releases was (EPA 2003b):

- *No or low impact*: No planned release or low likelihood of occurrence; if an accidental release or spill occurred, the potential for impacts to environment or public interests would be negligible.
- *Moderate impact*: There is a risk of accidental release, or a release has a low likelihood of occurrence but the impacts could be high.

- *High impact*: A high potential for accidental release exists, and the severity of the release would be high.

Based on the experience from these five mines, we cannot expect that spills are low probability events or that their total frequency can be accurately predicted based on overly simplistic models that only address two potential spill causes/sources.

Several recommendations arise from this analysis, both for the NEPA and EIS process and for later record keeping.

Within the NEPA/EIS process:

- Include an explicit, complete, and quantitative reagents list, as well as other chemicals for blasting, water treatment, spill mitigation, and materials associated with the mining machinery, such as hydraulic oil and antifreeze, that would be considered as hazardous materials being transported to or from the mine or used on-site.
- Include complete descriptions of the transportation methods, load sizes, and frequency for the hazardous materials listed above, as well as tailings and other hazardous wastes.
- Include quantitative transportation spill risk estimates for the aggregated total of trips for the whole mine operation's cumulative hazardous materials spill risk.
- The peer-revied literature for risk analysis of hazardous materials transportation is robust. Consider more detailed transportation spill risk models, with up-to-date risk rates and location-specific descriptions of the transportation corridor that allow for modification from national or regional average estimates of *R*.
- When assessing hazardous material spill risk, consider that the transportation corridor to model is not just defined by the length of the any newly built roads associated with the mine, but instead extends to the origin(s) and destination(s) of the hazardous materials. As noted by Barilla et al. (2009):

  > Generally HazMats have to be transported from a point of origin to one or more destination points. The origin points are fixed facilities where the HazMats are produced or stored. The HazMats are then transported from a production facility to storage, distribution, or another facility where the HazMat is required.

- Acknowledge that accident modeling only describes one potential way hazardous materials are released from vehicles, and that transportation-related releases can have a multitude of causes, many of which are not modeled. Modeling transportation accidents is a necessary step, but not sufficient to model all transportation spills or all the unintentional releases that occur at mines.
- Be explicit about the numbers of expected spills. Spill rates per year for individual pollutants from individually modeled sources (such as ore concentrate spills per year along the DMTS from truck accidents in the Red Dog SEIS (EPA 2009)) not only underestimate the overall spill rate, but they also give a value that is not useful or informative to most readers of EISs. The two goals of the EIS production process are to clearly state potential consequences of

projects and to inform stakeholders and decision makers of those impacts. The current treatment of spill risks in mining EISs does neither.

Within the state and federal spill recordkeeping agencies, there are many aspects of spill data that are necessary to have a fuller understanding of the impacts of the spills. What was spilled, where it was spilled, what media it impacted, and how it was cleaned up are all important details. Some of these have been reported in mine environmental audits or general plans of operations but they are not part of the ADEC spill database in many cases.

- Within ADEC'c spill database
    - Note if spilled substances broke containment and reached the environment, what clean-up protocols were followed, how successful they were, and if the clean-up created any hazardous waste that had to be transported. This may mean more detailed and finer scale location data within the mine site (in- or out-of-pit, within the mill site, etc.) presented as a new field. Some of those descriptors are present in select spill names or records that are found by the searches using the identifying spill number, but they are inconsistent and incomplete, making it hard to understand the proportion of spills directly affecting the environment.
    - Searching for spills by mine or responsible party is inefficient because there are so many variations on ways a single mine's spills are attributed. Simple spelling errors in the responsible party names would make it so that, in the case of Red Dog Mine, a search on "Cominco" would not return spills attributed to "Comicno" or "Comnico" in the database, nor would searches for Teck Alaska spills return any information about spills listing "TechCominco" as the responsible party. Similarly, within the database, it can be difficult to synthesize information for specific types of spills (e.g. transportation spills), spill causes, or substances (e.g. many spills listed as "other", misspellings of substance names, and mismatches between substances mentioned in spill names and those listed in the "substance subtype" field (e.g. "zinc", "zinc concentrate", and "zinc slurry" are not synonyms)).
    - Add tracking of sewage and wastewater spills to the spill database. Such releases are common and can negatively impact human health and the environment.

Although I have made suggestions to make the ADEC spills database more complete and more useful for studying broad questions about spills, ADEC is a remarkably thorough repository of spill record information and could serve as a model for other state and federal incident libraries. Unfortunately, there is very little within the ADEC spills database that is also within NRC or PHMSA databases. A clarification of the reporting requirements between the three organizations might help explain this discrepancy. If the NRC database is a complete record of all the spills that reached the environment, that would be a way to estimate the proportion of spills reported in ADEC that escape containment at the mines. If that were the case, the 197 spills attributed to the mines considered in this report that were listed in the NRC database from 1990-2020 represent <2.4% of the spill incidents. (ADEC (2021) had 8,157 spill incidents from July 1995-December 2020.) This value seems very low when compared to the 20% of spills at Fort Knox since 2012 that were out-of-pit or the 57.6% of oil spills at Greens Creek Mine which were not contained. The PHMSA spill database and portal have even less overlap regarding mining related spills.

Spill risks were only one aspect considered in the EISs (or less intensive EAs) of the five case study mines in this report, but they serve as an example of how these EISs have failed to use the latest, best available science in the EIS process, have not adequately considered the significant environmental consequences of their proposed actions, and have not informed the public about potential environmental impacts from mining spills in a comprehensive way that reflects the reality of mining operations.

CHAPTER 14
Summary

Introduction

This report has several objectives:

- Assess what spill risks are addressed in the permitting documents for five large hardrock mines in Alaska
- Use a consistent quantitative model for estimating the number of spills expected and probability of at least one spill
- Compare observed spills to predicted numbers
- Compare the spill histories of the five case study mines to those of the other mines in Alaska
- Offer model critiques
- Identify data gaps
- Synthesize the findings and make recommendations for the EIS/NEPA process for proposed new mines and mine expansions

The Alaska Department of Environmental Conservation maintains a public database of hazardous materials spills dating from July 1995 to the present. Spill data include location information, spill size and substance, and spill causes. Hazardous materials are divided into the substance classes crude oil, non-crude oil, extremely hazardous substances, hazardous substances, and process water.

The five mines studied in this report are three underground mines: Pogo, Kensington, and Greens Creek, and two open pit mines: Fort Knox/True North and Red Dog. I examined EIS/EAs for each mine, as well as environmental audits and General Plans of Operations when available to examine what spills risks were considered, what hazardous materials were transported, and any records of spills discussed.

Most of the quantitative spill estimates in mine EISs are for truck accidents, and the model $N = RT$, where N is the number of expected spills, T is the total miles traveled by hazardous materials, and R is the spill rate per truck mile, is most commonly used. The widely cited value for R is 1.87×10^{-7} spill per truck miles for two-lane rural roads (Harwood and Russell 1990), and T varies by mine. I applied the $N = RT$ model to all five mines in this report for all hazardous materials transported by truck to compare the model predictions of truck accident spills with the observed spill record since the mines began construction and operation.

Pogo

Pogo Mine is an underground gold mine approximately 38 miles northeast of Delta Junction in the interior of Alaska, predicted in its EIS to process 2,500 to 3,500 tons of ore per day (tpd).

Pogo Mine was permitted in 2003 and had an expected mine life of 11 years at an ore production rate of 2,500 tpd (EPA 2003b). As of 2017, the projected mine life at a milling rate of 3,000 tons per day was six years.

Pogo Mine has a 49.5-mile transportation corridor used to supply the mine with the necessary blasting agents, fuel, and reagents for a gravity/flotation/cyanide vat leach process. The cyanidation circuit was projected to process 250-350 tpd of flotation concentrate.

Nearly 5,000 tons of reagents and explosives were called for annually under the 2,500 tpd scenario, a figure that increases to more than 7,200 tons per year under the 3,500 tpd production rate. Under the 2,500 tpd production rate, Pogo Mine would require 1,000 tons each of explosives, lime, sodium cyanide, and sodium metabisulfite per year; those quantities increase to 1,500 tons annually under the 3,500 tpd ore production rate. Those values do not include other reagents needed in smaller quantities or diesel fuel (786,000 to 1,3000,000 gallons needed annually, depending on ore production).

Transportation of the reagents, fuel, explosives, and grinding media and liners were estimated to require 561 to 909 (loaded, one-way) trips per year, again depending on ore production, along a two-lane, all-season road with grades up to 7 or 8% that would have six single-lane bridges over five creeks. There were an estimated 100-161 loads required for diesel and 116-231 loads of propane to be delivered annually.

Based on the $N = RT$ model and using the Harwood and Russell (1990) estimate of $R = 1.9 \times 10^{-7}$ spills/mile, the 2003 EIS (EPA 2003b) estimated that there was a 1% chance of spill over the 11-year project life and the 2,500 tpd ore production rate. Once the remaining hazardous materials (propane, explosives, reagents, etc.) are included, the estimate of the expected number of spills along the transportation corridor was 0.057 to 0.068, and the probability of at least one spill was 5.6% for the 2,500 tpd ore production scenario and 6.5% for the 3,500 tpd ore production rate. (In the EIS, EPA (2003b) did not consider 1% to be a high risk, but a 6% chance of a spill was considered high.)

Based on data from ADEC (2021) there were 12 spills due to *collision/allision* and *rollover/capsize* incidents attributed to Pogo Mine from 1998-2020, four of which were diesel spills, four which were other forms of *non-crude oil* (gasoline and engine lube oil), and four spills of *hazardous substances* (ethylene glycol, propylene glycol, and “other”). There were an additional 53 transportation-related spills associated with Pogo Mine, for a total of 65 transportation spills.

There were an estimated 1,503 spills related to Pogo Mine from 1995-2020 in ADEC (2021). Spills related to vehicle or heavy equipment accidents (*collisions/allisions* + *rollover/capsizes*) represent less than 1% of the total incidents. Transportation spills from all causes were estimated to account for 4.3% of the spills associated with Pogo Mine.

Almost 1,300 of the spills at Pogo Mine were of *non-crude oil*. The cumulative volume of all the spills is over 260,000 gallons. The largest spill was 135,000 gallons of mill slurry due to a line failure in May 2015. While more than 95% of the spills were of <100 gallons, the 5% of spills that were ≥100 gallons accounted for 97.5% of the volume released. There were 17 spills of at least 1,000 gallons. More than 8,600 gallons of *non-crude oil* were spilled at Pogo Mine, including more than 4,000 gallons of hydraulic oil in more than 1,100 incidents. Although *non-crude oil* spills accounted for 86.1% of the number of recorded incidents, accidental releases of *hazardous substances* represented 89.6% of the volume spilled.

The most common causes of the 143 *hazardous substance* spills were *equipment failure* (64 spills), *containment overflow* (21 spills), and *line failure* (15 spills). The 1,291 *non-crude oil* spills were overwhelming attributed to *equipment failure* (971 spills), followed by *line failure* (136 spills) and *leaks* (67 spills). *Process water* spills were most often due to *human error* (20 spills) and *containment overflow* (14 spills).

The number of recorded incidents of *non-crude oil* spills increased dramatically in 2016 from fewer than 40 spills per year from 1998-2015 to 135-344 per year from 2016-2020.

In addition to the spill record from ADEC (2021), Pogo Mine has a history of raw sewage, drill water, storm water, treated water, and treated effluent spills, with 31 such releases totaling to 16,520 gallons from September 2004-March 2007 alone.

Kensington

Kensington Mine is an underground gold mine roughly 45 miles north-northwest of Juneau, Alaska, with infrastructure that includes mill facilities, a tunnel connecting Kensington Mine to Jualin Mine, permanent waste rock disposal facilities near the Kensington Mine and the Jualin Mine process area, and a tailings storage facility. Ore production was expected to be 2,000 tons per day (tpd) in the 2004 EIS (USFS 2004) and 3,000 tpd under the updated Plan of Operations (USFS 2021).

Kensington's processing facility is "a conventional milling gold froth flotation recovery circuit. The major components include crushing, grinding, gravity separation, flotation, thickening, and filtering" (USFS 2021).

A 12,000-foot tunnel connects Kensington Mine to Jualin Mine and is the primary access for workers and materials into the mine, as well as ore haulage between the mine and mill (USFS 2004). There are two roads from the coast to mine facilities: the 5.5-mile Jualin Road from the Slate Cove Marine Terminal and the 1.8-mile Comet Beach Road which connects Comet Beach to the Comet Portal (USFS 2021). There is a 3.5-mile buried tailings pipeline from the mill near the Jualin Mine portal to the tailings storage facility at Lower Slate Lake (USFS 2004). The amended plan of operations would have 37 daily trips carrying filtered tailings to the filtered tailings facility. (Assuming tailings are transported 365 days per year in 20-ton loads, this is 270,100 tons of filtered tailings per year.)

Reagents, blasting materials, and fuels are delivered to Slate Creek Cove and then transported by road to the mill, with ore concentrate making the reverse journey. Under the 2,000 tpd ore production scenario from the 2004 EIS (USFS 2004), 2,146-2,511 tons of chemicals and materials (excluding fuel and blasting agents) were to be used at Kensington Mine annually. When the ore production rate is increased to 3,000 tpd, the material and chemical needs are estimated as 2,854 tons per year.

The 2004 EIS estimated that 3,200,000 gallons of diesel would be used annually under Alternative D, requiring 492 truck trips with each truck hauling 6,500 gallons (USFS 2004). Under the amended plan of operations, those figures could increase to 4,800,000 gallons of diesel in 738 truckloads.

The total amount of hazardous materials transportation was estimated as 2,472 loads per year under the scenario described in the 2004 EIS and 17,213 loads per year under the amended plan of operations with expanded production and tailings haulage by truck.

Harwood and Russell's (1990) estimate of $R = 1.87 \times 10^{-7}$ spills per mile was used in the 2004 EIS to estimate the percent chance of diesel spills annually and over the expected project life for six Alternatives considered (USFS 2004). The road length, load size, and number of loads per year varied, but all Alternatives were expected to have a $\leq$0.5% chance of at least one diesel spill over the life of the project. Pipeline spill risks were also calculated. Once the other hazardous materials to be transported were included, the probability of at least one spill for Alternative D from 2006-2020 was 3.4% and the probability of at least one spill in the next 10 years under the amended plan of operations was 5.1% using the $N = RT$ model with the same value of R.

Based on data from ADEC (2021) there were four *collision/allision* and *rollover/capsize* spills associated with Kensington Mine through the end of 2020. There were an additional 30 spills associated with mine transportation from causes such as vehicle leaks and cargo not being secured, for a total of 34 transportation spills. Spills from accidents (*collision/allision* + *rollover/capsize*) were 11.8% of transportation spills.

Overall, ADEC (2021) listed 308 spills of 18 different hazardous materials at Kensington Mine, with a total of 6,272 gallons released. Most of the substances spilled were not mentioned in the permitting documents. The most frequently spilled substance was hydraulic oil (170 spills totaling 1,609 gallons). The greatest percentage (90.6%) of spill incidents involved *non-crude oil* products, mostly diesel fuel and hydraulic oil. *Non-crude oil* products were also 69.4% of the total volume released. Although 95.4% of the spills were <100 gallons, the remaining 4.6% of the spills (those $\geq$100 gallons) accounted for 64.1% of the volume released. The largest single spill incident was a release of 800 gallons of *process water* due to a coupler failing at slurry pond 1 on August 4, 2018.

Hazardous and *extremely hazardous substances* represented 9.1% of the number of spill incidents and 17.9% of the volume spilled. They were most often caused by *human error* (12 spills), or *line failure* (6 spills). *Non-crude oil spills* were most commonly caused by *line failure* (108 spills), *equipment failure* (52 spills), and *leaks* (40 spills). The number of reported spills per year has been increasing at Kensington Mine, especially for *non-crude oil*.

In addition to the spills reported to ADEC, Kensington Mine also had 28 sewage and grey water spills from 2008 to 2019, with a combined volume of 2,836.5 gallons. Eighty-one percent of that volume came from two spill incidents: a 950-gallon release of grey water at the Slate Cove lay down yard in

May 2010 and a 900-gallon release of grey water on the Jualin access road between Spur Road and the port in January 2017.

Kensington Mine has published annual reports from 2006-2021 with lists of their hydrocarbon spills (2005-2007) and all hazardous materials spills (2008-2020). Two reports (Coeur Alaska, Inc. 2007, 2021) mentioned spills but did not include tables showing them. Kensington Mine's list of spills has many discrepancies when compared against the records in ADEC (2021). Many of those differences were Kensington Mine listing sewage and grey water spills that were not in ADEC (2021), but there were multiple instances of other types of spills being listed in one source and not the other in both directions.

Greens Creek

Greens Creek Mine is an underground mine located on Admiralty Island, about 18 miles southwest of Juneau, that produces silver and gold, as well as lead and zinc concentrates. In the initial EIS the estimated life of the mine based on the known ore reserves was 11 years and the life of operations was 15-17 years for planning purposes (USFS 1983), but Greens Creek Mine is still in production today.

Initially, it was thought that Greens Creek Mine would produce about 800 tons per day of ore and 300 tons per day of waste rock (USFS 1983). The 1983 EIS predicted that 160 tons of zinc concentrate and 100 tons of lead concentrate would be produced per day (USFS 1983), for a combined production of 94,900 tons per year. The 2013 EIS more than doubled that rate, and described the annual production of zinc, lead, and bulk concentrates as 200,000 tons per year (~550 tons daily). By 2013, ore was mined at a rate of ~2,200 tons per day (USFS 2013a).

The major mine infrastructure includes "the mill and underground mine area, Site 23 waste rock storage facility, Hawk Inlet Facility, the [tailings disposal facility] TDF, Young Bay dock, approximately 13 miles of connecting roadways, a power intertie connecting the Mine to the Juneau area power grid, and various pipelines and outfalls for wastewater and stormwater" (Hecla Greens Creek Mining Company 2020). Ore is crushed and made into a slurry that goes through a flotation process to concentrate minerals, and filtered ore concentrate is shipped to an off-site smelter.

The road from the Hawk Inlet Facility, where supplies are brought in and ore concentrate is shipped out, to the mill site is 8.5 miles long (Hecla Greens Creek Mining Company 2020). Reagents in use at Greens Creek Mine include sodium cyanide, copper sulphate, and inorganic and organic salts (USFS 1983), as well as concentrated sulfuric acid, SIPX, MIBC, and lime (USFS 2003), but annual usage quantities were not given for the reagents, blasting agents, or fuel. Neither the EIS nor the later supplemental EIS (USFS 1983, 2013) included estimates of expected spill frequencies.

Based on an estimated number of annual truckloads for ore concentrate, mine supplies, and tailings with the $N = RT$ model using the Harwood and Russell (1990) value of R, 0.76 spills from transportation accidents would have been expected at Greens Creek Mine from 1989-2020 for a 53.4% chance of at least one spill over that time. According ADEC (2021) there were seven *collision/allision* incidents and three *rollover/capsize* incidents at Greens Creek Mine from 1995-2020. There were an additional 113 spills related to transportation from other causes, such as *vehicle leaks*, *cargo not secured*, and various forms of *equipment failure,* for a total of 123 spills related to transportation at Greens Creek Mine from 1995-2020. Accidents (*collision/allision* + *rollover/capsize* incidents) made up 8.1% of transportation spills.

The full ADEC (2021) record of spills for Greens Creek Mine listed 1,515 incidents from 1995-2020. Transportation spills from all causes comprised 8.1% of that list, and transportation accident-related spills were 0.66% of the total. The common type of spill was hydraulic oil, with 1,039 spills releasing 7,196 gallons. The largest single spill listed in ADEC (2021) was a 72,000-gallon process water spill from December 2004. Overall, more than 2,000 gallons of *hazardous substances* were spilled in 90 incidents, and more than 19,000 gallons *of non-crude oil* were spilled in just less than 1,400 incidents. There were nearly 14,000 pounds of *hazardous substances*, including arsenic, lead, zinc and zinc concentrate, tailings, and copper sulfate, spilled in 15 incidents (Table).

ADEC (2021) lists eight spills of ≥1,000 gallons at Greens Creek Mine. The spills of <1,000 gallons accounted for 99.4% of the incidents, but the remaining 0.6% of the spills represented 84.6% of the volume released. These records do not include some spills listed in spill logs from Greens Creek's most recent Plan of Operations (Hecla Greens Creek Mining Company 2020), which also showed a 2,000,000 to 9,000,000-gallon spill of treated process water in June 2013 among 42 spills listed in Greens Creek Mine records but not ADEC (2021).

True North/Fort Knox

Fort Knox Mine is a conventional open-pit gold mine 26 miles northeast of Fairbanks, Alaska. Fort Knox's initial major components were the mine site, the development rock and overburden stockpiles, the mill site, the tailings impoundment, and the water and power supplies (CH2M Hill 1993). After permitting in 1994, Fort Knox's construction began in 1995, and gold has been produced there since 1996 (SRK 2019). True North was a satellite deposit 12.5 miles away from Fort Knox, with the ore mined at True North hauled to Fort Knox for processing. The first ore from True North was processed at Fort Knox in March 2001 (Fairbanks Gold Mining, Inc., 2001), and True North Mine was closed in 2012 (SRK 2012). The Walter Creek Valley Heap Leach Facility (WCVHLF) at Fort Knox was authorized in 2007, with ore placement and leaching beginning in 2009 (SRK 2019).

Since the 1997, the average milling rate at Fort Knox has been above 36,000 tons per day, with a nominal milling rate of 36,287 tons per day (Sims 2015). Fort Knox has an operating capacity of 35,000 to 50,000 tons of ore per day to produce approximately 300,000 ounces of gold each year. Before the introduction of the heap leach facility, the steps for processing the ore were crushing, grinding, gravity concentration, cyanide leaching, gold recovery, cyanide detoxification, and discharge of tailings (CH2M Hill 1993). For higher grade ore, the mill at Fort Knox uses the conventional processes of crushing and finely grinding the ore in ball mills, followed by gravity concentration and agitated cyanide leaching, and finally a carbon-in-pulp (CIP) circuit for gold adsorption on carbon and carbon stripping. Lower grade ore is processed in a "run-of-mine valley-fill cyanide heap leaching operation where gold is recovered using two parallel carbon-in-column (CIC) circuits" (Sims 2015). The addition of a thickener to the ore process decreased the need for some reagents in 2002.

Fort Knox is about 26 miles from Fairbanks, and True North was 12 miles from Fort Knox. The route from Fairbanks to Fort Knox goes along the Steese Highway to Cleary Summit and then around Pedro Dome. Reagents in use at Fort Knox have included lime, sodium cyanide, sodium hydroxide, hydrochloric acid, sulfur dioxide, copper sulfate, lead nitrate, and ammonium nitrate, among others. Reagent quantities were given for cyanide, ammonium bisulfite, and copper sulfate in an environmental audit of Fort Knox (Golder Associates, Inc. 2004) and in a technical report a decade later (Sims 2015), but the original environmental assessment (CH2M Hill 1993) did not include the quantities required and load sizes, and neither were any associated environmental or health hazards.

Within the environmental assessment (CH2M Hill 1993), the possibility of accidental releases was acknowledged in the context of medical training and response, but there were no prospective estimates of the number of spills that might be associated with Fort Knox Mine, either at the mine and milling site or along the transportation corridor.

After estimating the quantities of reagents, fuel, and blasting materials for Fort Knox/True North based on the partial information given and reagent use at Pogo Mine, I estimated the number of truckloads of six reagents, ammonium nitrate, and diesel to be shipped to Fort Knox as 1,492 annually through 2002 and 1,272 in 2003 and later. With an additional daily trip for the remaining reagents, I used an estimate of 1,880 trips per year through 2002 and 1,600 annual trips in 2003 and later. Using the $N = RT$ model with Harwood and Russell's (1990) estimate of R, Fort Knox would have been expected to have 0.21 spills from transportation accidents from 1996-2020, with an 18.7% chance of there being at least one spill over that period.

Based on records from ADEC (2021), there were 31 *collision/allision* and *rollover/capsize* spills recorded for Fort Knox and True North Mines, which were 10.3% of the 301 spills related to transportation. More than 11,600 gallons were released due to transportation spills.

In all, there were 1,874 spills associated with Fort Knox and True North Mine and 75 spills associated with Alaska West Express and Lynden Transport along the Steese Highway, Elliot Highway, or in Fairbanks City or Fairbanks North Star Borough. If all the Alaska West Express and Lynden Transport spills are included with the Fort Knox/True North spills, there were a total of 1,949 spills associated with those mines from July 1995-December 2020.

The most frequently spilled substance was hydraulic oil, with 846 recorded incidents (43.5% of the number of incidents) and 42,433 gallons released (8.0% of the total volume). More than 88% of the spills were <100 gallons in size, and 1.5% (28 incidents) were ≥1,000 gallons. The spills of <100 gallons collectively accounted for 5.9% of the total volume released, and spills ≥1,000 gallons accounted for 85.3% of the volume. Spills classed as *hazardous substances* and *non-crude oil* had the largest numbers, but the largest volume spills were of *process water*. The largest individual spill was 305,370 gallons of process solution in May 2010.

Environmental audits (SRK 2012, 2019), a technical report (Sims 2015), and a waste management report (Kinross Gold Company 2020) considered spills at Fort Knox at various levels of detail. The description of spills in SRK (2019) allowed for an estimate that ~18 to 23% of spills at Fort Knox from 2012-2019 were out-of-pit. There were discrepancies in the spill records listed in Kinross Gold Company (2020) and ADEC (2021) for the fourth quarter of 2019.

Red Dog

Red Dog Mine is an open pit lead and zinc mine, roughly 82 miles north of Kotzebue and 47 miles inland from the coast of the Chukchi Sea (EPA 1984, 2009). Red Dog has a current annual output of 1,000,000 pounds of zinc concentrate. While many of the mine components (mine, mill, tailings pond, housing, and water supply facilities) are on private land owned by the NANA Regional Corporation, the transportation corridor goes through Cape Krusenstern National Monument (EPA 1984, 2009). Red Dog Mine began ore processing 1989 (EPA 2009), followed by an expansion into the Aqqaluk ore deposit. The initial estimates of the ore deposit were that >85 million tons of ore were present (EPA 1984). The expected life of the mine was at least 40 years but is now expected to last until 2031 or longer.

The Delong Mountain Transportation System (DMTS) includes a 30-foot wide gravel industrial haul road that is 52 miles long and port infrastructure. The road has nine bridges for crossing creeks. Pipelines to transport ore slurry, tailings impoundment water, and diesel to or from the port were considered but never built.

The expected initial ore concentrate production amounts were 479,000 tons/yr in the first five years and 754,000 tons/year in years six and later (EPA 1984). Production increased to 1.5 million tons of ore concentrate shipped from the port site annually (EPA 2009).

Red Dog uses zinc sulfate, copper sulfate, sodium cyanide, and MIBC, among other reagents. Reagent use increased from an estimated 5,530 tons per year during initial production to 11,731 tons per year in expanded production (EPA 1984) to 15,841 tons per year by 2009 (EPA 2009). In addition, Red Dog consumed an average of 16,710,880 gallons of diesel annually between 2000 and 2006. Approximately 39 one-way truck trips per day were averaged for ore concentrate, fuel and supplies (EPA 2009). The initial EIS left the transportation corridor risks as "undetermined probabilit[ies]" (EPA 1984). The supplemental EIS stated that "Traffic statistics using accident and spill data will be used to assess the effects of changes in transportation among the alternatives" (EPA 2009). The EPA (2009) estimated that 0.6 ore concentrate spills per year could be expected along the road from the mine to the port but did not then calculate the number of expected spills over the remaining life of the project or estimate spill rates for any other hazardous materials.

Based on production levels estimated for initial production (1989-1993), expanded production (1994-2002) and current production (2003-2020), the number of annual trips with hazardous materials (ore concentrate, reagents, diesel, and ammonium nitrate) increased from ~3,700/year, to ~5,600/year, to ~14,000/year. With more than 320,000 truckloads transporting hazardous materials 52 miles, 3.2 spills would have been expected from transportation accidents from 1989-2020 under the $N = RT$ model with Harwood and Russell's (1990) value for R and the probability of at least one such spill would have been 95.8%.

Based on records from ADEC (2021), *collision/allision* and *rollover/capsize* accounted for a combined 58 (12.1%) of the 481 transportation spills associated with Red Dog Mine from 1995-2020. The most common cause subtypes associated with transportation-related spills at Red Dog were *line failure* (114 spills), *leaks* (77 spills), and *cargo not secured* (57 spills). There were 25 spills of zinc or zinc concentrate from transportation-related incidents between 1995 and 2020, with 7 of those between 2012 and 2020.

Based on records from ADEC (2021), there were 2,882 spills attributable to Red Dog Mine from 1995-2020. There were 192 incidents with quantities in pounds, and the remaining 2,690 spill amounts were in gallons. Transportation spills (including all subcauses) were 16.7% of the total spills, with (*collision/allision* + *rollover/capsize*) spills as 2% of all spills associated with Red Dog. *Non-crude oil* and *hazardous substance* spills accounted for 2,441 out of 2,690 spills listed in gallons, with more than 1,000 spills of hydraulic oil. The *hazardous* and *extremely hazardous substances* spilled included cyanide, sulfuric acid, and glycols, as well as ore concentrates and slurry. While 56% of the spills were less than 10 gallons, the relative infrequency of larger spills was overshadowed by their contribution the overall volume of hazardous materials released. The 10% of the spills that were of 100 gallons or more amassed 98% of the total volume accidentally released. More than 20% of the spills listed by weight were of at least 1,000 pounds; those spills accounted for 99% of the materials released listed by weight. ADEC (2021) shows there were 128 spills of $\geq$1,000 gallons or pounds associated with Red Dog Mine from 1995-2020.

There were 1,048 hydraulic oil spills totaling to 11,363 gallons at Red Dog Mine. While those spills represent 39% of the number of spills listed by volume, they only account for 0.8% of the 1,450,397 gallons spilled. *Hazardous substances* (719,118 gallons) and *process water* (699,924 gallons) were 49.6% and 48.3% of the total spills given by volume, respectively.

Case study summary

Mining operations spills were the most common classification for spills associated with the mines, accounting for 89.7% of the incidents at the five mines in the case studies.

None of the mines had quantitative spill predictions for anything other than transportation spills, and the transportation spill risks calculated were limited to single substances spilled via truck accidents or pipelines. The math for implementing the $N = RT$ model is straightforward, but it cannot work unless the EIS or EA has enough specificity about what hazardous materials will be transported, how much of each, and in what size loads to calculate the number of trips. Most of those data were incomplete or had to be based on inference in the EISs examined in this report.

Based on the expected umber of spills from the $N = RT$ model and using a Poisson distribution to estimate the probability of at least one truck accident spill from the beginning of the projects through 2020, the probabilities of truck accident spills ranged from 3.4% for Kensington to 95.8% for Red Dog. Considering the expected number of miles traveled for all five mines through 2020, the $N = RT$ model would have predicted that there would have been 4.3 trucks accidents. Based on the records from ADEC (2021) there were 114 *collision/allision* and *rollover/capsize* accidents, which is 26.5 times as many as would have been predicted. These 114 accidents spilled nearly 6,000 gallons and 1,660,000 pounds of hazardous materials. The truck accident spills only represent a 11.4% of all 1,004 transportation-related releases from the five mines considered.

While truck accident and pipeline spills are the only spills with quantitative representation in any of the EIS/EAs examined, they are only a small portion all the transportation spills or of the overall number of spills. The five mines considered here had more than 8,150 spill incidents, releasing >2,360,000 gallons and >1,930,000 pounds of hazardous substance since July 1995.

Spill histories from other Alaskan mines

The five large mines considered in this report are responsible for 7,316 of 8,341 (87.7%) of *mining operations* spills in ADEC (2021). Usibelli Coal Mine was responsible for more than half of the mining operations spills not caused by the five largest hard rock mines (515 out of 1,025 spills).

Non-crude oil spills, often of diesel or hydraulic oil, made up the bulk of the spill incidents and spill volume. More than 90% of the spills (of all substances) from the smaller mines were <100 gallons.

National databases

The United States Coast Guard National Response Center (https://nrc.uscg.mil/) has annual records of reported spills from 1990-2021. The NRC lists 15,474 spills in Alaska from 1990-2020. Based on the information under *Responsible Company*, location fields, the description of the incident, and the substances spilled, I estimate that as many as 197 incidents in the NRC database were attributable to the five mines considered in this report, although I did not assign any of the NRC Alaska mining spills to Pogo Mine.

PHMSA is the Pipeline and Hazardous Materials Safety Administration. The PHMSA pipeline release database contained 36 records related to Alaska from prior or 1986 through 2020. All but three of the 36 pipeline spills recorded in Alaska were crude oil spills, and none of the spills were related to mining. PHMSA also has a portal that allows for searching for spills by state that had 96 records for Alaskan spills between 2001 and 2020. The PHMSA data do not appear reflect mine related spills attributed to pipes or lines in Alaskan mines.

There is concern that underreporting of spills might mean that national databases may only show a tenth of the actual spills that occur.

Reconsidering the $N = RT$ model

The $N = RT$ model is intuitive, straightforward to calculate, has precedent in EISs, and there is a ready estimate of R available. Unfortunately, for the five mines in this report, $N = RT$ fails to accurately predict spills from transportation accidents on Alaskan haul roads when $R = 1.87 \times 10^{-7}$ spills per mile.

Spill frequency may be estimated using local, regional, or national data, depending on which are most appropriate, reliable, and/or available. National data are available in the *Pocket Guide to Large Truck and Bus Statistics.* Based on the crash rate per million vehicle miles traveled (VMT) and proportion of crashes that resulted in known spills of hazardous materials, the rate of hazardous materials spills per VMT by large trucks ranged from 1.01×10^{-7} spills per mile traveled in 2010 to 2.36×10^{-7} spills per mile traveled in 2017. The known spill rate per number of miles traveled by heavy vehicles increased over 2009 to 2017 and had an average value of 1.615 x 10^{-7} spills per vehicle mile.

The national data described above do not take any differences in spill rates between types of hazardous materials into account. Battelle (2001) found that the average hazardous material accident rate was 3.2 x 10^{-7} spill per vehicle mile, based on estimated mileage figures from the 1997 Commodity Flow Survey. The rate varies by hazardous material class for 12 classes examined. *Non-flammable gases* have the lowest spill rate (spills and leaks) of 0.32 x 10^{-7} per mile, while *toxic materials* and *miscellaneous dangerous goods* have combined spill and leak rates of 6.4 x 10^{-7} and 6.2 x 10^{-7} per truck-mile, respectively.

More detailed estimates of *R* are possible by modifying the base rate by factors including the substance being transported, the road characteristics, vehicle speeds, traffic, weather, container type, and driver training, to name just a few. Quantitative risk analysis can use any of several models to evaluate risk based on several factors to assess risk in an absolute sense or to aide in comparing potential alternative routes.

NEPA process overview and EPA modeling guidelines

The EIS process under the National Environmental Policy Act has two main purposes: to ensure that federal agencies consider the environmental effects of their proposed actions and to inform the public.

Individual events that might not be considered significant are considered significant if their cumulative effect is significant. For consideration of spill impacts, it is important to note that "significance cannot be avoided … by breaking [an impact] down into small component parts."

The EPA has guidelines about the use and description of mathematical models employed in EIS, which include disclosing uncertainties, assumptions, gaps in knowledge, and the overall reliability of the resulting predictions.

Synthesis and recommendations

Of the five mines studied, only two, Pogo and Kensington, attempted quantitative spill predictions at the initial EIS phase and only one, Red Dog, examined mine specific spill rates in a supplemental EIS. The modeling of spill risks was restricted to trucking accidents of single materials such as ore concentrate or diesel and spills related to pipelines.

The *N* = *RT* model only applies to trucking accidents, such as *collisions/allisions* and *rollovers/capsizes*. Other types of transportation spills, such as *leaks*, *cargo not being secured*, or *overfilling of tanks*, are not considered in this model.

The *N* = *RT* model would predict that 4.3 trucking accident spills would occur through 2020. In practice, the five mines had a combined total of 114 truck accidents spills which released 5,924 gallons and 1,658,481 pounds of hazardous materials.

The total number of transportation spills was 1,004, resulting in 33,404 gallons and 1,771,077 pounds released.

Within EISs, spill impacts are usually only addressed qualitatively. Spills of individual substances, such as diesel, from specific sources, such as tanker trailers, and certain events, like accidents or fuel transfers, are described as low probability events, but the aggregate, cumulative risks and impacts of all the hazardous material spills from all sources and causes are not addressed. Although spill probabilities at mines are often characterized as low in permitting documents, especially for individual hazardous materials from specific sources, from July 1995-December 2020, there were 8,157 spill incidents that released 2,363,245 gallons and 1,938,520 pounds of hazardous materials at the five hardrock mines in these case studies.

The $N = RT$ model used to estimate transportation corridor risks was the only example implemented in any of the EISs examined, and even then, it was done poorly. EIS/EAs lack explicit, complete, and quantitative reagents lists, as well specifications of other chemicals for blasting, water treatment, and spill mitigation, that would be considered as hazardous materials being transported to or from the mine or used on-site. Only 12-20% of the substances recorded as spilled at these five mines in the ADEC database were mentioned in the EISs as part of reagent lists, fuels, or tailings that could be released. The $N = RT$ model uses a value of R that is now at least 30 years old to estimate hazardous material spill rates per vehicle mile. The model assumes that every mile has the same spill rate and does not account for any differences for Alaskan locations from the national data the estimate of R was based on.

The necessary data for a full understanding of the environmental impacts of spills at the mine sites, along the transportation corridors, or in assessing the quantity of hazardous materials and waste produced by the mines are not readily accessible or collected for analysis.

The EIS process under NEPA is intended to explicitly consider environmental impacts associated with proposed projects and inform the public. Neither of those has been accomplished for spill risks related to these five mines. Any forthcoming mining EISs should

- Include an explicit, complete, and quantitative hazardous materials list for substances transported to or from the mine or used on-site.
- Include complete descriptions of the transportation methods, load sizes, and frequency for the hazardous materials, as well as tailings and other hazardous wastes.
- Include quantitative transportation spill risk estimates for the aggregated total of trips for the whole mine operation’s cumulative hazardous materials spill risk.
- Consider more detailed transportation spill risk models, with up-to-date risk rates and location-specific descriptions of the transportation corridor.
- Explicitly state that the transportation corridor to model is not just defined by the length of the any newly built roads associated with the mine, but instead extends to the origin(s) and destination(s) of the hazardous materials.

- Acknowledge that accident modeling only describes one potential way hazardous materials are released from vehicles, and that transportation-related releases can have a multitude of causes, many of which are not modeled.
- Be explicit about the numbers of expected spills, even if those estimates are minimum values because there is insufficient data to model all potential spill causes.

ADEC's spill database is a remarkably thorough repository of spill record information and could serve as a model for other state and federal incident libraries. Still, there are many aspects of spill data that are necessary to have a fuller understanding of the impacts of the spills. What was spilled, where it was spilled, what media it impacted, and how it was cleaned up are all important details.

Spill risks were only one aspect considered in the EISs (or less intensive EAs) of the five case study mines in this report, but they serve as an example of how these EISs have not adequately considered the significant environmental consequences of their proposed actions or informed the public about potential environmental impacts. The two goals of the EIS production process are to clearly state potential consequences of projects and to inform stakeholders and decision makers of those impacts. The current treatment of spill risks in mining EISs does neither.

This report is important because it offers a hard look at how spill risks have been presented in mining EIS/EAs, qualitatively and quantitatively, and compared that with what could have been done at the time the documents were prepared and how the spill predictions have held up over time. The predictions in the EIS/EAs were inaccurate and presented an insufficient description of spill risks and impacts; these mines serve as examples of how decisionmakers and community members have not received a full and representative picture of the environmental consequences of approving large mining projects.

References

Alaska Department of Environmental Conservation (ADEC). 2007. Summary of Oil and Hazardous Substances Spills by Subarea (July 1, 1995-June 30, 2005). 124 pp.

ADEC. 2012. Compliance Order By Consent. Consent Order No. 11-0929-50-002. 19 pp.

ADEC. 2014. Amendment to Consent Order No. 11-0929050-0002. 3 pp.

ADEC. 2021. Statewide oil and hazardous substance spills database, 1995-present. https://dec.alaska.gov/applications/spar/publicmvc/perp/spillsearch.

ADEC Division of Spill Prevention and Response (DSPR). 2015. Situation Report: Pogo Mine Paste Backfill Line Rupture. (Revised.) 4 pp.

ADEC DSPR. 2021a. Site Report: Greens Creek Mine Port Facility Concentrates Storage Bldg. 5 pp. https://dec.alaska.gov/Applications/SPAR/PublicMVC/CSP/SiteReport/27226

ADEC DSPR. 2021b. Site Report: Kensington Mine Generator Pad. 4 pp.

ADEC DSPR. 2021c. Site Report: Red Dog Mine. https://dec.alaska.gov/Applications/SPAR/PublicMVC/CSP/SiteReport/1423

ADEC Division of Water. 2011. Notice of Violation. December 5, 2011. Enforcement Tracking Number 11-0929-40-9557. 4 pp.

ADEC Division of Water. 2015. APDES Inspection of Sumitomo Metal Mining Co. LLC. Pogo Gold Mine, permit numbers AK0053341 and AKR06AC58. 12 pp.

ADEC Division of Water. 2018a. APDES Inspection of Northern Star (Pogo) LLC, Permit number AK0053341. 14 pp.

ADEC Division of Water. 2018b. Compliance Letter: Failure to comply with permit conditions per 18 AAC 83 – Alaska Pollutant Discharge Elimination System Individual Permit Authorization Number AK 0053341. 3 pp.

ADEC Water Discharge Authorization Program. 2010. Alaska Pollutant Discharge Elimination System Permit Fact Sheet Permit Number AK 0053341. 47 pp.

ADEC Water Discharge Authorization Program. undated. Alaska Pollutant Discharge Elimination System Permit Fact Sheet - Preliminary Draft. Permit Number AK 0043206. Hecla Greens Creek Mining Company. 57 pp.

Alaska Department of Natural Resources. 2018. Notice of Violations of the Alaska Water Use Act, Dam Safety Statutes and Pertinent Regulations at Greens Creek Mine. 23 pp.

Alaska Industrial Development and Export Authority (AIDEA) and Arcadis. 2017. Delong Mountain Transportation System Asset Management Review. 96 pp.

Alaska Public Media. 2019. Kensington Gold Mine plans major expansion for operations past 2024.

American Association of State Highway and Transportation Officials (AASHTO). 2018. *A Policy on Geometric Design of Highways and Streets.* (The Green Book.) 7th Edition. 1,048 pp.

Anchorage Daily News. 2014a. Despite fine, Red Dog Mine opts out of building wastewater pipeline. Suzanna Caldwell. June 6, 2014.

Anchorage Daily News. 2014b. Permits allowing Alaska mine to discharge pollutants pondered as others wonder about pipeline. Yereth Rosen. January 5, 2014.

Anchorage Daily News. 2015. Pogo Mine reports 90,000-gallon spill of cement-like backfill.

Barilla, D., G. Leonardi, and A. Puglisi. 2009. Risk assessment for hazardous materials transportation. *Applied Mathematical Sciences* 3: 2295-2309.

Battelle. 2001. Comparative risks of hazardous materials and non-hazardous materials truck shipment accidents/incidents: final report. Federal Motor Carrier Safety Administration. March 2001. 190 pp.

Cocklan-Vendl, M., and J. E. Hemming. 1992. Regulatory processes associated with metal-mine development in Alaska: A case study of the Red Dog Mine. Final report prepared for the US Bureau of Mines by Dames and Moore. 35 pp.

Coeur Alaska, Inc. 2006. Kensington Gold Project 2005 Annual Report. 49 pp.

Coeur Alaska, Inc. 2007. Kensington Gold Project 2006 Annual Report. 159 pp.

Coeur Alaska, Inc. 2008. Kensington Gold Project 2007 Annual Report. 108 pp.

Coeur Alaska, Inc. 2009. Kensington Gold Project 2008 Annual Report. 243 pp.

Coeur Alaska, Inc. 2010. Kensington Gold Project 2009 Annual Report. 34 pp.

Coeur Alaska, Inc. 2011. Kensington Gold Project 2010 Annual Report. 38 pp.

Coeur Alaska, Inc. 2012. Kensington Gold Project 2011 Annual Report. 37 pp.

Coeur Alaska, Inc. 2013. Kensington Gold Project 2012 Annual Report. 39 pp.

Coeur Alaska, Inc. 2014. Kensington Gold Project 2013 Annual Report. 157 pp.

Coeur Alaska, Inc. 2015. Kensington Gold Project 2014 Annual Report. 208 pp.

Coeur Alaska, Inc. 2016. Kensington Gold Project 2015 Annual Report. 176 pp.

Coeur Alaska, Inc. 2017. Kensington Gold Project 2016 Annual Report. 194 pp.

Coeur Alaska, Inc. 2018. Kensington Gold Project 2017 Annual Report. 161 pp.

Coeur Alaska, Inc. 2019. Kensington Mine 2018 Annual Report. 143 pp.

Coeur Alaska, Inc. 2020. Kensington Mine 2019 Annual Report. 159 pp.

Coeur Alaska, Inc. 2021. Kensington Mine 2020 Annual Report. 156 pp.

Condon, P. D. and K. G. Lear. 2006. Geochemical and geotechnical characteristics of filter-pressed tailings at the Greens Creek Mine, Admiralty Island, Alaska. Paper presented at the 7th International Conference on Acid Rock Drainage (ICARD), March 26-30, 2006, St. Louis MO. R.I. Barnhisel (ed.) Published by the American Society of Mining and Reclamation (ASMR), 3134 Montavesta Road, Lexington, KY 40502.

Council on Environmental Quality. 2021. A Citizen's Guide to NPA: Having Your Voice Heard. 37pp.

Craft, R. 2004. Crashes involving trucks carrying hazardous materials. Federal Motor Carrier Safety Administration. FMCSA-RI-047-04.

Cunha, S. B. 2012. Comparison and analysis of pipeline failure statistics. IPC 2012-90186. *Proceedings of the 2012 International Pipeline Conference*, September 24-28, 2012, Alberta, Canada.

EPA. 1984. Red Dog Mine Project Northwest Alaska Final Environmental Impact Statement.

EPA. 2003a. EPA detailed comments on the draft environmental impact statement for the Greens Creek tailings disposal. 16 pp.

EPA. 2003b. Final Environmental Impact Statement Pogo Gold Mine Project, Delta, Alaska. National Pollutant Discharge Elimination System (NPDES) Permit Application No. AK-005334-1.

EPA. 2005. Comment letter on the FSEIS for the Kensington Gold Project. 3 pp.

EPA. 2006. Connors Drilling LLC and Kennecott Greens Creek Mining Company agree to pay $12,900 EPA penalty to settle Clean Water Act violations. EPA Newsroom. Release date 6/12/2006. https://archive.epa.gov/epapages/newsroom_archive/newsreleases/ 84a1666124b43d238525718b00627692.html

EPA. 2007. Notice of Violation. June 29, 2006 NPDES Compliance Evaluation Inspection, NPDES Permit No. AK-005334-1, MSGP Tracking No. AKR05A026. 4 pp.

EPA. 2009. Red Dog Mine Extension Aqqaluk Project Final Supplemental Environmental Impact Statement. Prepared by Tetra Tech.

EPA. 2010a. NPDES Inspection Report, Sumitomo Metal Mining Pogo, LLC (Teck-Pogo, Inc.) Delta Junction Alaska. 90 pp.

EPA. 2010b. Notice of Violation. September 15, 2010 NPDES Compliance Sampling Inspection, NPDES Permit No. AK-005334-1. 2 pp.

EPA. 2011. Water Compliance Inspection Report, Pogo Gold Mine APDES. 10 pp.

EPA. 2012. EPA's detailed comments on Greens Creek Mine DEIS. 14 pp.

EPA. 2013. Re: Greens Creek Mine tailings expansion final environmental impact statement and record of decision. EPA project number: 01-012-AFS. 3 pp.

EPA. 2014. An Assessment of Potential Mining Impacts on Salmon Ecosystems of Bristol Bay, Alaska. Environmental Protection Agency, Region 10. January 2014. Seattle, Washington. EPA 910-R-14-001.

EPA. 2021. Detailed comments on the Kensington Mine plan of operations Amendment 1 draft supplemental environmental impact statements. 29 pp.

EPA Enforcement and Compliance History (ECHO). 1997a. Civil Enforcement Case Report. Case number 10-1993-0310.

EPA ECHO. 1997b. Civil Enforcement Case Report for Case Number 10-1996-0017.

EPA ECHO. 2019a. Civil Enforcement Case Report for Case Number 10-2019-0100. https://echo.epa.gov/enforcement-case-report?id=10-2019-0100

EPA ECHO. 2019b. Civil Enforcement Case Report for Case Number 10-2019-0101. https://echo.epa.gov/enforcement-case-report?id=10-2019-0101

EPA ECHO. 2019c. Civil Enforcement Case Report for Case Number 10-2019-0102. https://echo.epa.gov/enforcement-case-report?id=10-2019-0102

EPA ECHO. 2019d. Civil Enforcement Case Report for Case Number 10-2019-0113. https://echo.epa.gov/enforcement-case-report?id=10-2019-0113

EPA ECHO. 2021a. Detailed Facility Report: DMTS Red Dog Port Facility. https://echo.epa.gov/detailed-facility-report?fid=110002465779

EPA ECHO. 2021b. Detailed Facility Report: Greens Creek Mine Admirality Island, Angoon, AK. https://echo.epa.gov/detailed-facility-report?fid=110032882735

EPA ECHO. 2021c. Detailed facility Report: Pogo Mine. https://echo.epa.gov/detailed-facility-report?fid=110009058802#pane3110009058802

EPA ECHO. 2021d. Detailed Facility Report: Red Dog Mine. https://echo.epa.gov/detailed-facility-report?fid=110000601705#environ110000601705

Erkut, E., S. A. Tjandra, and V. Verter. 2007. Chapter 9. Hazardous Materials Transportation. In Handbook on OR and MS, Vol 14. C. Barnhart and G. Laporte (Eds.). 83 pp. Elsevier. DOI: 10.1016/S0927-0507(06)14009-8

Erkut, E. and V. Verter. 1998. Modeling of Transport Risk for Hazardous Materials. *Operations Research* 46(5):625-642. https://doi.org/10.1287/opre.46.5.625

Etkin, D. S. 2006. Risk assessment of oil spills to US inland waterways. Environmental Research Consulting. 14 pp.

Fairbanks Gold Mining, Inc. 2000. True North Project Description. 36 pp.

Fairbanks Gold Mining, Inc. 2001. True North Project Description and Transportation Plan Amendments. 11 pp.

Federal Motor Carrier Safety Administration. 2014. *Pocket Guide to Large Truck and Bus Statistics*. October 2014 Update. 54 pp.

Federal Motor Carrier Safety Administration. 2015. *Pocket Guide to Large Truck and Bus Statistics*. April 2015. 56 pp.

Federal Motor Carrier Safety Administration. 2018. *Pocket Guide to Large Truck and Bus Statistics*. August 2018. 61 pp.

Federal Motor Carrier Safety Administration. 2020. *Pocket Guide to Large Truck and Bus Statistics*. January 2020. 62 pp.

Gerard, S. L. 2005. Department of Transportation's Ongoing Efforts to Improve the Safe and Secure Transportation of Hazardous Materials. Statement of Stacey L. Gerard, Acting Administrator/Chief Safety Officer PHMSA before the Subcommittee on Surface Transportation and Merchant Marine Committee on Commerce, Science, and Transportation, US Senate. April 5, 2005.

Golder Associates, Inc. 2004. Final Five-Year Environmental Audit Fort Knox Mine, True North Mine, and Twin Creek Road. 169 pp.

Ground Truth Trekking. 2014. Greens Creek Silver Mine. 2 pp.

Harwood, D. W. and E. R. Russell. 1990. Present Practices of Highway Transportation of Hazardous Materials. US Department of Transportation, Federal Highway Administration. May 1990. 266 pp.

Hecla Greens Creek Mining Company. 2019. Greens Creek Mine Final Environmental Audit. 76 pp.

Hecla Greens Creek Mining Company. 2020. General Plan of Operations. 2029 pp.

Hecla Mining Company. 2013. Hecla Green Creek Mine. 16 pp.

Hecla Mining Company. 2020. Company Overview. 72 pp.

Inanloo, B., B. Tansel, X. Jin, and A. Bernardo-Bricker. 2015. Cargo-specific accidental release impact zones for hazardous materials: risk and consequence comparison for ammonia and hydrogen fluoride. *Environ. Syst. Decis*. DOI 10.1007/s10669-015-9576-z

International Association of Oil and Gas Producers. 2010. OGP Risk Assessment Data Directory Report No. 434-4: Riser & pipeline release frequencies. March 2010. 18 pp.

Juneau Empire. 2006. Two firms in Southeast pay sizable environmental fines. http://juneauempire.com/stories/061306/sta_20060613050.shtml#.WB0CLOErJnY

Kazantzi, V., N. Kazantzis, and V. C. Gerogiannis. 2011. Simulating the effects of risk occurrences on a hazardous material transportation model. *Operations and Supply Chain Management* 4:135-144.

Kennecott Greens Creek Mining Company. 1990. Report to Alaska Department of Environmental Conservation. July 16, 1990. 14 pp.

Kinross Gold Company. 2009. Fort Knox Mine 2008 Annual Activity Report. 28 pp.

Kinross Gold Company. 2020. Fairbanks Gold Mining, Inc. Waste Management Permit #2014DB0002 Modification #2 Annual Report Fourth Quarter 2019 Monitoring Results. 136 pp.

Kravitz, M. and G. Blair. 2019. On assessing risks to fish habitats and populations associated with a transportation corridor for proposed mine operations in a salmon-rich watershed. *Environ. Manage*. 64:107-126. doi:10.1007/s00267-019-01171-w

Lubetkin, S. C. 2020. The tip of the iceberg: Three case studies of spill risk assessments used in environmental impact statements. *Marine Pollution Bulletin*. https://doi.org/10.1016/j.marpolbul.2019.110613

McDowell Group. 2018. The economic benefits of Alaska's mining industry. 71 pp.

Muhlbauer, W. K. 2004. *Pipeline Risk Management Manual: Ideas, Techniques, and Resources*. Third Edition. Gulf Professional Publishing, an imprint of Elsevier. Massachusetts.

Neitlich, P. N., J. M. Ver Hoef, S. D. Berryman, A. Mines, L. H. Geiser, L. M. Hasselbach, and A. E. Shiel. 2017. Trends in spatial patterns of heavy metal deposition on national park service lands along the Red Dog Mine haul road, Alaska, 2001-2006. PLoS ONE 12 (5): e0177936. https://doi.org/10.1371/journal.pone.0177936

New York Times. 2013. Plant explosion tears at the heart of a Texas town. April 18, 2013.

New York Times. 2020a. In maps: A two-mile radius around the blast was flattened. August 5, 2020.

New York Times. 2020b. Lebanese officials knew of the dangers posed by storage of ammonium nitrate at the port but failed to act. August 5, 2020.

New York Times. 2020c. The science behind the blast: Why fertilizer is so dangerous. August 5, 2020.

Northern Star Resources Limited. 2020. 2020 Pogo Plan of Operations. 29 pp.

PHMSA. 2010. Building Safe Communities: Pipeline Risk and its Application to Local Development Decisions. US Department of Transportation. October 2010. https://primis.phmsa.dot.gov/comm/publications/PIPA/PIPA-PipelineRiskReport-Final-20101021.pdf

PHMSA. 2021a. PHMSA data portal. https://portal.phmsa.dot.gov/analytics/saw.dll?Portalpages&PortalPath=%2Fshared%2FPDM%20Public%20Website%2F_portal%2FSC%20Incident%20Trend&Page=All%20Reported

PHMSA. 2021b. Pipeline Facility Incident Report Criteria History. https://www.phmsa.dot.gov/data-and-statistics/pipeline/pipeline-facility-incident-report-criteria-history

PHMSA. 2021c. Distribution, Transmission & Gathering, LNG, and Liquid Accident and Incident Data. https://www.phmsa.dot.gov/data-and-statistics/pipeline/distribution-transmission-gathering-lng-and-liquid-accident-and-incident-data

Qiao, Y., N. Keren, and M. S. Mannan. 2009. Utilization of accident databases and fuzzy sets to estimate frequency of HazMat transport accidents. *J. Hazardous Materials* 167: 374-382. doi:10.1016/j.jhazmat.2009.01.097

SRK Consulting. 2009. Environmental Audit of the Greens Creek Mine. Final Report. 225 pp.

Sims, J. 2015. Fort Knox Mine Fairbanks North Star Borough, Alaska, USA National Instrument 43-101 Technical Report. Prepared for Kinross Gold Corporation. 173 pp.

SRK Consulting. 2012. Environmental compliance and management systems audit: Fort Knox and True North Mines. 118 pp.

SRK Consulting. 2019. Environmental compliance and management systems audit: Fort Knox Gold Mine. 63 pp. (February 2019 revision of a December 2018 original.)

Sumitomo Metal Mining Pogo LLC. 2017. 2017 Pogo Plan of Operations Revision 1, February 2017. Submitted to ADEC Division of Water and Alaska Department of Natural Resources. 115 pp.

Teck. Undated. 2007 Sustainability Summary Red Dog Operations. 12 pp.

Teck Cominco Limited. Undated. Operation and Site Performance 2006 Pogo Mine. 4 pp.

Transportation Research Board. 2005. Chapter 2: Overview of Hazardous Materials Transportation. Pp 17-41 in *Cooperative Research for Hazardous Materials Transportation: Defining the Need, Converging on Solutions -- Special Report 283.* Washington, DC: The National Academies Press. https://doi.org/10.17226/11198.

Turner, Kent. 2003. Proposed Spill Site Concentrate Recovery Program, Winter 2003 Cape Krusenstern National Monument, Alaska. Prepared for Teck Cominco Alaska Incorporated. 10 pp.

United States Coast Guard National Response Center (https://nrc.uscg.mil/)

US Forest Service (USFS). 1983. Greens Creek Final Environmental Impact Statement. Admiralty Island National Monument, Alaska. Proposed by Noranda Mining, Inc. Project. January 1983. 369 pp.

USFS. 1992. Environmental assessment for additional waste rock disposal capacity at Greens Creek Mine Admiralty Island National Monument, Alaska.

USFS. 2003. Greens Creek Tailings Disposal Final Environmental Impact Statement. Volume 1. 777 pp.

USFS. 2004. Kensington Gold Project Final Supplemental Environmental Impact Statement. Prepared by Tetra Tech, Inc. Volume 1 (501 pp.) and Volume 2 (907 pp.)

USFS. 2013a. Greens Creek Mine Tailings Disposal Facility Expansion Final Environmental Impact Statement and Record of Decision. Volume 1 (514 pp.) and Volume 2 (440 pp.)

USFS. 2013b. Record of Decision Greens Creek Mine Tailings Disposal Facility Expansion. 38 pp.

USFS. 2020a. Draft Supplemental Environmental Impact Statement Plan of Operations Amendment 1 for the Kensington Mine. 250 pp.

USFS. 2020b. Stibnite Gold Project Draft Environmental Impact Statement. Forest Service, Region 4, Payette and Boise National Forests, Valley County, Idaho. August 2020.

USFS. 2021. Final Supplemental Environmental Impact Statement Plan of Operations Amendment 1 for the Kensington Mine. 360 pp.

Appendix A
Hazardous materials list with materials safety data sheet information

I compiled selected information from the material safety data sheets (MSDSs) for the reagents from two commercial suppliers (IXOM Safety Data Sheets (https://www.ixom.com/sds-search) and EChemi Safety Data Sheets (http://www.echemi.com)), as well as a few other commercial sources. Reagents and other hazardous materials are listed by ADEC substance class alphabetically (Table A.1) and the extracts from the MSDSs are in the same order. This list is more extensive than Table 8.9 because it includes reagents and chemicals listed in plans of operations that were not always part of the hazard materials described in EIS/EAs, as well as substances listed as “hazardous materials: other” that had more detail in their spill names. Information about each reagent may include chemical classification, hazard and precautionary statements, chemical and physical properties, including stability and reactivity, and information about toxicity to humans and ecological effects, if known.

Table A.1. Hazardous materials used or produced at the five case study mines that are mentioned in the EIS/EAs. L = listed among hazardous materials in the EIS/EAs; S = substance spilled; P = listed in a Plan of Operations or other report but not in an EIS/EA; shaded cell = substance had modeled spill risk in an EIS. *Asterisks indicate materials without MSDS extracts.

Reagents and hazardous materials listed	Pogo	Kensington	Greens Creek	Fort Knox/ True North	Red Dog
Extremely hazardous substances					
Anhydrous ammonia					S
Chlordane				S	
Formaldehyde				S	
Hydrochloric acid		S	S	L, S	
Hydrogen cyanide	S			S	
Hydrogen peroxide			P, S		
Muriatic acid			P		
Nitric acid	L				
Phosphoric acid, dimethyl 4- (methylthio)				S	
Sodium cyanide	L, S		L	L, S	L, S
Sulfur dioxide				L	
Sulfuric acid	L, S		L	S	L, S
Hazardous substances					
Acid, other*	S			S	S
Activated carbon	L			L	
Aerfroth 549*	P				
Aero 5688 Promoter*	P				
Aero 6697 Promoter*	P				
Aero Maxigold 900 Promoter	P				
Aero Promoter 208*	L				
Areophine*			P		
AGEFLOC WT2902*	P				
Ammonium bisulfite				L	
Anhydrous borax	P				
Antiscalant*					L
Bases*					S
Caustic alkali liquids*		S		S	S
Clear 215*	P				
Copper sulfate	L		L, S	L	L
Corrosion inhibitor*			S		S

Table A.1. (Continued.)

Reagents and hazardous materials listed	Pogo	Kensington	Greens Creek	Fort Knox/ True North	Red Dog
Hazardous substances (continued)					
Dextrin					L
Emulsion breaker*				S	S
Ethyl alcohol				S	S
Ethylene glycol	S	S	S	S	S
Explosives (ammonium nitrate)	L			L	S
Ferric chloride	S	S			
Flocculant*	L	L		L	L
Flotation scale inhibitor*		L			
Goldenwest 774*			P		
Glycol, other*	S	S	S	S	S
Gypsum					S
Lead				S	S
Lead nitrate				L	
Lime	L	L	L	L	L, S
Magnafloc					L, S
Magnesium oxide slurry*					S
Manganese dioxide	P				
Methyl alcohol				S	S
MIBC	L	L	L		L
Mill slurry*	S	M		S	S
Ore concentrate*		L	L		L, S, M
Permanganate		S			
Perol 351*			L		
Polymer*		L			
Potassium amyl xanthate	L	L			
Potassium ethyl xanthate					L
Potassium hydroxide		S			
Propylene glycol	S			S	S
SIPX (Sodium isopropyl xanthate)			L		L
Soda ash	L			L	
Sodium carbonate			P		
Sodium cetylsulfonate					L
Sodium hydroxide	L		L	L	
Sodium hypochlorite		S		S	S

Table A.1. (Continued.)

Reagents and hazardous materials listed	Pogo	Kensington	Greens Creek	Fort Knox/ True North	Red Dog
Hazardous substances (continued)					
Sodium isobutyl xanthate (SIBX)					L
Sodium metabisulfite	L				L
Sodium nitrate	P		P		
Sodium sulfide					L
Sodium sulfite			P		
Solvent*				S	S
Surfactant*		L			
Tetrachloroethene				S	
Unimax SD-200*			P		
Urea (solid)		S	P		
Zinc					S
Zinc slurry*	S				
Zinc sulphate					L
Non-crude oil					
Aviation fuel*			S	S	S
Creosote			S		
Diesel	L, S, M	L, S, M	L, S	L, S	L, S
Engine lube oil*		S	S	S	S
Engine lubricant*	S				
Gasoline	S		S	L, S	S
Grease*	S		S	S	S
Heating oil*				L	
Hydraulic oil*	S	S	S	S	S
Kerosene		S	S		
Propane	L				
Synthetic oil*			S	S	S
Transformer oil*		S			S
Transmission oil*	S	S	S	S	S
Used oil*	S		S	S	S
Process water					
Process water*	L, S	L, S	L, S	L, S	L, S
Produced water*	S				S
Source water*	S		S	S	S

Extremely hazardous substances

Anhydrous ammonia

Spilled at Red Dog

Extracts from ixom.com Safety Data Sheet (https://www.ixom.com/sds-search)

Classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for Transport by Road and Rail; DANGEROUS GOODS.
This material is hazardous according to Safe Work Australia; HAZARDOUS CHEMICAL.

Classification of the chemical:
Flammable Gases - Category 2
Gases under pressure - Liquefied Gas
Acute Inhalation Toxicity - Category 3
Skin Corrosion - Sub-category 1B
Eye Damage - Category 1
Specific target organ toxicity (single exposure) - Category 3

The following health/environmental hazard categories fall outside the scope of the Workplace Health and Safety Regulations: Acute Aquatic Toxicity - Category 1

SIGNAL WORD: DANGER

Hazard Statement(s):
H221 Flammable gas.
H280 Contains gas under pressure; may explode if heated.
H314 Causes severe skin burns and eye damage.
H331 Toxic if inhaled.
H335 May cause respiratory irritation.

Precautionary Statement(s):
Prevention:
P210 Keep away from heat, sparks, open flames, hot surfaces. No smoking.
P260 Do not breathe dust / fume / gas / mist / vapours / spray.
P264 Wash hands thoroughly after handling.
P271 Use only outdoors or in a well-ventilated area.
P273 Avoid release to the environment.
P280 Wear protective gloves / protective clothing / eye protection / face protection.

Response:
P301+P330+P331 IF SWALLOWED: Rinse mouth. Do NOT induce vomiting.
P303+P361+P353 IF ON SKIN (or hair): Take off immediately all contaminated clothing. Rinse skin with water/shower.
P321 Specific treatment (see First Aid Measures on Safety Data Sheet).
P363 Wash contaminated clothing before re-use.

P304+P340 IF INHALED: Remove person to fresh air and keep comfortable for breathing.
P311 Call a POISON CENTER or doctor/physician.
P305+P351+P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do.

Continue rinsing.
P310 Immediately call a POISON CENTER or doctor/physician.
P377 Leaking gas fire: Do not extinguish, unless leak can be stopped safely.
P381 Eliminate all ignition sources if safe to do so.
P391 Collect spillage.

Storage:
P403+P233 Store in a well-ventilated place. Keep container tightly closed.
P405 Store locked up.
P410 Protect from sunlight.

Fire fighting measures

Specific hazards arising from the chemical:
Flammable gas. May form flammable vapour mixtures with air. Avoid all ignition sources. All potential sources of ignition (open flames, pilot lights, furnaces, spark producing switches and electrical equipment etc) must be eliminated both in and near the work area. Do NOT smoke. Flammable concentrations of ammonia gas can accumulate in the vapour space of storage containers/vessels. Caution should be exercised when opening.

Stability and reactivity

Reactivity: Reacts violently with acids. Hygroscopic: absorbs moisture or water from surrounding air.

Chemical stability: Stable under normal ambient and anticipated storage and handling conditions of temperature and pressure. Ammonia dissolves exothermically in water. Can react explosively with chlorine and hypochlorites or other strong oxidising agents.

Critical pressure = 11.4 MPa.

Possibility of hazardous reactions: Corrosive to copper, zinc, and their alloys.

Conditions to avoid: Avoid exposure to heat, sources of ignition, and open flame.

Incompatible materials: Incompatible with oxidising agents, boron halides, acids, acid anhydrides, acid chlorides, halogens, interhalogens, heavy metals and their salts, ethylene oxide, acetaldehyde, calcium, hypochlorous acid, silver, acrolein, boron, perchlorates, chlorites, nitrogen tetroxide, sulfur.

Hazardous decomposition products: Hydrogen. Oxides of nitrogen.

Toxicological information

No adverse health effects expected if the product is handled in accordance with this Safety Data Sheet and the product label. Symptoms or effects that may arise if the product is mishandled and overexposure occurs are:

Ingestion: Not a likely route of exposure, however, swallowing liquid will result in freeze burns of the mouth, throat and stomach.

Eye contact: A severe eye irritant. Corrosive to eyes; contact can cause corneal burns. Contamination of eyes can result in permanent injury. Liquid splashes or spray may cause freeze burns to the eye.

Skin contact: Liquid splashes or spray may cause freeze burns. Contact with skin will result in severe irritation. Corrosive to skin - may cause skin burns.

Inhalation: Material is irritant to the mucous membranes of the respiratory tract (airways). Exposure to concentrations above the Exposure Standard of 25 ppm may cause irritation to the eyes, nose and throat. Higher concentrations may cause breathing difficulty, chest pain, bronchospasm, pink frothy sputum and pulmonary oedema. This may further predispose the patient to the development of acute bronchitis and pneumonia. Overexposure may result in death.

Acute toxicity:

Oral LD50 (rat): 350 mg/kg
Inhalation LC50 (rat): 2000 ppm/4hr
Skin corrosion/irritation: Irritant (human).
Serious eye damage/irritation: Severe irritant (human).
Chronic effects: Chronic exposure to ammonia may cause chemical pneumonitis and kidney damage.
Ammonia: Lowest Published Lethal Concentration (human) = 5,000 ppm/5 min.
Irritation of the respiratory tract and conjunctivae was found in workers inhaling 100 ppm ammonia and 20 ppm caused complaints and discomfort to unacclimatitised workers.
Studies on the effect on man of exposures in the 5-50 ppm range are few, however general field experience in a large number of workers exposed to ammonia from blueprinting and copying machines indicates a maximum acceptable concentration without severe complaints of 20-25 ppm.

Ecological information

Ecotoxicity Avoid contaminating waterways.

Persistence/degradability: The material is biodegradable. Ammonia is strongly adsorbed to soil and sediment particles and colloids in water.

Aquatic toxicity: Very toxic to aquatic organisms. Ammonia is readily oxidised to nitrite which is also very toxic to fish.

24hr LC50 (rainbow trout - fertilized egg) = >3.58 mg/L.
24hr LC50 (rainbow trout - alevins 0-50 days old) = >3.58 mg/L.
24hr LC50 (rainbow trout - fry 85 days old) = 0.068 mg/L.
24hr LC50 (rainbow trout - adult): 0.097 mg/L.
48hr LC50 (*Daphnia magna*): 24 - 189 mg/L.
96hr LC50 (rainbow trout): 0.53 mg/L.

Terrestrial toxicity: Expected to be harmful to terrestrial species

Transport information

Road and Rail: Transport Classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for Transport by Road and Rail; DANGEROUS GOODS.

Marine Transport: Classified as Dangerous Goods by the criteria of the International Maritime Dangerous Goods Code (IMDG Code) for transport by sea; DANGEROUS GOODS.

Air Transport: Classified as Dangerous Goods by the criteria of the International Air Transport Association (IATA) Dangerous Goods Regulations for transport by air; DANGEROUS GOODS.

UN No: 1005
Transport Hazard Class: 2.3 Toxic Gas
Subrisk 1: 8 Corrosive
Proper Shipping Name or Technical Name: AMMONIA, ANHYDROUS
IMDG EMS Fire: F-C
IMDG EMS Spill: S-U
Marine Pollutant Yes

Chlordane

Spilled at Fort Knox/True North

Extracts from EChemi Safety Data Sheet for chlordane (https://www.echemi.com/sds/chlordane-pid_Seven41322.html)

> Hazard identification
> Classification of the substance or mixture
> Acute toxicity - Category 4, Oral
> Acute toxicity - Category 4, Dermal
> Carcinogenicity, Category 2
> Hazardous to the aquatic environment, short-term (Acute) - Category Acute 1
> Hazardous to the aquatic environment, long-term (Chronic) - Category Chronic 1
>
> Signal word: Warning
>
> *Hazard statement(s):*
> H302 Harmful if swallowed
> H312 Harmful in contact with skin
> H351 Suspected of causing cancer
> H410 Very toxic to aquatic life with long lasting effects
>
> *Precautionary statement(s):*
> *Prevention*
> P264 Wash ... thoroughly after handling.
> P270 Do not eat, drink or smoke when using this product.
> P280 Wear protective gloves/protective clothing/eye protection/face protection/hearing protection/...
> P203 Obtain, read and follow all safety instructions before use.
> P273 Avoid release to the environment.
>
> *Response*
> P301+P317 IF SWALLOWED: Get medical help.
> P330 Rinse mouth.
> P302+P352 IF ON SKIN: Wash with plenty of water/...
> P317 Get medical help.
> P321 Specific treatment (see ... on this label).
> P362+P364 Take off contaminated clothing and wash it before reuse
> P318 IF exposed or concerned, get medical advice.
> P391 Collect spillage.
>
> *Storage*
> P405 Store locked up.
>
> *Disposal*

P501 Dispose of contents/container to an appropriate treatment and disposal facility in accordance with applicable laws andregulations, and product characteristics at time of disposal.

First-aid measures

Most important symptoms/effects, acute and delayed
SYMPTOMS: Symptoms of exposure to this compound include blurred vision, confusion, ataxia, delirium, coughing, abdominal pain, nausea, irritability and anuria. Other symptominclude nervousness, loss of coordination, unconsciousness and dry red skin. It may also cause neuroblastoma. It is moderately irritating to the skin and can cause deep depression anchanges. Symptoms of acute poisoning with this type of compound include vomiting, diarrhea, paraesthesia, excitement, giddiness, fatigue, tremors, convulsions, coma, possibly puedema; liver, kidney and myocardial toxicity and hypothermia. Also, respiration may be accelerated initially and later depressed. Symptoms of chronic poisoning with this type of compound may include headache, loss of appetite, muscular weakness, fine tremors, apprehensive mental state, aplastic anemia and acute leukemia. ACUTE/CHRONIC HAZARD compound is readily absorbed through the skin as well as through other portals. It is toxic by skin absorption and orally. When heated to decomposition it emits toxic fumes of organchloride products, carbon monoxide and carbon dioxide. (NTP, 1992)

Fatal oral dose to adult humans is between 6 and 60 g with onset of symptoms within 45 minutes to several hours after ingestion, although symptoms have occurred following very sdoses either orally or by skin exposure. Some reports of delayed development of liver disease, blood disorders and upset stomach. Chlordane is considered to be borderline between moderately and highly toxic substance. (EPA, 1998)

Fire-fighting measures

Specific hazards arising from the chemical: This chemical is combustible. (NTP, 1992)

Flammable/combustible material; may be ignited by heat, sparks or flames. Vapors may travel to a source of ignition and flash back. Run-off to sewers may create fire or explosion Containers may explode in heat of fire. Vapors are toxic indoors and outdoors. Chlordane degrades under natural environmental conditions to photoisomers, such as photo-cis- chlorwhich are more toxic to certain animals than chlordane and also showed higher bioaccumulation. Loses chlorine in presence of alkaline reagents; should not be formulated with any carrier, diluent or emulsifier which has alkaline reaction. (EPA, 1998)

Stability and reactivity

Reactivity: NIOSH considers chlordane to be a potential occupational carcinogen.

Decomposes on burning. Decomposes on contact with bases. This produces toxic fumes including phosgene and hydrogen chloride. Attacks iron, zinc, plastics, rubber and coatings

Chemical stability: Dehydrohalogenates in presence of alkali

Possibility of hazardous reactions: CHLORDANE, a mixture of related chlorinated cyclodienes, is decomposed by alkalis. Corrodes iron and zinc. Can react with strong oxidizing agents. Attacks some forms of plastirubber and coatings (NTP, 1992)

Conditions to avoid: no data available

Incompatible materials: Loses ...chlorine in presence of alkaline reagents and should not be formulated with any solvent, carrier, diluent or emulsifier, which has alkaline reaction.

Hazardous decomposition products: Toxic gases and vapors, such as hydrogen chloride, chlorine, phosgene, and carbon monoxide. ...

Toxicological information

Acute toxicity
Oral: LD50 Rat oral 590 mg/kg
Inhalation: LC50 Cat inhalation 100 mg/cu m/4 hours
Dermal: LD50 Rat (female) percutaneous 690 mg/kg

Ecological information

Toxicity
- Toxicity to fish: LC50 Rainbow trout 42 ug/l/96 hr (95% confidence limit 37-48 ug/l) @ 12 deg C, wt 1.0 g. Static bioassay without aeration, pH 7.2-7.5, water hardness 40-50 m calcium carbonate and alkalinity of 30-35 mg/l.
- Toxicity to daphnia and other aquatic invertebrates: no data available
- Toxicity to algae: no data available
- Toxicity to microorganisms: no data available

Persistence and degradability: A pure culture of *Nocardiopsis* sp. isolated from soil was able to degrade chlordane with dichlorochlordene, oxychlordane, heptachlor, heptachlor-endo-epoxide, chlordene, chlorohyand 3-hydroxy-trans-chlordene produced as metabolites(1).

Bioaccumulative potential: *Lagodon rhomboides* (pinfish) exposed to chlordane exhibited a bioconcentration factor of 6227. Duration of 96 hr.

Mobility in soil: The extremely low mobility of chlordane within soil ... after 14 months and 72 inches (183 cm) of rainfall /was observed/. Chlordane was found not to have extensively penetrated nine inches (23 cm). Most of the residues (85-90%) were found in the 0-3 inch (0-8 cm) cultivated layer. Nine to 15% and 1.2-1.6% were found in the 3-6 inch (8-15 cm) and 6-9 in23 cm) layers, respectively.

Formaldehyde

Spilled at Fort Knox/True North

From ixom.com Safety Data Sheet (https://www.ixom.com/sds-search) for FORMALDEHYDE 37% SOLUTIONS

HAZARDS IDENTIFICATION

Classified as a Dangerous Good according to NZS 5433:2012 Transport of Dangerous Goods on Land.

Classified as hazardous according to criteria in the HS (Minimum Degrees of Hazard) Regulations 2001.

SIGNAL WORD: DANGER

Subclasses:

Subclass 3.1 Category D (low hazard) - Flammable Liquids.

Subclass 6.1 Category B - Substances which are acutely toxic.

Subclass 6.5 Category B - Substances that are contact sensitisers.

Subclass 6.6 Category B - Substances that are suspected human mutagens.

Subclass 6.7 Category A - Substances that are known or presumed human carcinogens.

Subclass 6.9 Category B - Substances that are harmful to human target organs or systems.

Subclass 8.2 Category C - Substances that are corrosive to dermal tissue.

Subclass 8.3 Category A - Substances that are corrosive to ocular tissue.

Subclass 9.1 Category D - Substances that are slightly harmful to the aquatic environment or are otherwise designed for biocidal action.

Subclass 9.2 Category A - Substances that are very ecotoxic in the soil environment.

Subclass 9.3 Category B - Substances that are ecotoxic to terrestrial vertebrates.

Hazard Statement(s):

H227 Combustible liquid.

H301+H311 Toxic if swallowed or in contact with skin.

H314 Causes severe skin burns and eye damage.

H317 May cause an allergic skin reaction.

H330 Fatal if inhaled.

H341 Suspected of causing genetic defects.

H350 May cause cancer.

H373 May cause damage to organs through prolonged or repeated exposure.

H421 Very toxic to the soil environment.

H432 Toxic to terrestrial vertebrates.

Precautionary Statement(s):

Prevention:

P102 Keep out of reach of children.

P103 Read label before use.

P201 Obtain special instructions before use.

P202 Do not handle until all safety precautions have been read and understood.
P210 Keep away from heat/sparks/open flames/hot surfaces. No smoking.
P260 Do not breathe mist/vapours/spray.
P264 Wash hands thoroughly after handling.
P271 Use only outdoors or in a well-ventilated area.
P272 Contaminated work clothing should not be allowed out of the workplace.
P273 Avoid release to the environment.
P280 Wear protective gloves/protective clothing/eye protection/face protection.
P281 Use personal protective equipment as required.
P284 Wear respiratory protection.

Response:
P301+P330+P331 IF SWALLOWED: Rinse mouth. Do NOT induce vomiting.
P301+P310 IF SWALLOWED: Immediately call a POISON CENTER or doctor/physician.
P302+P352 IF ON SKIN: Wash with plenty of soap and water.
P303+P361+P353 IF ON SKIN (or hair): Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower.
P333+P313 If skin irritation or rash occurs: Get medical advice/attention.
P321 Specific treatment (see First Aid Measures on the Safety Data Sheet).
P361 Remove/Take off immediately all contaminated clothing.
P363 Wash contaminated clothing before re-use.
P304+P340 IF INHALED: Remove to fresh air and keep at rest in a position comfortable for breathing.
P310 Immediately call a POISON CENTER or doctor/physician.
P320 Specific treatment is urgent (see First Aid Measures on the Safety Data Sheet).
P305+P351+P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P308+P313 IF exposed or concerned: Get medical advice/attention.
P312 Call a POISON CENTER or doctor/physician if you feel unwell.
P314 Get medical advice/attention if you feel unwell.
P370+P378 In case of fire: Use extinguishing media as outlined in Section 5 of this Safety Data Sheet for extinction.
P391 Collect spillage.

Fire fighting measures

Specific hazards arising from the substance or mixture: Combustible liquid. Corrosive substance.
Special protective equipment and precautions for fire-fighters: On burning will emit toxic fumes, including those of oxides of carbon . Heating can cause expansion or decomposition of the material, which can lead to the containers exploding.

Physical and chemical properties

pH: 2.4-4

Stability and reactivity

Reactivity: No information available.

Chemical stability: At elevated temperatures, oxidation of formaldehyde produces formic acid.

Possibility of hazardous reactions: None known.

Conditions to avoid: Avoid exposure to heat, sources of ignition, and open flame.

Incompatible materials: Incompatible with oxidising agents.

Hazardous decomposition products: Oxides of carbon.

Toxicological information

No adverse health effects expected if the product is handled in accordance with this Safety Data Sheet and the product label. Symptoms or effects that may arise if the product is mishandled and overexposure occurs are:

Ingestion: Swallowing can result in nausea, vomiting, diarrhoea, abdominal pain, convulsions and loss of consciousness.

Eye contact: A severe eye irritant. Corrosive to eyes; contact can cause corneal burns. Contamination of eyes can result in permanent injury.

Skin contact: Contact with skin will result in severe irritation. Corrosive to skin - may cause skin burns. A skin sensitiser. Repeated or prolonged skin contact may lead to allergic contact dermatitis. Component/s of this material can be absorbed through the skin with resultant adverse effects.

Inhalation: Material is irritant to the mucous membranes of the respiratory tract (airways).

Acute toxicity: No LD50 data available for the product. For the constituent Formaldehyde :
Oral LD50 (rat): 100 mg/kg
Inhalation LC50 (rat): 203 mg/m3
Skin corrosion/irritation: Severe irritant (rabbit).
Serious eye damage/irritation: Severe irritant (rabbit).
Chronic effects: Suspected of causing genetic effects. May cause cancer by inhalation. For formaldehyde: This material has been classified by the International Agency for Research on Cancer (IARC) as a Group 1. Group 1 – The agent is carcinogenic to humans. Chronic inhalation studies in animals have shown that formaldehyde causes nasal cancer in rats. Exposure to methanol from skin contact, inhalation or swallowing, at concentrations

greater than 1000 ppm can result in permanent blindness and central nervous system effects.

Ecological information

Ecotoxicity: Avoid contaminating waterways.
Mobility in soil: Very toxic to the soil environment.

Transport information

Road and Rail Transport
Classified as a Dangerous Good according to NZS 5433:2012 Transport of Dangerous Goods on Land.

Marine Transport
Classified as Dangerous Goods by the criteria of the International Maritime Dangerous Goods Code (IMDG Code) for transport by sea; DANGEROUS GOODS.

Air Transport
Classified as Dangerous Goods by the criteria of the International Air Transport Association (IATA) Dangerous Goods Regulations for transport by air; DANGEROUS GOODS

Hydrochloric acid

Listed for Fort Knox/True North; spilled at Kensington, Greens Creek, and Fort Knox/True North

From ixom.com Safety Data Sheet (https://www.ixom.com/sds-search)

Extracts from the hydrochloric acid 33% SDS

> Classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for Transport by Road and Rail; DANGEROUS GOODS.
>
> This material is hazardous according to Safe Work Australia; HAZARDOUS CHEMICAL.
>
> *Classification of the chemical:*
> Corrosive to Metals - Category 1
> Skin Corrosion - Sub-category 1B
> Eye Damage - Category 1
> Specific target organ toxicity (single exposure) - Category 3
>
> SIGNAL WORD: DANGER
>
> *Hazard Statement(s):*
> H290 May be corrosive to metals.
> H314 Causes severe skin burns and eye damage.
> H335 May cause respiratory irritation.
>
> *Precautionary Statement(s):*
> *Prevention:*
> P234 Keep only in original container.
> P260 Do not breathe mist, vapours, spray.
> P264 Wash hands thoroughly after handling.
> P271 Use only outdoors or in a well-ventilated area.
> P280 Wear protective gloves / protective clothing / eye protection / face protection
>
> *Accidental release measures*
>
> Emergency procedures/Environmental precautions: Clear area of all unprotected personnel. If contamination of sewers or waterways has occurred advise local emergency services.
>
> Personal precautions/Protective equipment/Methods and materials for containment and cleaning up: Slippery when spilt. Avoid accidents, clean up immediately. Wear protective equipment to prevent skin and eye contact and breathing in vapours. Work up wind or increase ventilation. Contain - prevent run off into drains and waterways. Use absorbent (soil, sand or other inert material). Collect and seal in properly labelled containers or drums for disposal. Neutralise residues with lime or soda ash. Wash area down with excess water.

Physical and chemical properties

Solubility: Miscible with water.
pH: <1

Toxicological information

Ingestion: Swallowing can result in nausea, vomiting, diarrhoea, abdominal pain and chemical burns to the gastrointestinal tract.

Eye contact: A severe eye irritant. Corrosive to eyes; contact can cause corneal burns. Contamination of eyes can result in permanent injury.

Skin contact: Contact with skin will result in severe irritation. Corrosive to skin - may cause skin burns.

Inhalation: Breathing in mists or aerosols will produce respiratory irritation.

Ecological information

Ecotoxicity Avoid contaminating waterways.

Hydrogen cyanide

Spilled at Pogo and Fort Knox/True North

Extracts from Electronic Fluorocarbons, LLC Safety Data Sheet for hydrogen cyanide (https://efgases.com/app/uploads/Hydrogen-Cyanide-SDS.pdf)

Hazards identification

Dangerous goods.
Hazardous substance.

Classification of the substance or mixture:

Flammable liquids - category 1
Acute oral toxicity - category 1
Acute dermal toxicity - category 1
Acute inhalation toxicity - category 1
Specific target organ toxicity (single exposure) - category 1

The following health/environmental hazard categories fall outside the scope of the workplace health and safety regulations:

Acute aquatic toxicity - category 1
Chronic aquatic toxicity - category 1

SIGNAL WORD: DANGER

Hazard statement(s):
H224 Extremely flammable liquid and vapour.
H300+H310+H330 Fatal if swallowed, in contact with skin or if inhaled.
H370 Causes damage to organs.

Precautionary statement(s):
Prevention:
P210 Keep away from heat / sparks / open flames / hot surfaces. No smoking.
P233 Keep container tightly closed.
P240 Ground / bond container and receiving equipment.
P241 Use explosion-proof electrical / ventilating / lighting equipment.
P242 Use only non-sparking tools.
P243 Take precautionary measures against static discharge.
P260 Do not breathe mist / vapours / spray.
P264 Wash hands thoroughly after handling.
P270 Do not eat, drink or smoke when using this product.
P271 Use only outdoors or in a well-ventilated area.
P280 Wear protective gloves / protective clothing / eye protection / face protection.
P284 Wear respiratory protection.

Response:
P301+P310 If swallowed: immediately call a poison center or doctor/physician.
P330 Rinse mouth.

P302+P350 If on skin: gently wash with plenty of soap and water.
P303+P361+P353 If on skin (or hair): take off immediately all contaminated clothing. Rinse skin with water/shower.
P310 Immediately call a poison center or doctor/physician.
P320 Specific treatment is urgent (see first aid measures on this safety data sheet).
P322 Specific measures (see first aid measures on safety data sheet).
P361 Take off immediately all contaminated clothing.
P363 Wash contaminated clothing before re-use.
P304+P340 If inhaled: remove person to fresh air and keep comfortable for breathing.
P307+P311 If exposed: call a poison center or doctor/physician.
P314 Get medical advice/attention if you feel unwell.
P370+p378 In case of fire: use extinguishing media as outlined in section 5 of this safety data sheet to extinguish.

Storage:
P403+P233 Store in a well-ventilated place. Keep container tightly closed.
P403+P235 Store in a well-ventilated place. Keep cool.
P405 Store locked up.

Disposal:
P501 dispose of contents/container in accordance with local/regional/national/ international regulations.

Poisons schedule (susmp): s7 dangerous poison.

First aid measures

May be fatal if inhaled, swallowed or absorbed through skin. At all places where there is a risk of cyanide poisoning, items to facilitate the prompt and effective treatment of cyanide poisoning (as determined by the treatment protocol to be employed) should be kept in an accessible and convenient location.

Recommended items include:
- an oxygen resuscitator and a source of oxygen and a clearly marked CYANIDE ANTIDOTE box containing:
- an approved airway, elasticised tourniquet, 5 mL sterile disposable syringe and needles for blood samples, fluoride heparinised blood sample tubes, skin prep swabs, dressing and adhesive tape

-either:
- 2 cyanokits containing hydroxocobalamin 5g x 2 amps and the prescribing information outlining side effects and precautions OR
- 2 ampoules of kelocyanor (dicobalt edetate), including the prescribing information outlining side effects and precautions
- intravenous injection equipment
- a copy of the appropriate Safety Data Sheet and
- a written copy of the relevant treatment protocol

Protect the rescuer

Prior to any attempt at rescue, an assessment of the dangers must be undertaken and measures including the use of appropriate personal protective equipment must be applied to protect the rescuer. Personal protective equipment may include:
- protective gloves to avoid contact with contaminated skin, clothing and equipment
- chemical goggles to protect the eyes
- suitable respiratory protective equipment to prevent inhalation of sodium cyanide dust.

Inhalation:
Shout and send for help.
Remove the person from the source of exposure and ideally to a source of fresh air.
Look for verbal and physical responses from the person suffering from poisoning. Check that they are breathing.
If patient is breathing: oxygen, preferably 100% oxygen if available, should be administered by a qualified person. If the person has collapsed or is unconscious, lie on their side, ensuring airway is clear and open.
If patient is not breathing: ensure airway is clear and open and commence resuscitation using a resuscitation bag or mask connected to an oxygen source (or 100% oxygen via a non rebreathing facemask). Do not use mouth-to-mouth resuscitation. Oxygen, preferably 100% oxygen if available, should be administered by a qualified person. Check for pulse. If pulse is absent start external cardiac massage.

Transport promptly to hospital or medical centre.

Skin contact:
If skin or hair contact occurs, immediately remove any contaminated clothing and place in a sealed bag for decontamination or disposal. Wash skin and hair thoroughly with running water. Transport promptly to hospital or medical centre. Treat as for 'inhaled'.

Eye contact:
Immediately wash in and around the eye area with large amounts of water for at least 15 minutes. Eyelids to be held apart. Remove clothing if contaminated and wash skin. Urgently seek medical assistance. Transport promptly to hospital or medical centre. Treat as for 'inhaled'.

Ingestion:
Do not give anything by mouth. Treat as for 'inhaled'.

Indication of immediate medical attention and special treatment needed:
Be certain that victims have been decontaminated properly. Victims who have undergone decontamination pose no serious risks of secondary contamination to rescuers or medical staff treating the victim. In such cases, Support Zone personnel require no specialized protective gear.

Upon presentation, immediately assess the need or otherwise for assisted ventilation, administer 100% oxygen, insert intravenous lines and institute cardiac and blood pressure monitoring if available.

Assess and monitor level of consciousness.

Obtain arterial/venous blood gas as metabolic acidosis, often severe, combined with a small difference between the arterial and venous oxygen saturation levels (<10 mmhg) suggests cyanide poisoning: correct any severe metabolic acidosis (pH below 7.20) and concurrent electrolyte imbalances (for example, hyperkalaemia, hypercalcaemia).

Take a blood sample in a fluoride heparinised tube for analysis of blood cyanide levels to confirm poisoning, but do not delay treatment while awaiting results. Treatment decisions must be made on clinical grounds.

Symptoms of fear and anxiety about possible cyanide poisoning may mimic those of mild, or the early stages, of cyanide poisoning. It is therefore important to establish cyanide poisoning has actually occurred before administering an antidote as some cyanide antidotes have severe side effects if administered in the absence of cyanide poisoning or if the dose is too great.

If a history of exposure to cyanide has been confirmed and the patient presents with, or develops, severe symptoms of cyanide poisoning (particularly if the patient has lost consciousness, is lapsing into unconsciousness or enters cardiac arrest) then antidote administration may be required.

Antidotes

There are two main antidotes for severe cyanide poisoning

- hydroxocobalamin (preferred) or
- dicobalt edetate (Kelocyanor)

Hydroxocobalamin

Reconstitute the hydroxocobalamin by diluting one flask (5g) of the freeze-dried with 200mL of 0.9% saline and shake rigorously. Administer 5 grams of reconstituted solution via a fast intravenous drip over 15 minutes (approximately 15mL/ min). A further (5g) dose may be given if necessary at a slower rate of infusion - 30 min - 2 hours (or alternatively I.V. sodium thiosulphate 12.5g (50mL) may be given by slow intravenous injection) through a separate IV line. Hydroxocobalamin should not be administered if person has known hypersensitivity to Vitamin B12.

Dicobalt edetate (Kelocyanor)

Note: overzealous administration of the antidote is contraindicated and may result in serious adverse reactions of an anaphylactic (allergic) nature. Adverse reactions reported include gross oedema of the face and neck, urticaria, palpitations, hypotension, convulsions, vomiting, chest pains, difficulty in breathing, and collapse.

Administer one ampoule containing 300mg dicobalt edetate in 20mLglucose solution (kelocyanor) intravenously by slow injection. The initial effect is a fall in blood pressure, rise in pulse rate, and sometimes retching. Immediately after this phase, lasting about one minute, the patient should recover. The injection should be discontinued if allergic adverse effects are noted. A second dose may be given if the response is inadequate and allergic adverse effects have not been observed (or alternatively I.V. sodium thiosulphate 12.5g (50mL) may be given by slow intravenous injection through a separate IV line.

If cyanide has been swallowed, gastric lavage, charcoal and cathartics may be used after antidote treatment if less than two hours have elapsed since ingestion if recommended by an appropriately qualified specialist physician in a specific case although the effectiveness of this measure is not strongly supported by evidence.

Cases of proven and symptomatic cyanide poisoning should be monitored for at least 24 hours and longer if antidote administration had been required for severe poisoning. Eye splashes should be assessed by an ophthalmologist within 24 hours (as cyanide is a severe eye irritant). Persons without symptoms but with significant areas of skin contact should be observed for at least 6 hours to ensure there are no delayed effects.

Fire fighting measures

Suitable extinguishing media: Dry agent (dry chemical powder).
Unsuitable extinguishing media: Carbon dioxide.
Hazchem or emergency action code: 2WE
Specific hazards arising from the substance or mixture: Extremely flammable. Toxic substance.
Special protective equipment and precautions for fire-fighters: Fire fighters to wear self-contained breathing apparatus and suitable protective clothing if risk of exposure to vapour or products of combustion.

Accidental release measures

Emergency procedures/environmental precautions:
Clear area of all unprotected personnel. Shut off all possible sources of ignition. If contamination of sewers or waterways has occurred advise local emergency services. For large spills notify the emergency services.
Personal precautions/protective equipment/methods and materials for containment and cleaning up:

Clear area of all unprotected personnel. Wear protective equipment to prevent skin and eye contact and breathing in vapours/dust.

Stability and reactivity

Reactivity: reacts with oxidising agents.
Chemical stability: no information available.
Possibility of hazardous reactions: if not stabilised, can polymerise violently.
Conditions to avoid: avoid exposure to heat, sources of ignition, and open flame.
Incompatible materials: incompatible with oxidising agents.
Hazardous decomposition products: cyanides.

Toxicological information

Ingestion: swallowing can result in nausea, vomiting, diarrhoea, abdominal pain, convulsions and loss of consciousness. Collapse and possible death may occur.
Eye contact: may be an eye irritant.
Skin contact: contact with skin may result in irritation. Can be absorbed through the skin. Effects can include those described for 'ingestion'.
Inhalation: breathing in high concentrations may result in the same symptoms described for 'Ingestion'. High inhaled concentrations may lead to a feeling of suffocation and cause difficulty in breathing, headaches, dizziness and loss of consciousness. Can cause suffocation.

Acute toxicity:
Oral LD50 (mice): 3700 ug/kg

Chronic effects: Repeated or prolonged skin contact may lead to irritant contact dermatitis - 'cyanide rash' - characterised by itching and skin eruptions. Chronic and subchronic exposure to cyanide is known to induce thyroid effects due to the cyanide metabolite, thiocyanate. Thiocyanate adversely affects the thyroid gland via competitive inhibition of iodide uptake and perturbation of the homeostatic feedback mechanisms that regulate the synthesis and secretion of essential thyroid hormones.

Ecological information

Ecotoxicity: avoid contaminating waterways

Aquatic toxicity: very toxic to aquatic organisms. May cause long term adverse effects in the aquatic environment

Transport information

Road and rail transport: DANGEROUS GOODS.
UN No: 1051
Transport hazard class: 6.1 Toxic
Subrisk 1: 3 flammable liquid
Packing group: I
Proper shipping name or technical name: HYDROGEN CYANIDE, STABILIZED
Hazchem or emergency action code: 2WE

Marine transport: DANGEROUS GOODS.
UN No: 1051
Transport hazard class: 6.1 Toxic
Subrisk 1: 3 flammable liquid
Packing group: I
Proper shipping name or technical name: HYDROGEN CYANIDE, STABILIZED
IMDG EMS fire: F-E
IMDG EMS spill: S-D
Marine pollutant Yes

Air transport: DANGEROUS GOODS.
Transport prohibited under the International Air Transport Association (IATA) Dangerous Goods Regulations for transport by air in Passenger and Cargo Aircraft, and Cargo Aircraft Only.
Transport hazard class: 6.1 Toxic
Subrisk 1: 3 flammable liquid
Packing group: I
Proper shipping name or technical name: HYDROGEN CYANIDE, STABILIZED

Regulatory information

Classification: HAZARDOUS SUBSTANCE.
Classification of the substance or mixture:

- Flammable liquids - Category 1
- Acute oral toxicity - Category 1
- Acute dermal toxicity - Category 1
- Acute inhalation toxicity - Category 1
- Specific target organ toxicity (single exposure) - Category 1

The following health/environmental hazard categories fall outside the scope of the Workplace Health and Safety Regulations:

- Acute aquatic toxicity - Category 1
- Chronic aquatic toxicity - Category 1

Hazard statement(s):

H224 Extremely flammable liquid and vapour.
H300+H310+H330 Fatal if swallowed, in contact with skin or if inhaled.
H370 Causes damage to organs.

Poisons schedule (SUSMP): S7 Dangerous Poison.

Hydrogen peroxide

Listed in the plan of operations for Greens Creek; spilled at Greens Creek

Extracts from ixom.com Safety Data Sheet (https://www.ixom.com/sds-search) for hydrogen peroxide 20-60% solution

Hazards identification

Classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for Transport by Road and Rail; DANGEROUS GOODS.
This material is hazardous according to Safe Work Australia; HAZARDOUS CHEMICAL.

Classification of the chemical:
Oxidising liquids - Category 2
Skin Corrosion - Sub-category 1B
Eye Damage - Category 1
Acute Oral Toxicity - Category 4
Acute Inhalation Toxicity - Category 4
Specific target organ toxicity (single exposure) - Category 3

SIGNAL WORD: DANGER

Hazard Statement(s):
H272 May intensify fire; oxidizer.
H302+H332 Harmful if swallowed or if inhaled.
H314 Causes severe skin burns and eye damage.
H335 May cause respiratory irritation

Precautionary Statement(s):
Prevention:
P210 Keep away from heat. No smoking.
P220 Keep and store away from clothing, incompatible materials, combustible materials.
P221 Take any precaution to avoid mixing with combustibles / incompatible materials.
P260 Do not breathe mist, vapours, spray.
P264 Wash hands thoroughly after handling.
P270 Do not eat, drink or smoke when using this product.
P271 Use only outdoors or in a well-ventilated area.
P280 Wear protective gloves / protective clothing / eye protection / face protection.

Response:
P301+P330+P331 IF SWALLOWED: Rinse mouth. Do NOT induce vomiting.
P301+P312 IF SWALLOWED: Call a POISON CENTER or doctor/physician if you feel unwell.
P303+P361+P353 IF ON SKIN (or hair): Take off immediately all contaminated clothing. Rinse skin with water/shower.
P304+P340 IF INHALED: Remove person to fresh air and keep comfortable for breathing.
P312 Call a POISON CENTER or doctor/physician if you feel unwell.
P305+P351+P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.

P310 Immediately call a POISON CENTER or doctor/physician.
P321 Specific treatment (see First Aid Measures on Safety Data Sheet).
P363 Wash contaminated clothing before re-use.
P370+P378 In case of fire: Use extinguishing media as outlined in Section 5 of this Safety Data Sheet to extinguish.

Physical and chemical properties

pH: 1-4

Stability and reactivity

Conditions to avoid: Avoid exposure to heat.

Incompatible materials: Incompatible with acids, reducing agents, alkalis, heavy metals and their salts, dust, enzymes, combustible material, organic chemicals, cyanides, dirt, rust, hexavalent chromium compounds.

Hazardous decomposition products: Oxygen, which will support combustion

Toxicological information

Ingestion: Swallowing can result in nausea, vomiting, diarrhoea, abdominal pain and chemical burns to the gastrointestinal tract. Decomposition may occur in the stomach leading to the production of oxygen gas. This may cause distension of the stomach and the possibility of some bleeding. Death may occur if large amounts are ingested.

Eye contact: A severe eye irritant. Corrosive to eyes; contact can cause corneal burns. Contamination of eyes can result in permanent injury.

Skin contact: Contact with skin will result in severe irritation. Corrosive to skin - may cause skin burns.

Inhalation: Breathing in vapour will produce respiratory irritation.

Acute toxicity: Oral LD50 (rat): 841 mg/kg (60% solution)

Respiratory or skin sensitisation: No information available.

Chronic effects: Available evidence from animal studies indicate that repeated or prolonged exposure to this material could result in effects on the lungs.

Ecological information

Ecotoxicity Avoid contaminating waterways.

Muriatic acid

Listed in the plan of operations for Greens Creek

See information regarding **hydrochloric acid**.

Nitric acid

Listed for Pogo

Extracts from ixom.com Safety Data Sheet (https://www.ixom.com/sds-search) for nitric acid 30% (Data sheets for 1, 30, 40, 40-50, 45, and 60-64% solutions were available.)

Hazards identification

Classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for Transport by Road and Rail; DANGEROUS GOODS.

This material is hazardous according to Safe Work Australia; HAZARDOUS CHEMICAL.

Classification of the chemical:
Corrosive to Metals - Category 1
Skin Corrosion - Sub-category 1A
Eye Damage - Category 1

SIGNAL WORD: DANGER

Hazard Statement(s):
H290 May be corrosive to metals.
H314 Causes severe skin burns and eye damage.

Precautionary Statement(s):
Prevention:
P234 Keep only in original container.
P260 Do not breathe mist, vapours, spray.
P264 Wash hands thoroughly after handling.
P280 Wear protective gloves / protective clothing / eye protection / face protection.

Response:
P301+P330+P331 IF SWALLOWED: Rinse mouth. Do NOT induce vomiting.
P303+P361+P353 IF ON SKIN (or hair): Take off immediately all contaminated clothing. Rinse skin with water/shower.
P363 Wash contaminated clothing before re-use.
P321 Specific treatment (see First Aid Measures on Safety Data Sheet).
P305+P351+P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P310 Immediately call a POISON CENTER or doctor/physician.
P304+P340 IF INHALED: Remove person to fresh air and keep comfortable for breathing.
P390 Absorb spillage to prevent material damage.

Stability and reactivity

Reactivity: Reacts with strong alkalis. Corrodes metals.

Chemical stability: Stable under normal ambient and anticipated storage and handling conditions of temperature and pressure.

Possibility of hazardous reactions: Reacts with metals liberating flammable hydrogen gas. May cause fire in contact with organic materials such as wood, cotton or straw, evolving toxic nitrogen oxides gases (brown fumes).

Conditions to avoid: Avoid exposure to light. Avoid contact with foodstuffs.

Incompatible materials: Incompatible with strong alkalis, organic chemicals, reducing agents, carbides, chlorates, metals.

Hazardous decomposition products: Oxides of nitrogen.

Toxicological information

Ingestion: Swallowing can result in nausea, vomiting, diarrhoea, abdominal pain and chemical burns to the gastrointestinal tract.

Eye contact: A severe eye irritant. Corrosive to eyes; contact can cause corneal burns. Contamination of eyes can result in permanent injury.

Skin contact: Contact with skin will result in severe irritation. Corrosive to skin - may cause skin burns.

Inhalation: Breathing in mists or aerosols may produce respiratory irritation. Nitric acid may decompose to a toxic brown gas of nitrogen dioxide. Inhalation of the gas may result in chest discomfort, shortness of breath and possible pulmonary oedema, the onset of which may be delayed.

Chronic effects: Chronic overexposure to vapour, fumes or aerosols may produce adverse effects on the lungs and erosion of the teeth.

Ecological information

Ecotoxicity Avoid contaminating waterways.

Phosphoric acid, dimethyl 4- (methylthio)

Spilled at Fort Knox/True North

Extracts from the PubChem compound summary for dimethyl P-(methylthio)phenyl phosphate (https://pubchem.ncbi.nlm.nih.gov/compound/18621)

Synonyms:

Dimeth
yl 4-(methylthio)phenyl phosphate
Phosphoric acid, dimethyl 4-(methylthio)phenyl ester

Signal DANGER

Hazard Statements
H300: Fatal if swallowed [Danger Acute toxicity, oral]
H310: Fatal in contact with skin [Danger Acute toxicity, dermal]

Precautionary Statement(s):
Prevention:
P262 Do not get in eyes, on skin, or on clothing.
P264 Wash ... thoroughly after handling.
P270 Do not eat, drink or smoke when using this product.
P280 Wear protective gloves/protective clothing/eye protection/face protection.

Response:
P301+P310 IF SWALLOWED: Immediately call a POISON CENTER or doctor/physician.
P302+P350 IF ON SKIN: Gently wash with plenty of soap and water.
P310 Immediately call a POISON CENTER or doctor/physician.
P321 Specific treatment (see ... on this label).
P322 Specific measures (see ...on this label).
P330 Rinse mouth.
P361 Take off immediately all contaminated clothing.
P363 Wash contaminated clothing before reuse.

Storage:
P405 Store locked up.

Disposal:
P501 Dispose of contents/container to ...

Hazard Classes and Categories
Acute Toxicity 1
Acute Toxicity 2

Health Hazards
Highly toxic by oral or skin exposure. Its effects are probably due to action on the nervous system. This compound may cause death through respiratory arrest. (EPA, 1998)

Fire Hazards

When heated to decomposition, it emits very toxic fumes of sulfur oxides and phosphorus oxides. (Non-Specific -- Organophosphorus Pesticide, Liquid, n.o.s.) Fire and runoff from fire control water may produce irritating or poisonous gases. Hydrolyzed by alkalies at 99.5F. (EPA, 1998)

WHEN HEATED TO DECOMP, CAN EMIT HIGHLY TOXIC FUMES OF PO(X). /PHOSPHATES/

The primary hazard of this material is the flammability of the carrier. /Organophosphorus pesticide, liq, NOS (cmpd & prepn) (insecticides, other than agricultural, NEC)/

First Aid Measures

Warning: Effects may be delayed up to 12 hours. Caution is advised. Note: Phosphoric acid, dimethyl 4-(methylthio)phenyl ester is a cholinesterase inhibitor.

Signs and Symptoms of Phosphoric Acid, Dimethyl 4-(Methylthio) Phenyl Ester Exposure: Acute exposure to phosphoric acid, dimethyl 4-(methylthio)phenyl ester may produce the following signs and symptoms: sweating, pinpoint pupils, blurred vision, headache, dizziness, profound weakness, muscle spasms, seizures, and coma. Mental confusion and psychosis may occur. Excessive salivation, nausea, vomiting, anorexia, diarrhea, and abdominal pain may occur. The heart rate may decrease following oral exposure or increase following dermal exposure. Chest pain may be noted. Hypotension (low blood pressure) may be observed, although hypertension (high blood pressure) is not uncommon. Respiratory signs include dyspnea (shortness of breath), pulmonary edema, respiratory depression, and respiratory paralysis.

Emergency Life-Support Procedures: Acute exposure to phosphoric acid, dimethyl 4-(methylthio)phenyl ester may require decontamination and life support for the victims. Emergency personnel should wear protective clothing appropriate to the type and degree of contamination. Air-purifying or supplied-air respiratory equipment should also be worn, as necessary. Rescue vehicles should carry supplies such as plastic sheeting and disposable plastic bags to assist in preventing spread of contamination.

Inhalation Exposure: 1. Move victims to fresh air. Emergency personnel should avoid self-exposure to phosphoric acid, dimethyl 4-(methylthio)- phenyl ester. 2. Evaluate vital signs including pulse and respiratory rate, and note any trauma. If no pulse is detected, provide CPR. If not breathing, provide artificial respiration. If breathing is labored, administer oxygen or other respiratory support. 3. Obtain authorization and/or further instructions from the local hospital for administration of an antidote or performance of other invasive procedures. 4. Transport to a health care facility.

Dermal/Eye Exposure: 1. Remove victims from exposure. Emergency personnel should avoid self-exposure to phosphoric acid, dimethyl 4- (methylthio)phenyl ester. 2. Evaluate vital signs including pulse and respiratory rate, and note any trauma. If no pulse is detected, provide CPR. If not breathing, provide artificial respiration. If breathing is labored, administer oxygen or other respiratory support. 3. Remove and isolate contaminated clothing as soon as possible. 4. If eye exposure has occurred, eyes must be flushed with lukewarm water for at least 15 minutes. 5. Wash exposed skin areas thoroughly with water. 6. Obtain authorization and/or further instructions from the local hospital for administration of an antidote or performance of other invasive procedures. 7. Transport to a health care facility.

Ingestion Exposure: 1. Evaluate vital signs including pulse and respiratory rate, and note any trauma. If no pulse is detected, provide CPR. If not breathing, provide artificial respiration. If breathing is labored, administer oxygen or other respiratory support. 2. Obtain authorization and/or further instructions from the local hospital for administration of an antidote or performance of other invasive procedures. 3. Vomiting may be induced with syrup of Ipecac. If elapsed time since ingestion of phosphoric acid, dimethyl 4-(methylthio)- phenyl ester exposure is unknown or suspected to be greater than 30 minutes, do not induce vomiting and proceed to Step 4. Ipecac should not be administered to children under 6 months of age.

Warning: Ingestion of phosphoric acid, dimethyl 4 (methylthio)phenyl ester may result in sudden onset of seizures or loss of consciousness. Syrup of Ipecac should be administered only if victims are alert, have an active gag reflex, and show no signs of impending seizure or coma. If ANY uncertainty exists, proceed to Step 4. The following dosages of Ipecac are recommended: children up to 1 year old, 10 mL (1/3 oz); children 1 to 12 years old, 15 mL (1/2 oz); adults, 30 mL (1 oz). Ambulate (walk) the victims and give large quantities of water. If vomiting has not occurred after 15 minutes, Ipecac may be readministered. Continue to ambulate and give water to the victims. If vomiting has not occurred within 15 minutes after second administration of Ipecac, administer activated charcoal. 4. Activated charcoal may be administered if victims are conscious and alert. Use 15 to 30 g (1/2 to 1 oz) for children, 50 to 100 g (1-3/4 to 3-1/2 oz) for adults, with 125 to 250 mL (1/2 to 1 cup) of water. 5. Promote excretion by administering a saline cathartic or sorbitol to conscious and alert victims. Children require 15 to 30 g (1/2 to 1 oz) of cathartic; 50 to 100 g (1-3/4 to 3-1/2 oz) is recommended for adults. 6. Transport to a health care facility. (EPA, 1998)

Accidental release measures

Isolation and evacuation

Excerpt from ERG Guide 152 [Substances - Toxic (Combustible)]: As an immediate precautionary measure, isolate spill or leak area in all directions for at least 50 meters (150 feet) for liquids and at least 25 meters (75 feet) for solids. SPILL: Increase, in the downwind direction, as necessary, the isolation distance shown above. FIRE: If tank, rail car or tank truck is involved in a fire, ISOLATE for 800 meters (1/2 mile) in all directions; also, consider initial evacuation for 800 meters (1/2 mile) in all directions. (ERG, 2016)

Toxicity

Toxicological information

Acute effects

Organism	Test Type	Route	Dose	Reference
rat	LD50	oral	7 mg/kg	Toxicology and Applied Pharmacology., 21(315), 1972 [PMID:5027965]
mouse	LD50	oral	18 mg/kg	Archives of Toxicology., 34(103), 1975 [PMID:1242884]
rabbit	LD50	skin	48 mg/kg	Pesticide Index, Frear, E.H., ed., State College, PA, College Science Pub., 1969, 4(189), 1969
bird - wild	LD50	oral	560 ug/kg	Toxicology and Applied Pharmacology., 21(315), 1972 [PMID:5027965]

Non-human toxicity values

LD50 Mouse (CD-1 male) oral 23.4 mg/kg
LD50 Mouse (CD-1 female) oral 17.8 mg/kg

Ecotoxicity values

LD50 Duck oral 1.12 mg/kg (95% confidence limit: 0.811-1.56 mg/kg) 3-4 mo old females
LD50 Pheasant oral 0.688 mg/kg (95% confidence limit: 0.531-0.842) 3-4 mo old males
LD50 Pheasant oral 0.500-1.00 mg/kg, 4 mo old females

Sodium cyanide

Listed at Pogo, Greens Creek, Fort Knox/True/North, and Red Dog; spilled at Pogo, Fort Knox/True/North, and Red Dog

Extracts from ixom.com Safety Data Sheet (https://www.ixom.com/sds-search)

> Classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for Transport by Road and Rail; DANGEROUS GOODS.
>
> This material is hazardous according to Safe Work Australia; HAZARDOUS CHEMICAL.
>
> *Classification of the chemical:*
> Corrosive to Metals - Category 1
> Acute Dermal Toxicity - Category 1
> Acute Inhalation Toxicity - Category 2
> Acute Oral Toxicity - Category 2
> Skin Irritation - Category 2
> Eye Damage - Category 1
> Specific target organ toxicity (repeated exposure) - Category 1 Acute Aquatic Toxicity - Category 1
> Chronic Aquatic Toxicity - Category 1
>
> SIGNAL WORD: DANGER
>
> *Hazard Statement(s):*
> H290 May be corrosive to metals.
> H300+H310+H330 Fatal if swallowed, in contact with skin or if inhaled.
> H315 Causes skin irritation.
> H318 Causes serious eye damage.
> H372 Causes damage to organs through prolonged or repeated exposure.
> H410 Very toxic to aquatic life with long lasting effects.
>
> *Prevention:*
> P234 Keep only in original container.
> P260 Do not breathe mist, vapours, spray.
> P262 Do not get in eyes, on skin, or on clothing.
> P264 Wash hands thoroughly after handling.
> P270 Do not eat, drink or smoke when using this product.
> P271 Use only outdoors or in a well-ventilated area.
> P273 Avoid release to the environment.
> P280 Wear protective gloves / protective clothing / eye protection / face protection.
> P284 Wear respiratory protection.
>
> *Other Hazards:*
> AUH029 Contact with water liberates toxic gas.

AUH032 Contact with acids liberates very toxic gas.
AUH070 Toxic by eye contact.

Poisons Schedule (SUSMP): S7 Dangerous Poison

Accidental release measures

Emergency procedures/Environmental precautions: Clear area of all unprotected personnel. Isolate spill or leak area immediately. Shut off all possible sources of ignition. Work up wind or increase ventilation. Do not allow container or product to get into drains, sewers, streams or ponds. If contamination of sewers or waterways has occurred advise local emergency services. For large spills notify the Emergency Services.

Personal precautions/Protective equipment/Methods and materials for containment and cleaning up: Avoid breathing in dust. Work up wind or increase ventilation. Wear protective equipment to prevent skin and eye contact and breathing in vapours/dust. DO NOT allow material to get wet. Contain - prevent run off into drains and waterways. Spillage area and contaminated solids can be detoxified by treatment with an excess of dilute sodium hypochlorite, calcium hypochlorite, or ferrous sulfate after the addition of soda ash or lime to raise the pH to greater than 10.5. Allow 1 hour for complete decomposition before washing spillage area down with large quantities of water to ensure maximum dilution. Collect and seal in properly labelled containers or drums for disposal.

Toxicological information

Ingestion: Highly toxic. Swallowing can result in nausea, vomiting, diarrhoea, abdominal pain, convulsions and loss of consciousness. May cause cyanosis (blueness of the skin) due to lack of oxygen in the blood. May cause a weak or irregular heart beat, drop in blood pressure or cardiac arrest. Collapse and possible death may occur.

Eye contact: Causes serious eye damage. A severe eye irritant. Contamination of eyes can result in permanent injury.

Skin contact: Contact with skin will result in irritation. Toxic in contact with skin. Can be absorbed through the skin. Effects can include those described for 'INGESTION'.

Inhalation: Breathing in high concentrations may result in the same symptoms described for 'INGESTION'. High inhaled concentrations may lead to a feeling of suffocation and cause difficulty in breathing, headaches, dizziness and loss of consciousness. Can cause suffocation. Material is toxic - inhalation may be fatal.

Chronic effects: Repeated or prolonged skin contact may lead to irritant contact dermatitis - 'cyanide rash' - characterised by itching and skin eruptions. Chronic and subchronic exposure to cyanide is known to induce thyroid effects due to the cyanide metabolite, thiocyanate. Thiocyanate adversely affects the thyroid gland via competitive

> inhibition of iodide uptake and perturbation of the homeostatic feedback mechanisms that regulate the synthesis and secretion of essential thyroid hormones. Other chronic effects reported include headache, eye irritation, fatigue, shortness of breath and nose bleeds.

Ecological information

Ecotoxicity: Avoid contaminating waterways. Avoid release to the environment.

Bioaccumulative potential: Not expected to bioconcentrate or bioaccumulate.

Mobility in soil: Toxic to the soil environment.

Aquatic toxicity: Very toxic to aquatic organisms. May cause long lasting harmful effects to aquatic life.

Sulfur dioxide

Listed at Fort Knox/True North

Extracts from echemi.com Safety Data Sheet (https://www.echemi.com/sds/sulfurdioxide-pid_Rock21514.html)

Hazard identification
Classification of the substance or mixture
Gases under pressure: Liquefied gas
Skin corrosion, Sub-category 1B
Acute toxicity - Category 3, Inhalation

Signal word DANGER

Hazard statement(s)
H314 Causes severe skin burns and eye damage
H331 Toxic if inhaled

Precautionary statement(s)
Prevention
P260 Do not breathe dust/fume/gas/mist/vapours/spray.
P264 Wash ... thoroughly after handling.
P280 Wear protective gloves/protective clothing/eye protection/face protection/hearing protection/...
P261 Avoid breathing dust/fume/gas/mist/vapours/spray.
P271 Use only outdoors or in a well-ventilated area.

Response
P301+P330+P331 IF SWALLOWED: Rinse mouth. Do NOT induce vomiting.
P363 Wash contaminated clothing before reuse.
P304+P340 IF INHALED: Remove person to fresh air and keep comfortable for breathing.
P316 Get emergency medical help immediately.
P321 Specific treatment (see ... on this label).
P305+P351+P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easyContinue rinsing.

Storage
P410+P403 Protect from sunlight. Store in a well-ventilated place.
P405 Store locked up.
P403+P233 Store in a well-ventilated place. Keep container tightly closed.

Disposal

P501 Dispose of contents/container to an appropriate treatment and disposal facility in accordance with applicable laws andregulations, and product characteristics at time of disposal.

First-aid measures

Description of necessary first-aid measures
If inhaled: Fresh air, rest. Artificial respiration may be needed. Refer for medical attention.

Following skin contact: ON FROSTBITE: rinse with plenty of water, do NOT remove clothes. Refer for medical attention .

Following eye contact: Rinse with plenty of water for several minutes (remove contact lenses if easily possible). Refer for medical attention.

Following ingestion: Rinse mouth with water. Do not induce vomiting. Never give anything by mouth to an unconscious person. Call a doctor or Poison Control Center immediately.

Accidental release measures

Personal precautions, protective equipment and emergency procedures
Evacuate danger area! Consult an expert! Personal protection: complete protective clothing including self-contained breathing apparatus. Ventilation. NEVER direct water jet on liquid.

Environmental precautions
Prevent further spillage or leakage if it is safe to do so. Do not let the chemical enter drains. Discharge into the environment must be avoided.

Stability and reactivity

Reactivity: no data available

Chemical stability: no data available

Possibility of hazardous reactions: The gas is heavier than air. The solution in water is a medium strong acid. Reacts violently with sodium hydride. Attacks plastic.

Sulfuric acid

Listed at Pogo, Greens Creek, and Red Dog; spilled at Pogo, Fort Knox/True North, and Red Dog

Extracts from ixom.com Safety Data Sheet (https://www.ixom.com/sds-search) for sulfuric acid 10-51%. (Data sheets for <5, 5-10, 10-51, and >51% solutions were available.)

Hazards identification

Classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for Transport by Road and Rail; DANGEROUS GOODS.

This material is hazardous according to Safe Work Australia; HAZARDOUS CHEMICAL.

Classification of the chemical:
Skin Corrosion - Sub-category 1A
Eye Damage - Category 1
Specific target organ toxicity (single exposure) - Category 3

SIGNAL WORD: DANGER

Hazard Statement(s):
H290 May be corrosive to metals.
H314 Causes severe skin burns and eye damage.
H335 May cause respiratory irritation.

Precautionary Statement(s):
Prevention:
P234 Keep only in original container.
P260 Do not breathe mist, vapours, spray.
P264 Wash hands thoroughly after handling.
P271 Use only outdoors or in a well-ventilated area.
P280 Wear protective gloves / protective clothing / eye protection / face protection.

Response:
P301+P330+P331 IF SWALLOWED: Rinse mouth. Do NOT induce vomiting.
P303+P361+P353 IF ON SKIN (or hair): Take off immediately all contaminated clothing. Rinse skin with water/shower.
P321 Specific treatment (see First Aid Measures on Safety Data Sheet).
P363 Wash contaminated clothing before re-use.
P304+P340 IF INHALED: Remove person to fresh air and keep comfortable for breathing.
P312 Call a POISON CENTER or doctor/physician if you feel unwell.
P305+P351+P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P310 Immediately call a POISON CENTER or doctor/physician.
P390 Absorb spillage to prevent material damage.

Stability and reactivity

Reactivity: Reacts with alkalis.

Chemical stability: Stable under normal ambient and anticipated storage and handling conditions of temperature and pressure.

Possibility of hazardous reactions: Corrosive to most metals. Reacts exothermically with water.

Conditions to avoid: Avoid exposure to moisture.

Incompatible materials: Incompatible with many metals, organic chemicals, alkalis.

Hazardous decomposition products: Sulfur dioxide.

Toxicological information

Ingestion: Swallowing can result in nausea, vomiting, diarrhoea, abdominal pain and chemical burns to the gastrointestinal tract.

Eye contact: A severe eye irritant. Corrosive to eyes; contact can cause corneal burns. Contamination of eyes can result in permanent injury.

Skin contact: Contact with skin will result in severe irritation. Corrosive to skin - may cause skin burns.
Inhalation: Breathing in mists or aerosols will produce respiratory irritation.

Acute toxicity: No LD50 data available for the product. For the constituent Sulfuric acid (1):
Oral LD50 (rat): 2140 mg/kg
Inhalation LC50 (rat): 510 mg/m³/2hours

Respiratory or skin sensitisation: No information available.

Chronic effects: No information available for the product.

For the component Sulfuric acid: Repeated overexposure may lead to chronic conjunctivitus, lung damage and dental erosion. The International Agency for Research on Cancer (IARC) have concluded that occupational exposure to strong inorganic acid mists containing sulfuric acid is carcinogenic to humans, causing cancer of the larynx and to a lesser extent, the lung. No direct link has been established with sulfuric acid, itself, and cancer in humans. Exposure to any mist or aerosol during the use of this product should be avoided and exposure should not exceed the exposure standard. (2)

Ecological information

Ecotoxicity Avoid contaminating waterways.

(1) `Registry of Toxic Effects of Chemical Substances'. Ed. D. Sweet, US Dept. of Health & Human Services: Cincinnati, 2019.

(2) International Agency for Research on Cancer. In: `IARC Monographs on the Evaluation of Carcinogenic Risk

Hazardous substances

Activated carbon

Listed at Pogo and Fort Knox/True North

Extracts from ixom.com Safety Data Sheet (https://www.ixom.com/sds-search) for activated carbon (not spontaneously combustible)

Not classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for transport by Road and Rail; NON-DANGEROUS GOODS.
This product has been tested according to "United Nations Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria Part III - 33.3.1.3" and is not classified as a Class 4.2 dangerous good.
This material is hazardous according to Safe Work Australia; HAZARDOUS CHEMICAL.

Classification of the chemical:
Eye Irritation - Category 2A
Specific target organ toxicity (single exposure) - Category 3

SIGNAL WORD: WARNING

Hazard Statement(s):
H319 Causes serious eye irritation.
H335 May cause respiratory irritation.

Precautionary Statement(s):
Prevention:
P261 Avoid breathing dust / fume / gas / mist / vapours / spray.
P264 Wash hands thoroughly after handling.
P271 Use only outdoors or in a well-ventilated area.
P280 Wear protective gloves / protective clothing / eye protection / face protection.

Response:
P305+P351+P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P337+P313 If eye irritation persists: Get medical advice/attention.
P304+P340 IF INHALED: Remove person to fresh air and keep comfortable for breathing.
P312 Call a POISON CENTER or doctor/physician if you feel unwell.

Stability and reactivity

Possibility of hazardous reactions: Dust explosion hazard. Hazardous polymerisation will not occur.

Conditions to avoid: Avoid dust generation. Avoid exposure to moisture.
Incompatible materials: Incompatible with strong oxidising agents. Incompatible with hydrocarbons.

Hazardous decomposition products: Oxides of carbon.

Toxicological information

Ingestion: No adverse effects expected, however, large amounts may cause nausea and vomiting.

Eye contact: An eye irritant.

Skin contact: Contact with skin may result in irritation.

Inhalation: Breathing in dust will result in respiratory irritation.

Ecological information

Ecotoxicity Avoid contaminating waterways.

Aero Maxgold 900 Promoter

Listed in the plan of operations for Pogo

Extract from Aero Maxgold 900 Promoter Safety Data Sheet (https://mynevadacounty.com/DocumentCenter/View/30438/16-Collector---Aero-Maxgold-900-SDS-US-EN)

Hazards identification
Classification of the substance or mixture HCS 2012 (29 CFR 1910.1200)
Flammable liquids, Category 3
Acute toxicity, Category 4
Skin irritation, Category 2
Serious eye damage, Category 1
Skin sensitization, Category 1
Germ cell mutagenicity, Category 2
Specific target organ systemic toxicity - repeated exposure, Category 1

H226: Flammable liquid and vapor.
H302: Harmful if swallowed.
H315: Causes skin irritation.
H318: Causes serious eye damage.
H317: May cause an allergic skin reaction.
H341: Suspected of causing genetic defects.
H372: Causes damage to organs through prolonged or repeated exposure if swallowed. (Liver), Oral

Signal Word - DANGER

Hazard Statements
- H226 Flammable liquid and vapor.
- H302 Harmful if swallowed.
- H315 Causes skin irritation.
- H317 May cause an allergic skin reaction.
- H318 Causes serious eye damage.
- H341 Suspected of causing genetic defects.
- H372 Causes damage to organs (Liver) through prolonged or repeated exposure if swallowed.

Precautionary Statements
Prevention
- P201 Obtain special instructions before use.
- P202 Do not handle until all safety precautions have been read and understood.
- P210 Keep away from heat/sparks/open flames/hot surfaces. No smoking.
- P233 Keep container tightly closed.
- P240 Ground/bond container and receiving equipment.
- P241 Use explosion-proof electrical/ ventilating/ lighting/ equipment.

- P242 Use only non-sparking tools.
- P243 Take precautionary measures against static discharge.
- P260 Do not breathe dust/ fume/ gas/ mist/ vapors/ spray.
- P264 Wash skin thoroughly after handling. - P270 Do not eat, drink or smoke when using this product.
- P272 Contaminated work clothing must not be allowed out of the workplace.
- P280 Wear protective gloves/ protective clothing/ eye protection/ face protection.

Response
- P301 + P312 + P330 IF SWALLOWED: Call a POISON CENTER/doctor if you feel unwell. Rinse mouth.
- P303 + P361 + P353 IF ON SKIN (or hair): Take off immediately all contaminated clothing. Rinse skin with water/shower.
- P305 + P351 + P338 + P310 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. Immediately call a POISON CENTER/doctor.
- P308 + P313 IF exposed or concerned: Get medical advice/ attention.
- P333 + P313 If skin irritation or rash occurs: Get medical advice/ attention.
- P362 Take off contaminated clothing and wash before reuse.
- P370 + P378 In case of fire: Use dry sand, dry chemical or alcohol-resistant foam to extinguish.

Storage
- P403 + P235 Store in a well-ventilated place. Keep cool.
- P405 Store locked up.

Disposal
- P501 Dispose of contents/ container to an approved waste disposal plant.

Other hazards which do not result in classification
- H400: Very toxic to aquatic life.
- H410: Very toxic to aquatic life with long lasting effects.

First aid measures

Description of first-aid measures

In case of inhalation - Quickly move the person away from the contaminated area. Make the affected person rest. - Immediate medical attention is required. - Show this sheet to the doctor. - Be prepared to provide first aid or medical support if necessary.

In case of skin contact - Wash off immediately with plenty of water for at least 15 minutes. - Use appropriate protective equipment when treating a contaminated person. - Always obtain medical attention. - Show this sheet to the doctor. - Be prepared to provide first aid or medical support if necessary.

In case of eye contact - Rinse immediately with plenty of water, also under the eyelids, for at least 15 minutes. - Keep eye wide open while rinsing. - Show this sheet to the doctor.

- Always obtain medical advice, even if there are no symptoms. - Be prepared to provide first aid or medical support if necessary.

In case of ingestion - Do NOT induce vomiting. - Immediate medical attention is required. - Show this sheet to the doctor. - Do not give anything to drink. - Be prepared to provide first aid or medical support if necessary

Most important symptoms and effects, both acute and delayed

Symptoms - Symptoms will depend on the target organs. - Inhalation may provoke the following symptoms: - Cough - Breathing difficulties - Irritation - Redness - Swelling of tissue - Ingestion may provoke the following symptoms: - Nausea - Diarrhea - Abdominal pain - May cause respiratory tract irritation. - allergic rhinitis - Severe allergic skin reactions, bronchiospasm and anaphylactic shock - Itching - Dermatitis - Causes skin burns. - Lachrymation - Conjunctivitis - Causes eye burns. - The gas deadens the sense of smell. Do not depend on odor to detect presence of gas.

Effects - Effects on health may appear after exposure. - Serious effects on health may appear after prolonged or repeated exposure. - The effects will depend on target organs. - Chronic exposure is suspected of causing genetic effects on basis of animal data. Effects on human have not been proven. - Chronic exposure may cause allergic dermatitis. - Exposure may cause allergic rhinitis, conjunctivitis, asthma or shock. - If ingested, severe burns of the mouth and throat, as well as a danger of perforation of the esophagus and the stomach. - In case of inhalation, irritation/corrosion of the respiratory tract. - Risk of respiratory disorder - May cause irreversible skin damage. - Chronic exposure may cause dermatitis. - May cause irreversible eye damage. - Loss of the eye

Indication of any immediate medical attention and special treatment needed
Notes to physician - Be aware to maintain life support if necessary. - Take victim immediately to hospital. - Immediate medical attention is required. - Consult with an ophthalmologist immediately in all cases. - Burns must be treated by a physician. - Treat symptomatically. - Contact a poison control center. - Keep under medical supervision for at least 48 hours. - Contact the occupational physician in case of exposure.

Firefighting measures

Specific hazards during fire fighting: - On combustion, toxic gases are released.
Hazardous combustion products: - Carbon disulfide may be formed under fire conditions.
Advice for firefighters: - Do not flush to sewer which may contain acid. - This could result in generation of toxic and flammable carbon disulfide and carbonyl sulfide

Accidental release measures

Environmental precautions - Stop the leak. Turn leaking containers leak-side up to prevent the escape of liquid. - Contain the spilled material by diking. - Do not let product enter drains. - Do not allow uncontrolled discharge of product into the environment. - Spills may be reportable to the National Response Center (800-424-8802) and to state and/or local agencies

Stability and reactivity

Conditions to avoid - Keep away from heat, sparks and flame. - Strong acids and oxidizing agents

Incompatible materials - Strong acids - Aluminum - Oxidizing agents

Hazardous decomposition products

Hazardous decomposition products - Carbonyl sulfide - Carbon dioxide (CO2) - carbon disulphide.

Thermal decomposition - Alkyl sulfides - Hydrogen cyanide (hydrocyanic acid) - Hydrogen sulfide - Alkyl mercaptans - Carbon monoxide - Sulphur dioxide

Toxicological information

Acute toxicity

Acute oral toxicity: This product is classified as acute toxicity category 4

Skin corrosion/irritation: Irritating to skin

Serious eye damage/eye irritation: Risk of serious damage to eyes

STOT-repeated exposure

Target Organs: Liver The substance or mixture is classified as specific target organ toxicant, repeated exposure, category 1 according to GHS criteria

Ecological information

Ecotoxicity assessment

Short-term (acute) aquatic hazard Very toxic to aquatic life.

Long-term (chronic) aquatic hazard Very toxic to aquatic life with long lasting effects

Regulatory information

SARA HAZARD DESIGNATION SECTIONS 311/312 (40 CFR 370)	
Flammable (gases, aerosols, liquids, or solids)	Yes
Acute toxicity (any route of exposure)	Yes
Skin corrosion or irritation	Yes
Serious eye damage or eye irritation	Yes
Respiratory or skin sensitization	Yes
Germ cell mutagenicity	Yes
Specific target organ toxicity (single or repeated exposure)	Yes

Ammonium bisulfite

Listed at Fort Knox/True North

Extracts from EChemi for ammonium bisulfite safety data sheet (https://www.echemi.com/sds/ammonium-bisulfite-temppid160705001980.html)

Classification of the substance or mixture
Eye irritation, Category 2

SIGNAL WORD: WARNING

Hazard statement(s)
H319 Causes serious eye irritation

Precautionary statement(s)
Prevention
P264 Wash ... thoroughly after handling.
P280 Wear protective gloves/protective clothing/eye protection/face protection/hearing protection/...

Response
P305+P351+P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.

First-aid measures

Description of necessary first-aid measures

If inhaled

Move the victim into fresh air. If breathing is difficult, give oxygen. If not breathing, give artificial respiration and consult a doctor immediately. Do not use mouth to mouth resuscitate the victim ingested or inhaled the chemical.

Following skin contact

Take off contaminated clothing immediately. Wash off with soap and plenty of water. Consult a doctor.

Following eye contact

Rinse with pure water for at least 15 minutes. Consult a doctor.

Following ingestion

Rinse mouth with water. Do not induce vomiting. Never give anything by mouth to an unconscious person. Call a doctor or Poison Control Center immediately.

Most important symptoms/effects, acute and delayed

Excerpt from ERG Guide 154 [Substances - Toxic and/or Corrosive (Non-Combustible)]: TOXIC; inhalation, ingestion or skin contact with material may cause severe injury or death

Contact with molten substance may cause severe burns to skin and eyes. Avoid any skin contact. Effects of contact or inhalation may be delayed. Fire may produce irritating, corrosive and/or toxic gases. Runoff from fire control or dilution water may be corrosive and/or toxic and cause pollution. (ERG, 2016)

Indication of immediate medical attention and special treatment needed, if necessary
Basic treatment: Establish a patent airway. Suction if necessary. Watch for signs of respiratory insufficiency and assist ventilations if necessary. Administer oxygen by nonrebreather at 10 to 15 L/min. Monitor for signs of pulmonary edema and treat if necessary. Monitor for shock and treat if necessary. For eye contamination, flush eyes immediately with water. Irrigate each eye continuously with normal saline during transport . Do not use emetics. For ingestion, rinse mouth and administer 5 mg/kg up to 200 ml of water for dilution if the patient can swallow, has a strong gag reflex, and does not drool . Do not attempt to neutralize. Ammonia and related compounds

Fire-fighting measures

Suitable extinguishing media

Excerpt from ERG Guide 154 [Substances - Toxic and/or Corrosive (Non-Combustible)]: SMALL FIRE: Dry chemical, CO_2 or water spray. LARGE FIRE: Dry chemical, CO_2, alcohol-resistant foam or water spray. Move containers from fire area if you can do it without risk. Dike fire-control water for later disposal; do not scatter the material. FIRE INVOLVING TANKS OR CAR/TRAILER LOADS: Fight fire from maximum distance or use unmanned hose holders or monitor nozzles. Do not get water inside containers. Cool containers with flooding quantities of water until well after fire is out. Withdraw immediately in case of rising sound from venting safety devices or discoloration of tank. ALWAYS stay away from tanks engulfed in fire. (ERG, 2016)

Specific hazards arising from the chemical

Excerpt from ERG Guide 154 [Substances - Toxic and/or Corrosive (Non-Combustible)]: Non-combustible, substance itself does not burn but may decompose upon heating to produce corrosive and/or toxic fumes. Some are oxidizers and may ignite combustibles (wood, paper, oil, clothing, etc.). Contact with metals may evolve flammable hydrogen gas. Containers may explode when heated. For electric vehicles or equipment, ERG Guide 147 (lithium ion batteries) or ERG Guide 138 (sodium batteries) should also be consulted. (ERG, 2016)

Special Hazards of Combustion Products: None (USCG, 1999)

Special protective actions for fire-fighters

In case of fire in the surroundings, use appropriate extinguishing media.

Accidental release measures

Personal precautions, protective equipment and emergency procedures

Personal protection: particulate filter respirator adapted to the airborne concentration of the substance. Sweep spilled substance into covered containers. If appropriate, moisten first prevent dusting. Wash away remainder with plenty of water.

Environmental precautions

Personal protection: particulate filter respirator adapted to the airborne concentration of the substance. Sweep spilled substance into covered containers. If appropriate, moisten first to prevent dusting. Wash away remainder with plenty of water.

Methods and materials for containment and cleaning up

Collect and arrange disposal. Keep the chemical in suitable and closed containers for disposal. Remove all sources of ignition. Use spark-proof tools and explosion-proof equipment. Adhered or collected material should be promptly disposed of, in accordance with appropriate laws and regulations.

Handling and storage

Precautions for safe handling

Handling in a well ventilated place. Wear suitable protective clothing. Avoid contact with skin and eyes. Avoid formation of dust and aerosols. Use non-sparking tools. Prevent fire caused by electrostatic discharge steam.

Conditions for safe storage, including any incompatibilities

Separated from strong oxidants, acids and food and feedstuffs. Well closed. KEEP WELL CLOSED.

Physical and chemical properties and safety characteristics

Physical state Ammonium bisulfite is a solution of yellow crystals. It is a strong irritant to skin and mucous membranes. It is toxic by skin absorption. It may be corrosive to metals.

Stability and reactivity

Reactivity

Decomposes on heating and on contact with acids. This produces toxic fumes including sulfur oxides, nitrogen oxides and ammonia. Reacts violently with oxidants. Attacks many metals in the presence of water.

Chemical stability

no data available

Possibility of hazardous reactions

Inorganic reducing agents, such as AMMONIUM BISULFITE, react with oxidizing agents to generate heat and products that may be flammable, combustible, or otherwise reactive reactions with oxidizing agents may be violent. Sulfites and hydrosulfites (dithionites) can react explosively with strong oxidizing agents. Sulfites generate gaseous sulfur dioxide in with oxidizing acids and nonoxidizing acids.

Conditions to avoid

no data available

Incompatible materials

Many sulfides react violently and explosively on contact with powerful oxidizers. Sulfides

Hazardous decomposition products

When heated to decomp it emits toxic vapors of /ammonia/.

Toxicological information

Acute toxicity

Oral: LD50 - rat (male/female) - ca. 2 610 mg/kg bw.
Inhalation: LC50 - rat (male) - > 5.5 mg/L air.
Dermal: LD50 - rat (male) - > 2 000 mg/kg bw.

Ecological information

Toxicity

Toxicity to fish: LC50 - *Leuciscus idus* - > 215 - < 464 mg/L - 96 h.
Toxicity to *daphnia* and other aquatic invertebrates: EC50 - *Daphnia magna* - 89 mg/L - 48 h.
Toxicity to algae: EC50 - *Desmodesmus subspicatus* (previous name: *Scenedesmus subspicatus*) - 43.8 mg/L - 72 h.
Toxicity to microorganisms: EC50 - activated sludge of a predominantly domestic sewage - > 1 000 mg/L - 3 h. Remarks: Respiration rate.

Disposal considerations

Disposal methods

Product

The material can be disposed of by removal to a licensed chemical destruction plant or by controlled incineration with flue gas scrubbing. Do not contaminate water, foodstuffs, feed by storage or disposal. Do not discharge to sewer systems.

Ammonium nitrate

Listed at Pogo and Fort Knox True North; spilled at Red Dog

Extracts from ixom.com Safety Data Sheet (https://www.ixom.com/sds-search) for ammonium nitrate

Classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for Transport by Road and Rail; DANGEROUS GOODS.
This material is hazardous according to Safe Work Australia; HAZARDOUS CHEMICAL.

Classification of the chemical:
Oxidising solids - Category 3
Eye Irritation - Category 2A

SIGNAL WORD: WARNING

Hazard Statement(s):
H272 May intensify fire; oxidizer.
H319 Causes serious eye irritation.

Precautionary Statement(s):
Prevention:
P210 Keep away from heat, sparks, open flames, hot surfaces. No smoking.
P220 Keep and store away from clothing, incompatible materials, combustible materials.
P221 Take any precaution to avoid mixing with combustibles / incompatible materials.
P264 Wash hands thoroughly after handling.
P280 Wear protective gloves / protective clothing / eye protection / face protection

Accidental release measures

Emergency procedures/Environmental precautions: Shut off all possible sources of ignition. Clear area of all unprotected personnel. Do not allow the product to mix with combustible/organic materials. Do not allow container or product to get into drains, sewers, streams or ponds. If contamination of sewers or waterways has occurred advise local emergency services.

Personal precautions/Protective equipment/Methods and materials for containment and cleaning up: Clean up spillages immediately. Contain - prevent run off into drains and waterways. Wear protective equipment to prevent skin and eye contact and breathing in dust. Sweep up, but avoid generating dust. Collect in properly labelled containers, with loose fitting lids, for disposal. (Loose fitting lids). DO NOT return spilled material to original container for re-use. Ensure that contaminated material (clothing, pallets) is thoroughly washed.

Physical and chemical properties

Physical state: Granular Solid / Prills

Colour: White to Off-white
Odour: Negligible
Molecular Formula: NH_4NO_3
Solubility: Soluble in water
pH: 4.5 - 5.2 (10% solution @20°C)

Toxicological information

Ingestion: Swallowing can result in nausea, vomiting, diarrhoea, and abdominal pain. Swallowing large amounts may result in headaches, dizziness and a reduction in blood pressure (hypotension).

Eye contact: An eye irritant.

Skin contact: Repeated or prolonged skin contact may lead to irritation. Can be absorbed through cut, broken, or burnt skin with resultant adverse effects. Contact with molten material may cause skin burns. See effects as noted under 'Inhalation'.

Inhalation: Breathing in dust may result in respiratory irritation. Blasting may produce a toxic brown gas of nitrogen dioxide. Inhalation of the gas may result in chest discomfort, shortness of breath and possible pulmonary oedema, the onset of which may be delayed.

Absorption of ammonium nitrate by inhalation, ingestion or through burnt or broken skin may cause dilation of blood vessels by direct smooth muscle relaxation and may also cause methaemoglobinaemia. May cause dizziness, drowsiness, nausea and headache due to central nervous system effects.

Ecological information

Ecotoxicity Avoid contaminating waterways. Ammonium nitrate is a plant nutrient. Large scale contamination may kill vegetation and cause poisoning in livestock and poultry.

Low toxicity to aquatic life. TL_m 96: 10-100 ppm
Ammonia: 48hr LC50 (*Cyprinus carpio*): 1.15-1.72mg un-ionised NH_3/L; 95-102 mg total NH_3/L
Nitrates: 96hr LC50 (Chinook salmon, rainbow trout, bluegill): 420-1360 mg NO_3^-/L

Mobility in soil: The material is water soluble and may disperse in soil.

Aquatic toxicity: Ammonium nitrate was evaluated at 5, 10, 25 and 50 mg (NH_4^+)/L. The fertility of *Daphnia magna* was decreased at 50 mg/L. Post embryonic growth of crustacea was impaired at 10, 25 and 50 mg/L.

Anhydrous borax

Listed in the plan of operations for Pogo

Extracts from ixom.com Safety Data Sheet (https://www.ixom.com/sds-search)

Not classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for transport by Road and Rail; NON-DANGEROUS GOODS.
This material is hazardous according to Safe Work Australia; HAZARDOUS CHEMICAL.

Classification of the chemical:
Eye Irritation - Category 2A
Toxic to Reproduction - Category 1B

SIGNAL WORD: DANGER

Hazard Statement(s):
H319 Causes serious eye irritation.
H360 May damage fertility or the unborn child.

Precautionary Statement(s):
Prevention:
P201 Obtain special instructions before use.
P202 Do not handle until all safety precautions have been read and understood.
P264 Wash hands thoroughly after handling.
P280 Wear eye protection.
P281 Use personal protective equipment as required.

Response:
P305+P351+P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P337+P313 If eye irritation persists: Get medical advice/attention.
P308+P313 IF exposed or concerned: Get medical advice/attention.

Storage:
P405 Store locked up.

Disposal:
P501 Dispose of contents and container in accordance with local, regional, national, international regulations.

Poisons Schedule (SUSMP): S5 Caution.

First aid measures

Inhalation:
Remove victim from area of exposure - avoid becoming a casualty. Remove contaminated clothing and loosen remaining clothing. Allow patient to assume most

comfortable position and keep warm. Keep at rest until fully recovered. Seek medical advice if effects persist.

Skin Contact:

If skin contact occurs, remove contaminated clothing and wash skin with running water. If irritation occurs seek medical advice.

Eye Contact:

If in eyes, hold eyelids apart and flush the eye continuously with running water. Continue flushing until advised to stop by a Poisons Information Centre or a doctor, or for at least 15 minutes.

Ingestion:

Rinse mouth with water. If swallowed, give a glass of water to drink. If vomiting occurs give further water. Seek immediate medical assistance.

Indication of immediate medical attention and special treatment needed:

Supportive care only is required for adult ingestion of less than a few grams of the product. For ingestion of larger amounts, maintain fluid and electrolyte balance and maintain adequate kidney function. Gastric lavage is only recommended for heavily exposed, symptomatic patients in whom emesis has not emptied the stomach. Haemodialysis should be reserved for patients with massive acute absorption, especially for patients with compromised renal function. Boron analyses of urine or blood are only useful for verifying exposure and are not useful for evaluating severity of poisoning or as a guide in treatment.

Fire fighting measures

Suitable Extinguishing Media:

Not combustible, however, if material is involved in a fire use: Extinguishing media appropriate to surrounding fire conditions.

Specific hazards arising from the chemical:

Non-combustible material. Decomposes on heating emitting toxic fumes including those of oxides of sodium, oxides of boron.

Special protective equipment and precautions for fire-fighters:

Fire fighters to wear self-contained breathing apparatus and suitable protective clothing if risk of exposure to products of decomposition.

Accidental release measures

Emergency procedures/Environmental precautions:

Clear area of all unprotected personnel. May cause damage to trees or vegetation by root absorption. Advise local water authority that none of the affected water should be used for irrigation or for the abstraction of potable water until natural dilution returns the boron value to its normal environmental background level or meets local quality standards. If contamination of sewers or waterways has occurred advise local emergency services.

Personal precautions/Protective equipment/Methods and materials for containment and cleaning up:
Wear protective equipment to prevent skin and eye contact and breathing in dust. Work up wind or increase ventilation. Cover with damp absorbent (inert material, sand or soil). Sweep or vacuum up, but avoid generating dust. Collect and seal in properly labelled containers or drums for disposal.

Handling and storage

This material is a Scheduled Poison S5 and must be stored, maintained and used in accordance with the relevant regulations.

Precautions for safe handling:
Avoid skin and eye contact and breathing in dust. Avoid handling which leads to dust formation. Keep out of reach of children. When using do not eat, drink or smoke. Wash hands thoroughly after handling.

Conditions for safe storage, including any incompatibilities:
Store in a cool, dry, well ventilated place. Store away from foodstuffs. Protect from moisture. Store away from incompatible materials described in Section 10. Keep containers closed when not in use - check regularly for spills.

Physical and chemical properties

Physical state: Crystalline Solid
Colour: White
Odour: Odourless
pH: 9.23 (2.48% w/w solution)

Stability and reactivity

Possibility of hazardous reactions:
Reacts with strong reducing agents such as metal hydrides or alkali metals to generate hydrogen gas which is highly flammable

Conditions to avoid: Avoid dust generation. Avoid exposure to moisture.
Incompatible materials: Incompatible with strong reducing agents.

Hazardous decomposition products: Oxides of sodium. Oxides of boron.

Toxicological information

Ingestion: Swallowing can result in nausea, vomiting, diarrhoea, and abdominal pain.
Eye contact: An eye irritant.

Skin contact: Contact with skin may result in irritation. Symptoms of accidental over-exposure to high doses of inorganic borate salts have been associated with absorption through large areas of severely damaged skin. These may include delayed effects of skin redness and peeling.
Inhalation: Breathing in dust may result in respiratory irritation.
Acute toxicity:
Oral LD50 (rat): >2500 mg/kg
Dermal LD50 (rabbit): >2000 mg/kg
Inhalation LC50 (rat): >2 mg/L
Skin corrosion/irritation: Non-irritant (rabbit).
Serious eye damage/irritation: Irritant (rabbit).
Respiratory or skin sensitisation: Not a skin sensitiser (guinea pig).
Chronic effects: Animal feeding studies in rat, mouse and dog, at high doses, have demonstrated effects on fertility and testes. The doses administered were many times in excess of those to which humans would normally be exposed.
Reproductive toxicity: May damage fertility or the unborn child.

Ecological information

Ecotoxicity
Avoid contaminating waterways.

Persistence/degradability: Biodegradation is not an applicable endpoint since the product is an inorganic chemical.

Bioaccumulative potential: This product shows a low bioaccumulation potential.

Regulatory information

Classification: This material is hazardous according to Safe Work Australia; HAZARDOUS CHEMICAL.
Classification of the chemical:
Eye Irritation - Category 2A
Toxic to Reproduction - Category 1B
Hazard Statement(s):
H319 Causes serious eye irritation.
H360 May damage fertility or the unborn child.
Poisons Schedule (SUSMP): S5 Caution.

Copper sulfate

Listed at Pogo, Greens Creek, Fort Knox/True North, and Red Dog; spilled at Greens Creek

Extracts from ixom.com Safety Data Sheet (https://www.ixom.com/sds-search)

Classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for Transport by Road and Rail; DANGEROUS GOODS.
Environmentally Hazardous Substances meeting the descriptions of UN 3077 or UN 3082 are not subject to the provisions of the Australian Code for the Transport of Dangerous Goods by Road and Rail when transported by road or rail in: packagings that do not incorporate a receptacle exceeding 500 kg(L); or IBCs.

This material is hazardous according to Safe Work Australia; HAZARDOUS CHEMICAL.

Classification of the chemical:
Acute Oral Toxicity - Category 4
Skin Irritation - Category 2
Eye Irritation - Category 2A
Acute Aquatic Toxicity - Category 1
Chronic Aquatic Toxicity - Category 1

SIGNAL WORD: WARNING

Hazard Statement(s):
H302 Harmful if swallowed.
H315 Causes skin irritation.
H319 Causes serious eye irritation.
H410 Very toxic to aquatic life with long lasting effects.

Precautionary Statement(s):
Prevention:
P264 Wash hands thoroughly after handling.
P270 Do not eat, drink or smoke when using this product.
P273 Avoid release to the environment.
P280 Wear protective gloves / protective clothing / eye protection / face protection.

Response:
P301+P312 IF SWALLOWED: Call a POISON CENTER or doctor/physician if you feel unwell.
P330 Rinse mouth.
P302+P352 IF ON SKIN: Wash with plenty of soap and water.
P321 Specific treatment (see First Aid Measures on Safety Data Sheet).
P332+P313 If skin irritation occurs: Get medical advice/attention.
P362 Take off contaminated clothing and wash before reuse.
P305+P351+P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P337+P313 If eye irritation persists: Get medical advice/attention.

P391 Collect spillage.

Toxicological information

Ingestion: Swallowing can result in nausea, vomiting, diarrhoea, and gastrointestinal irritation.

Eye contact: An eye irritant.

Skin contact: Contact with skin will result in irritation. May cause skin sensitisation in sensitive individuals. Repeated or prolonged skin contact may lead to allergic contact dermatitis.

Inhalation: Breathing in dust may result in respiratory irritation. Breathing in fumes from heating may produce symptoms of 'metal fume fever'. This condition is characterised by influenza type symptoms occurring a few hours after exposure and lasting up to 48 hours. Symptoms may include chills, fever, headache, tightness of the chest, coughing, weakness, dryness of nose and mouth, muscular pain, nausea, and vomiting.

Acute toxicity:
Oral LD50 (rat): 482 mg/kg (anhydrous)
Dermal LD50 (rat): >2000 mg/kg (anhydrous)

Ecological information

Ecotoxicity: Avoid contaminating waterways.
Aquatic toxicity: Very toxic to aquatic organisms. May cause long lasting harmful effects to aquatic life.
48hr EC50 (*Daphnia magna*): 0.024 mg/L

Dextrin

Listed at Red Dog

Extracts from ixom.com Safety Data Sheet (https://www.ixom.com/sds-search) for dextrin

Not classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for transport by Road and Rail; NON-DANGEROUS GOODS.
Based on available information, not classified as hazardous according to Safe Work Australia; NON-HAZARDOUS CHEMICAL.
Poisons Schedule (SUSMP): None allocated.

Inhalation: Remove victim from area of exposure - avoid becoming a casualty. Remove contaminated clothing and loosen remaining clothing. Allow patient to assume most comfortable position and keep warm. Keep at rest until fully recovered. Seek medical advice if effects persist.

Skin Contact: If skin or hair contact occurs, remove contaminated clothing and wash skin and hair with soap and water. If irritation occurs seek medical advice.

Eye Contact: If in eyes, wash out immediately with water. In all cases of eye contamination, it is a sensible precaution to seek medical advice.

Ingestion: Rinse mouth with water. If swallowed, do NOT induce vomiting. Give a glass of water. Seek medical advice.

Indication of immediate medical attention and special treatment needed: Treat symptomatically.

Fire fighting measures

Suitable Extinguishing Media: Fine water spray, normal foam, dry agent (carbon dioxide, dry chemical powder).

Specific hazards arising from the chemical: Combustible solid. On burning will emit toxic fumes, including those of oxides of carbon.

Special protective equipment and precautions for fire-fighters: Fire fighters to wear self-contained breathing apparatus and suitable protective clothing if risk of exposure to vapour or products of combustion. Keep containers cool with water spray.

Accidental release measures

Emergency procedures/Environmental precautions: Shut off all possible sources of ignition. If contamination of sewers or waterways has occurred advise local emergency services.

Personal precautions/Protective equipment/Methods and materials for containment and cleaning up: Wear protective equipment to prevent skin and eye contact and breathing in dust. Work up wind or increase ventilation. Cover with damp absorbent (inert material, sand or soil). Sweep or vacuum up, but avoid generating dust. Collect and seal in properly labelled containers or drums for disposal. After cleaning, flush away any residual traces with water.

Stability and reactivity

Reactivity: No information available.

Chemical stability: Stable.

Possibility of hazardous reactions: Dust explosion hazard. Hazardous polymerisation will not occur.

Conditions to avoid: Avoid exposure to heat, sources of ignition, and open flame. Avoid dust generation.

Incompatible materials: Incompatible with oxidising agents.

Hazardous decomposition products: Oxides of carbon.

Toxicological information

Symptoms or effects that may arise if the product is mishandled and overexposure occurs are:

Ingestion: No adverse effects expected, however, large amounts may cause nausea and vomiting.

Eye contact: May be an eye irritant. Exposure to the dust may cause discomfort due to particulate nature. May cause physical irritation to the eyes.

Skin contact: Repeated or prolonged skin contact may lead to irritation.

Inhalation: Breathing in dust may result in respiratory irritation.

Acute toxicity: No LD50 data available for the product.

Skin corrosion/irritation: May cause mechanical irritation.

Serious eye damage/irritation: May cause mechanical irritation.

Respiratory or skin sensitisation: No information available.

Ethyl alcohol

Spilled at Fort Knox/True North and Red Dog

Extracts from ixom.com Safety Data Sheet (https://www.ixom.com/sds-search)

Classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for Transport by Road and Rail; DANGEROUS GOODS.
This material is hazardous according to Safe Work Australia; HAZARDOUS CHEMICAL.
Classification of the chemical:
Flammable liquids - Category 2
Eye Irritation - Category 2A

SIGNAL WORD: DANGER

Hazard Statement(s):
H225 Highly flammable liquid and vapour.
H319 Causes serious eye irritation.

Precautionary Statement(s):
Prevention:
P210 Keep away from heat, sparks, open flames, hot surfaces. No smoking.
P233 Keep container tightly closed.
P240 Ground or bond container and receiving equipment.
P241 Use explosion-proof electrical, ventilating, lighting equipment.
P242 Use only non-sparking tools.
P243 Take precautionary measures against static discharge.
P264 Wash hands thoroughly after handling.
P280 Wear eye protection.

Response:
P303+P361+P353 IF ON SKIN (or hair): Take off immediately all contaminated clothing. Rinse skin with water/shower.
P305+P351+P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P337+P313 If eye irritation persists: Get medical advice/attention.
P370+P378 In case of fire: Use extinguishing media as outlined in Section 5 of this Safety Data Sheet to extinguish.

Storage:
P403+P235 Store in a well-ventilated place. Keep cool.

Disposal:
P501 Dispose of contents and container in accordance with local, regional, national, international regulations.

Fire fighting measures

Specific hazards arising from the chemical:

Highly flammable liquid. Avoid all ignition sources. All potential sources of ignition (open flames, pilot lights, furnaces, spark producing switches and electrical equipment etc) must be eliminated both in and near the work area. Do NOT smoke. Vapour may travel a considerable distance to source of ignition and flash back. May form flammable vapour mixtures with air.

Special protective equipment and precautions for fire-fighters: On burning will emit toxic fumes, including those of oxides of carbon . Heating can cause expansion or decomposition of the material, which can lead to the containers exploding. If safe to do so, remove containers from the path of fire.

Keep containers cool with water spray. Fire fighters to wear self-contained breathing apparatus and suitable protective clothing if risk of exposure to vapour or products of combustion.

Stability and reactivity

Reactivity:

Hygroscopic: absorbs moisture or water from surrounding air.

Chemical stability: Stable under normal conditions of use. Aluminium containers should be avoided as aluminium alcoholates may be formed under certain conditions.

Possibility of hazardous reactions: Hazardous polymerisation will not occur.

Conditions to avoid: Avoid exposure to heat, sources of ignition, and open flame.

Incompatible materials: Incompatible with oxidising agents, acids, acid chlorides, alkali metals, ammonia, potassium tert-butoxide, peroxides.

Hazardous decomposition products: Oxides of carbon.

Toxicological information

No adverse health effects expected if the product is handled in accordance with this Safety Data Sheet and the product label. Symptoms or effects that may arise if the product is mishandled and overexposure occurs are:

Ingestion: Swallowing can result in nausea, vomiting and central nervous system depression. If the victim is showing signs of central system depression (like those of drunkenness) there is greater likelihood of the patient breathing in vomit and causing damage to the lungs.

Eye contact: An eye irritant.

Skin contact: Contact with skin may result in irritation. Will have a degreasing action on the skin.

Repeated or prolonged skin contact may lead to irritant contact dermatitis.

Inhalation: Material may be irritant to the mucous membranes of the respiratory tract (airways). Breathing in vapour can result in headaches, dizziness, drowsiness, and possible nausea. Breathing in high concentrations can produce central nervous system depression, which can lead to loss of co-ordination, impaired judgement and if exposure is prolonged, unconsciousness.

Acute toxicity:
Oral LD50 (rat): 10470 mg/kg
Inhalation LC50 (rat): 124.7 mg/L/4hr
Skin corrosion/irritation: Non-irritant (rabbit).
Serious eye damage/irritation: Irritant (rabbit).

Chronic effects: Available evidence from animal studies indicate that repeated or prolonged exposure to this material could result in effects on the liver, kidneys, gastrointestinal tract and heart muscle.

Ecological information

Ecotoxicity Avoid contaminating waterways.
Persistence/degradability: The material is readily biodegradable.
Bioaccumulative potential: This product shows a low bioaccumulation potential.
Mobility in soil: No information available.
96hr LC50 (fathead minnow): 15.3 mg/L

Transport information

Road and Rail Transport
Classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for Transport by Road and Rail; DANGEROUS GOODS.

Marine Transport
Classified as Dangerous Goods by the criteria of the International Maritime Dangerous Goods Code (IMDG Code) for transport by sea; DANGEROUS GOODS.

Air Transport
Classified as Dangerous Goods by the criteria of the International Air Transport Association (IATA) Dangerous Goods Regulations for transport by air; DANGEROUS GOODS.

Ethylene glycol

Spilled at Pogo, Kensington, Greens Creek, Fort Knox/True North, and Red Dog

Extracts from ixom.com Safety Data Sheet (https://www.ixom.com/sds-search) for **monoethylene glycol**

Not classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for transport by Road and Rail; NON-DANGEROUS GOODS.

This material is hazardous according to Safe Work Australia; HAZARDOUS CHEMICAL.

Classification of the chemical:
Acute Oral Toxicity - Category 4
Specific target organ toxicity (single exposure) - Category 3
Specific target organ toxicity (repeated exposure) - Category 2

SIGNAL WORD: WARNING

Hazard Statement(s):
H302 Harmful if swallowed.
H335 May cause respiratory irritation.
H373 May cause damage to organs through prolonged or repeated exposure.

Precautionary Statement(s):
Prevention:
P260 Do not breathe mist, vapours, spray.
P264 Wash hands thoroughly after handling.
P270 Do not eat, drink or smoke when using this product.
P271 Use only outdoors or in a well-ventilated area.

Response:
P301+P312 IF SWALLOWED: Call a POISON CENTER or doctor/physician if you feel unwell.
P330 Rinse mouth.
P304+P340 IF INHALED: Remove person to fresh air and keep comfortable for breathing.
P312 Call a POISON CENTER or doctor/physician if you feel unwell.
P314 Get medical advice/attention if you feel unwell.

Toxicological information

Ingestion: Initial symptoms following a large dose (>100ml) are those of alcohol intoxication progressing to vomiting, headache, stupor, convulsions and unconsciousness. Respiratory system involvement may occur 12 - 24 hours after ingestion. Symptoms may include hyperventilation and rapid shallow breathing. Death may occur from respiratory failure or pulmonary oedema.

Eye contact: A mild eye irritant.

Skin contact: Contact with skin will result in mild irritation. Will have a degreasing action on the skin. Repeated or prolonged skin contact may lead to irritant contact dermatitis. Can be absorbed through the skin. Effects can include those described for 'INGESTION'.

Inhalation: Breathing in vapour will produce respiratory irritation. Breathing in vapour can result in headaches, dizziness, drowsiness, and possible nausea.

Acute toxicity: Oral LD50 (rat): 4700 mg/kg

Skin corrosion/irritation: Mild irritant (rabbit).

Serious eye damage/irritation: Mild irritant (rabbit).

Respiratory or skin sensitisation: No information available.

Chronic effects: Available evidence from animal studies indicate that repeated or prolonged exposure to this material could result in effects on the central nervous system, liver and kidneys.

Aspiration hazard: No information available.

Estimated minimum lethal dose (human) following ingestion of ethylene glycol is thought to be 1.4ml/kg. High doses of ethylene glycol in rats and mice have resulted in reproductive and developmental toxicity following exposure by the oral and inhalation (respirable aerosol) routes. These particular data sets are not considered relevant to normal industrial use but do emphasise the need for care in handling.

Ecological information

Ecotoxicity Avoid contaminating waterways.

96hr LC50 (fish): >10,000 mg/L (marine water); 8050 mg/L (fresh water).

Extracts from ixom.com Safety Data Sheet (https://www.ixom.com/sds-search) for **polyethylene glycol**

Not classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for transport by Road and Rail; NON-DANGEROUS GOODS.
Based on available information, not classified as hazardous according to Safe Work Australia; NON-HAZARDOUS CHEMICAL.

Stability and reactivity

Conditions to avoid: Avoid exposure to heat, sources of ignition, and open flame. Avoid dust generation.

Incompatible materials: Incompatible with strong acids and oxidising agents.

Hazardous decomposition products: Oxides of carbon.

Ecological information

Ecotoxicity Avoid contaminating waterways.

Ferric chloride

Spilled at Pogo and Kensington

From ixom.com Safety Data Sheet (https://www.ixom.com/sds-search)

Extracts from the ferric chloride (anhydrous) SDS

Classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for Transport by Road and Rail; DANGEROUS GOODS.

This material is hazardous according to Safe Work Australia; HAZARDOUS CHEMICAL.

Classification of the chemical:
Corrosive to Metals - Category 1
Acute Oral Toxicity - Category 4
Skin Corrosion - Sub-category 1C
Eye Damage - Category 1

SIGNAL WORD: DANGER

Hazard Statement(s):
H290 May be corrosive to metals.
H302 Harmful if swallowed.
H314 Causes severe skin burns and eye damage

Precautionary Statement(s):
Prevention:
P234 Keep only in original container.
P260 Do not breathe dust / fume / gas / mist / vapours / spray.
P264 Wash hands thoroughly after handling.
P270 Do not eat, drink or smoke when using this product.
P280 Wear protective gloves / protective clothing / eye protection / face protection.

Accidental release measures

Emergency procedures/Environmental precautions: Clear area of all unprotected personnel. Avoid breathing in dust. Work up wind or increase ventilation. Wear protective equipment to prevent skin and eye contact and inhalation of vapours/dusts. If contamination of sewers or waterways has occurred advise local emergency services.

Personal precautions/Protective equipment/Methods and materials for containment and cleaning up: Contain - prevent run off into drains and waterways. Use absorbent (soil, sand or other inert material). Sweep up, but avoid generating dust. Collect and seal in properly labelled containers or drums for disposal. DO NOT allow material to get wet.

Physical and chemical properties

Soluble in water
pH: 2.0 (0.1M aq. sol.)

Toxicological information

Ingestion: Swallowing can result in nausea, vomiting, diarrhoea, and gastrointestinal irritation. May cause chemical burns.

Eye contact: A severe eye irritant. Corrosive to eyes; contact can cause corneal burns. Contamination of eyes can result in permanent injury.

Skin contact: Contact with skin will result in severe irritation. Corrosive to skin - may cause skin burns.

Inhalation: Breathing in dust will result in respiratory irritation. Inhalation can result in sneezing, coughing and burns to the throat.

Ecological information

Ecotoxicity Avoid contaminating waterways

Gypsum

Spilled at Red Dog under "other hazardous substances"

From ixom.com Safety Data Sheet (https://www.ixom.com/sds-search)

Not classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for transport by Road and Rail; NON-DANGEROUS GOODS.
Based on available information, not classified as hazardous according to Safe Work Australia; NON-HAZARDOUS CHEMICAL.

Fire fighting measures

Special protective equipment and precautions for fire-fighters:
Decomposes on heating emitting toxic fumes, including those of oxides of sulfur.

Stability and reactivity

Reactivity: No information available.

Chemical stability: Stable under normal ambient and anticipated storage and handling conditions of temperature and pressure.

Possibility of hazardous reactions: Contact with diazomethane vapour generates heat which can lead to detonation. Can react violently with aluminium powder, phosphorus.

Conditions to avoid: Avoid dust generation.

Incompatible materials: Incompatible with phosphorus, aluminium in powder form, diazomethane.

Hazardous decomposition products: Oxides of sulfur.

Toxicological information

No adverse health effects expected if the product is handled in accordance with this Safety Data Sheet and the product label. Symptoms or effects that may arise if the product is mishandled and overexposure occurs are:

Ingestion: No adverse effects expected, however, large amounts may cause nausea and vomiting. May cause physical obstruction.

Eye contact: May be an eye irritant. Exposure to the dust may cause discomfort due to particulate nature. May cause physical irritation to the eyes.

Skin contact: Repeated or prolonged skin contact may lead to irritation.
Inhalation: Breathing in dust may result in respiratory irritation.

Acute toxicity:

Average Toxicity Estimate (ATE mix, oral): >2,000 mg/kg
Average Toxicity Estimate (ATE mix, dermal): >2,000 mg/kg
Average Toxicity Estimate (ATE mix, inhalation): >5 mg/L

Ecological information

Ecotoxicity Avoid contaminating waterways.

Hydrated lime (slaked lime, milk of lime, calcium hydroxide)

Listed at Pogo, Kensington, Greens Creek, Fort Knox/True North, and Red Dog; spilled at Red Dog under "other hazardous substances"

Extracts from ixom.com Safety Data Sheet (https://www.ixom.com/sds-search) for calcium hydroxide

Not classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for transport by Road and Rail; NON-DANGEROUS GOODS.
This material is hazardous according to Safe Work Australia; HAZARDOUS CHEMICAL.

Classification of the chemical:
Skin Irritation - Category 2
Eye Damage - Category 1
Specific target organ toxicity (single exposure) - Category 3

SIGNAL WORD: DANGER

Hazard Statement(s):
H315 Causes skin irritation.
H318 Causes serious eye damage.
H335 May cause respiratory irritation.

Precautionary Statement(s):
Prevention:
P261 Avoid breathing dust / fume / gas / mist / vapours / spray.
P264 Wash hands thoroughly after handling.
P271 Use only outdoors or in a well-ventilated area.
P280 Wear protective gloves / protective clothing / eye protection / face protection.

Response:
P302+P352 IF ON SKIN: Wash with plenty of soap and water.
P321 Specific treatment (see First Aid Measures on Safety Data Sheet).
P332+P313 If skin irritation occurs: Get medical advice/attention.
P362 Take off contaminated clothing and wash before reuse.
P304+P340 IF INHALED: Remove person to fresh air and keep comfortable for breathing.
P312 Call a POISON CENTER or doctor/physician if you feel unwell.
P305+P351+P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P310 Immediately call a POISON CENTER or doctor/physician.

Stability and reactivity

Reactivity: Reacts with acids.

Chemical stability: Stable under normal ambient and anticipated storage and handling conditions of temperature and pressure. Absorbs carbon dioxide from air. Attacks aluminium, lead and brass in the presence of moisture. Decomposes with loss of water at approximately 580°C to form calcium oxide (quicklime).

Possibility of hazardous reactions: None known.

Conditions to avoid: Avoid exposure to moisture. Avoid exposure to air.

Incompatible materials: Incompatible with acids, nitromethane, nitroethane, nitroparaffins, nitropropane, maleic anhydride.

Hazardous decomposition products: Calcium oxide.

Toxicological information

Ingestion: Swallowing can result in nausea, vomiting, diarrhoea, abdominal pain and chemical burns to the gastrointestinal tract.

Eye contact: A severe eye irritant. Contamination of eyes can result in permanent injury.

Skin contact: Contact with skin will result in irritation.

Inhalation: Breathing in dust will result in respiratory irritation.

Acute toxicity: Oral LD50 (rat): 7340 mg/kg.

Skin corrosion/irritation: Irritant (rabbit).

Serious eye damage/irritation: Severe irritant (rabbit).

Respiratory or skin sensitisation: No information available.

Chronic effects:

Mutagenicity: No information available.

Carcinogenicity: Not listed as carcinogenic according to the International Agency for Research on Cancer (IARC).

Reproductive toxicity: No information available.

Specific Target Organ Toxicity (STOT) - single exposure: May cause respiratory irritation.

Aspiration hazard: No information available.

Ecological information

Ecotoxicity Avoid contaminating waterways.

Persistence/degradability: Biodegradation is not an applicable endpoint since the product is an inorganic chemical.

Bioaccumulative potential: Does not bioaccumulate.

Mobility in soil: No information available.

48hr EC50 (*Daphnia magna*): 49.1 mg/L
96hr LC50 (fish): 33.9 mg/kg (*Clarias gariepinus*)

Lead

Spilled at Fort Knox/True North and Red Dog mines

Extracts from Fisher Scientific Safety Data Sheet for lead metal sheet (https://beta-static.fishersci.com/content/dam/fishersci/en_US/documents/programs/education/regulatory-documents/sds/chemicals/chemicals-l/S25383A.pdf)

Hazards identification
Classification of the substance or mixture
Irritant: Acute toxicity (oral, dermal, inhalation), category 4
Health hazard: Reproductive toxicity, category 1A
Specific target organ toxicity following repeated exposure, category 2
Environmentally damaging: Acute hazards to the aquatic environment, category 1
Chronic hazards to the aquatic environment, category 1

Signal word: DANGER

Hazard statements:
Harmful if swallowed
Harmful if inhaled
May damage fertility or the unborn child
May cause damage to organs through prolonged or repeated exposure
Very toxic to aquatic life
Very toxic to aquatic life with long lasting effects

Precautionary statements:
If medical advice is needed, have product container or label at hand
Keep out of reach of children
Read label before use
Wash skin thoroughly after handling
Do not eat, drink, or smoke while using this product
Avoid release to the environment
Avoid breathing dust/fume/gas/mist/vapours/spray
Use only outdoors or in a well-ventilated area
Obtain special instructions before use
Do not handle until all safety precautions have been read and understood
Use personal protective equipment as required
IF SWALLOWED: Call a POISON CENTER or doctor/physician if you feel unwell. Rinse mouth
IF INHALED: Remove the victim to fresh air and keep at rest in a position comfortable for breathing.
If exposed or concerned: Get medical advice/attention
Store locked up
Dispose of contents and container to an approved waste disposal plant

Combustible dust hazard: May form combustible dust concentrations in air (during processing)

First aid measures

After inhalation: Loosen clothing as necessary and position individual in a comfortable position. Move exposed to fresh air. Give artificial respiration as necessary. If breathing is difficult give oxygen. Get medical assistance if cough or other symptoms appear.

After skin contact: Rinse/flush exposed skin gently using soap and water for 15-20 minutes. See medical advice if discomfort or irritation persists.

After eye contact: Protect unexposed eye. Rinse/flush exposed eye(s) gently using water for 15-20 minutes. Remove contact lens(es) if able to do so during rinsing. Seek medical attention if irritation persists or if concerned.

After swallowing: Rinse mouth thoroughly. Do not induce vomiting. Have exposed individual drink sips of water. See medical attention if irritation, discomfort or vomiting persist.

Most important symptoms and effects, both acute and delayed:
Irritation, nausea, headache, shortness of breath
Indication of any immediate medical attention and special treatment needed:
If seeking medical attention, provide SDS document to physician. Physician should treat symptomatically.

Fire fighting measures

Special hazards arising from the substance or mixture: Lead oxides. Combustion products may include carbon oxides or other toxic vapors. Thermal decomposition can lead to release of irritating gases and vapors.

Accidental release measures

Environmental precautions: Prevent from reaching drains, sewer or waterway. Collect contaminated soil for characterization per [Disposal considerations]. Should not be released into environment.

Stability and reactivity

Incompatible materials: Strong acids. Strong oxidizing agents. Strong bases. Oxidizing agents.

Hazardous decomposition products: Lead oxides.

Toxicological information

Carcinogenicity: Possibly carcinogenic to humans. Reasonably anticipated to be a human carcinogen.

Reproductive toxicity:

Reproductive toxicity – rat – inhalation Effects on Newborn: Biochemical and metabolic.

Reproductive toxicity – rat – oral Effects on Newborn: behavioral.

Ecological information

Ecotoxicity

LC50 – *Micropterus dolomieui*: 2.2 mg/l – 96.0h

EC50 – *Skeletonema costatum*: 7.94 mg/l – 10 d.

Disposal considerations

Contact a licensed waste disposal service to dispose of this material.

Transport information

UN-Number 3077

Environmentally hazardous substance, solid, n.o.s. (lead)

Transport hazard class: 9 Miscellaneous dangerous substances and articles

Packing group III

Lead nitrate

Listed at Fort Knox/True North

From ixom.com Safety Data Sheet (https://www.ixom.com/sds-search)

Classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for Transport by Road and Rail; DANGEROUS GOODS.
This material is hazardous according to Safe Work Australia; HAZARDOUS CHEMICAL.

Classification of the chemical:
Oxidising solids - Category 2
Acute Oral Toxicity - Category 4
Acute Inhalation Toxicity - Category 4
Toxic to Reproduction - Category 1A
Mutagenicity - Category 2
Carcinogenicity - Category 2
Specific target organ toxicity (repeated exposure) - Category 2
Acute Aquatic Toxicity - Category 1
Chronic Aquatic Toxicity - Category 1

SIGNAL WORD: DANGER

Hazard Statement(s):
H272 May intensify fire; oxidizer.
H302+H332 Harmful if swallowed or if inhaled.
H318 Causes serious eye damage.
H341 Suspected of causing genetic defects.
H351 Suspected of causing cancer.
H360 May damage fertility or the unborn child.
H373 May cause damage to organs through prolonged or repeated exposure.
H410 Very toxic to aquatic life with long lasting effects.

Precautionary Statement(s):
Prevention:
P201 Obtain special instructions before use.
P202 Do not handle until all safety precautions have been read and understood.
P210 Keep away from heat, sparks, open flames, hot surfaces. No smoking.
P220 Keep and store away from clothing, incompatible materials, combustible materials.
P221 Take any precaution to avoid mixing with combustibles / incompatible materials.
P260 Do not breathe mist, vapours, spray.
P264 Wash hands thoroughly after handling.
P270 Do not eat, drink or smoke when using this product.
P271 Use only outdoors or in a well-ventilated area.
P273 Avoid release to the environment.
P280 Wear protective gloves / protective clothing / eye protection / face protection.
P281 Use personal protective equipment as required.

Response:

P301+P312 IF SWALLOWED: Call a POISON CENTER or doctor/physician if you feel unwell.
P312 Call a POISON CENTER or doctor/physician if you feel unwell.
P330 Rinse mouth.
P304+P340 IF INHALED: Remove person to fresh air and keep comfortable for breathing.
P305+P351+P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P310 Immediately call a POISON CENTER or doctor/physician.
P308+P313 IF exposed or concerned: Get medical advice/attention.
P314 Get medical advice/attention if you feel unwell.
P370+P378 In case of fire: Use extinguishing media as outlined in Section 5 of this Safety Data Sheet to extinguish.
P391 Collect spillage.

Physical state and chemical properties

pH: 3.0-4.0 (20% aq. solution)

Stability and reactivity

Conditions to avoid: Avoid dust generation. Avoid exposure to heat, sources of ignition, and open flame.

Incompatible materials: Incompatible with ammonium thiocyanate, powdered carbon, hydrogen peroxide, lead hypophosphite, combustible materials, organic materials, strong reducingagents, powdered metals.

Hazardous decomposition products: Lead fume. Oxides of nitrogen. Oxides of lead.

Toxicological information

Ingestion: Swallowing can result in nausea, vomiting, diarrhoea, and abdominal pain. Swallowing large amounts may result in lethargy, motor weakness, muscle tenderness and inco-ordination. Death may occur if large amounts are ingested.

Eye contact: A severe eye irritant. Contamination of eyes can result in permanent injury.

Skin contact: Contact with skin may result in irritation.

Inhalation: Breathing in dust may result in respiratory irritation.

Acute toxicity: No oral LD50 data available for the product.

Chronic effects: Absorption of lead over a prolonged period of time (by any route) can produce adverse effects on the blood, central and peripheral nervous systems and reproductive systems, and renal injury. Long term exposure to low concentrations of lead (by any route) may result in blood effects, anaemia, central and peripheral nervous system damage, gastrointestinal disturbances, renal injury, foetotoxicity, developmental deficiencies in neonates and children, and testicular damage including decreased sperm count.

Lead compounds, inorganic: Have been classified by the International Agency for Research on Cancer (IARC) as a Group 2A carcinogen. Group 2A - The agent is probably carcinogenic to humans.

Mutagenicity: Suspected of causing genetic defects.

Carcinogenicity: Suspected of causing cancer.

Reproductive toxicity: May damage fertility or the unborn child.

Specific Target Organ Toxicity (STOT) - single exposure: No information available.

Specific Target Organ Toxicity (STOT) - repeated exposure: May cause damage to organs through prolonged or repeated exposure.

Ecological information

Ecotoxicity: Avoid contaminating waterways.

Persistence/degradability: No information available.

Bioaccumulative potential: No information available.

Mobility in soil: No information available.

Aquatic toxicity: Very toxic to aquatic organisms. May cause long lasting harmful effects to aquatic life.

48hr EC50 (*Daphnia magna*): 0.5-2.0 mg/L
96hr LC50 (fish): 0.4-1.3 mg/L (Carp)

Lime (quick lime, calcium oxide)

Listed at Pogo, Kensington, Greens Creek, Fort Knox/True North, and Red Dog; spilled at Red Dog under "other hazardous substances"

Extracts from echemi.com Safety Data Sheet (http://www.echemi.com/sds/calcium-oxide-pd180727113170.html):

Classification of the substance or mixture
Flammable liquids, Category 3
Aspiration hazard, Category 1
Hazardous to the aquatic environment, long-term (Chronic) - Category Chronic 2

Signal word Danger

Hazard statement(s)
H226 Flammable liquid and vapour
H304 May be fatal if swallowed and enters airways
H411 Toxic to aquatic life with long lasting effects

Precautionary statement(s):
Prevention
P210 Keep away from heat, hot surfaces, sparks, open flames and other ignition sources. No smoking.
P233 Keep container tightly closed.
P240 Ground and bond container and receiving equipment.
P241 Use explosion-proof [electrical/ventilating/lighting/...] equipment.
P242 Use non-sparking tools.
P243 Take action to prevent static discharges.
P280 Wear protective gloves/protective clothing/eye protection/face protection/hearing protection/...
P273 Avoid release to the environment.

Accidental release measures

Personal precautions, protective equipment and emergency procedures: Avoid dust formation. Avoid breathing mist, gas or vapours. Avoid contacting with skin and eye. Use personal protective equipment. Wear chemical impermeable gloves. Ensure adequate ventilation. Remove all sources of ignition. Evacuate personnel to safe areas. Keep people away from and upwind of spill/leak.

Environmental precautions: Prevent further spillage or leakage if it is safe to do so. Do not let the chemical enter drains. Discharge into the environment must be avoided.

Ecological information

Toxicity:

Toxicity to fish: LL50 - *Cyprinus carpio* - 6.8 mg/L - 96 h.

Toxicity to daphnia and other aquatic invertebrates: EL50 - *Daphnia magna* - 5.3 mg/L - 48 h.

Toxicity to algae: EL50 - *Pseudokirchneriella subcapitata* (previous names*: Raphidocelis subcapitata*, *Selenastrum capricornutum*) - 15 mg/L - 72 h.

Toxicity to microorganisms: NOEC - 10 mg/L - 28 d.

Magnafloc

Listed and spilled (under "other hazardous substances") at Red Dog

Extracts from ixom.com Safety Data Sheet (https://www.ixom.com/sds-search) for Magnafloc

> Not classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for transport by Road and Rail; NON-DANGEROUS GOODS.
>
> This material is hazardous according to Safe Work Australia; HAZARDOUS CHEMICAL. Classification of the chemical:
>
> Aspiration hazard - Category 1
>
> SIGNAL WORD: DANGER
>
> *Hazard Statement(s):*
> H304 May be fatal if swallowed and enters airways.
>
> *Precautionary Statement(s):*
> *Prevention:*
> P102 Keep out of reach of children.
>
> *Response:*
> P301+P310 IF SWALLOWED: Immediately call a POISON CENTER or doctor/physician.
> P331 Do NOT induce vomiting.
>
> *Storage:*
> P405 Store locked up.
>
> *Disposal:*
> P501 Dispose of contents and container in accordance with local, regional, national, international regulations.
>
> *Other Hazards*:
> AUH066 Repeated exposure may cause skin dryness or cracking.
> Poisons Schedule (SUSMP): None allocated.
>
> Inhalation: Remove victim from area of exposure - avoid becoming a casualty. Remove contaminated clothing and loosen remaining clothing. Allow patient to assume most comfortable position and keep warm. Keep at rest until fully recovered. Seek medical advice if effects persist.
>
> Skin Contact: If skin contact occurs, remove contaminated clothing and wash skin with soap and water. If irritation occurs, seek medical advice.

Eye Contact: If in eyes, wash out immediately with water. In all cases of eye contamination it is a sensible precaution to seek medical advice.

Ingestion: Rinse mouth with water. If swallowed, do NOT induce vomiting. Give a glass of water. If vomiting occurs, the head should be kept low so that vomit does not enter the lungs. Never give anything by the mouth to an unconscious patient. Get to a doctor or hospital quickly.

Indication of immediate medical attention and special treatment needed: Treat symptomatically. Delayed pulmonary oedema may result. No known specific antidote.

Fire fighting measures

Suitable Extinguishing Media: Fine water spray, normal foam, dry agent (carbon dioxide, dry chemical powder).

Unsuitable Extinguishing Media: Water jet.

Specific hazards arising from the chemical: Combustible liquid.

Special protective equipment and precautions for fire-fighters: On burning will emit toxic fumes, including those of oxides of carbon . Fire fighters to wear self-contained breathing apparatus and suitable protective clothing if risk of exposure to vapour or products of combustion.

Accidental release measures

Emergency procedures/Environmental precautions: Shut off all possible sources of ignition. Clear area of all unprotected personnel. If contamination of sewers or waterways has occurred advise local emergency services.

Personal precautions/Protective equipment/Methods and materials for containment and cleaning up: Slippery when spilt. Avoid accidents, clean up immediately. Wear protective equipment to prevent skin and eye contact and breathing in vapours. Work up wind or increase ventilation. Contain - prevent run off into drains and waterways. Use absorbent (soil, sand or other inert material). Collect and seal in properly labelled containers or drums for disposal. For large amounts, pump off product. Use common salt (sodium chloride) to aid removal of residues.

Physical and chemical properties

pH: 3.9-4.4 (1%(m), 25°C)

Toxicological information

Ingestion: Swallowing can result in nausea, vomiting and central nervous system depression. If the victim is showing signs of central system depression (like those of drunkenness) there is greater likelihood of the patient breathing in vomit and causing damage to the lungs. Aspiration hazard - this material can enter lungs during swallowing or vomiting and cause lung inflammation and damage.

Eye contact: May be an eye irritant.

Skin contact: Contact with skin may result in irritation. Repeated exposure may cause skin dryness or cracking.

Inhalation: Material may be irritant to the mucous membranes of the respiratory tract (airways). Vapours may cause drowsiness and dizziness.

Acute toxicity: No LD50 data available for the product. For a product of similar structure or composition: Oral LD50 (rat): >2000 mg/kg

Chronic effects: Not listed as carcinogenic according to the International Agency for Research on Cancer (IARC).

Ecological information

Ecotoxicity Avoid contaminating waterways.
48hr EC50 (*Daphnia magna*): >100 mg/L
96hr LC50 (fish): >100 mg/L

Manganese dioxide

Listed in the plan of operations for Pogo

Extract from the safety data sheet from Fisher Scientific (https://beta-static.fishersci.com/content/dam/fishersci/en_US/documents/programs/education/regulatory-documents/sds/chemicals/chemicals-m/S25420.pdf)

Hazards identification
Classification of the substance or mixture: Irritant
Acute toxicity (oral, dermal, inhalation), category 4
Acute toxicity – inhalation - category 4
Acute toxicity – oral - category 4

Signal word: WARNING

Hazards statements
Harmful if swallowed
Harmful if inhaled

Precautionary statements
If medical advice is needed, have product container or label at hand
Keep out of reach of children
Read label before use
Do not eat, drink or smoke when using this product
Avoid breathing dust/fumes/gas/mist/vapours/spray
Wash skin thoroughly after handling
Use only outdoors or in a well-ventilated area
IF SWALLOWED: Call a POISON CENTER or doctor/physician if you feel unwell. Rinse mouth
IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing
Call a POISON CENTER or doctor/physician if you feel unwell
Dispose of contents and container to an approved waste disposal plant

First aid measures

After inhalation: Loosen clothing as necessary and position individual in a comfortable position. Give artificial respiration if necessary. If breathing is difficult give oxygen. Get medical assistance in cough or other symptoms appear.

After skin contact: Rinse/flush exposed skin gently using soap and water for 15-20 minutes. Seek medical advice if discomfort or irritation persists.

After eye contact: Protect unexposed eye. Rinse/flush exposed eye(s) gently using water for 15-20 minutes. Remove contact lens(es) if able to do so during rinsing. Seek medical attention if irritation persists or if concerned.

After swallowing: Rinse mouth thoroughly. Do not induce vomiting. Have exposed individuals drink sips of water. Seek medical attention if irritation, discomfort or vomiting persists. Never give anything by mouth to an unconscious person.

Most important symptoms and effects, both acute and delayed:
Irritation, nausea, headache, shortness of breath.
Indication of any immediate medical attention and special treatment needed:
If seeking medical attention, provide SDS document to physician. Physician should treat symptomatically.

Firefighting measures
Special hazards arising from the substance or mixture: Combustion products may include carbon oxides or other toxic vapors. Thermal decomposition can lead to release of irritating gases and vapors.

Accidental release measures
Environmental precautions: Precent from reaching drains, sewer or waterway. Collect contaminated soil for characterization per [*Disposal considerations*]. Should not be released into environment.

Stability and reactivity
Incompatible materials: Strong acids. Strong bases. Organic materials.

Disposal considerations

Contact a licensed professional waste disposal service to dispose of this material.

Methyl alcohol (methanol)

Spilled at Fort Knox/True North and Red Dog

Extracts from EChemi for methanol (https://www.echemi.com/sds/methanol-reagent-pd20150901274.html)

Hazard identification
Classification of the substance or mixture
Flammable liquids, Category 2
Acute toxicity - Category 3, Oral
Acute toxicity - Category 3, Dermal
Acute toxicity - Category 3, Inhalation
Specific target organ toxicity single exposure, Category 1

SIGNAL WORD: DANGER

Hazard statement(s)
H225 Highly flammable liquid and vapour
H301 Toxic if swallowed
H311 Toxic in contact with skin
H331 Toxic if inhaled
H370 Causes damage to organs

Precautionary statement(s)
Prevention
P210 Keep away from heat, hot surfaces, sparks, open flames and other ignition sources. No smoking.
P233 Keep container tightly closed.
P240 Ground and bond container and receiving equipment.
P241 Use explosion-proof [electrical/ventilating/lighting/...] equipment.
P242 Use non-sparking tools.
P243 Take action to prevent static discharges.
P280 Wear protective gloves/protective clothing/eye protection/face protection/hearing protection/...
P264 Wash ... thoroughly after handling.
P270 Do not eat, drink or smoke when using this product.
P261 Avoid breathing dust/fume/gas/mist/vapours/spray.
P271 Use only outdoors or in a well-ventilated area.
P260 Do not breathe dust/fume/gas/mist/vapours/spray.

Response
P303+P361+P353 IF ON SKIN (or hair): Take off immediately all contaminated clothing. Rinse affected areas with water [shower].
P370+P378 In case of fire: Use ... to extinguish.
P301+P316 IF SWALLOWED: Get emergency medical help immediately.
P321 Specific treatment (see ... on this label).
P330 Rinse mouth.

P302+P352 IF ON SKIN: Wash with plenty of water/...
P316 Get emergency medical help immediately.
P361+P364 Take off immediately all contaminated clothing and wash it before reuse.
P304+P340 IF INHALED: Remove person to fresh air and keep comfortable for breathing.
P308+P316 IF exposed or concerned: Get emergency medical help immediately.
Storage
P403+P235 Store in a well-ventilated place. Keep cool.
P405 Store locked up.
P403+P233 Store in a well-ventilated place. Keep container tightly closed.

Disposal

P501 Dispose of contents/container to an appropriate treatment and disposal facility in accordance with applicable laws and regulations, and product characteristics at time of disposal.

Stability and reactivity

Reactivity: Reacts violently with oxidants. This generates fire and explosion hazard.

Chemical stability: no data available

Possibility of hazardous reactions: Dangerous fire hazard when exposed to heat, flame or oxidizers. The vapour mixes well with air, explosive mixtures are easily formed. METHANOL reacts violently with acetyl bromide [Merck 11th ed. 1989]. Mixtures with concentrated sulfuric acid and concentrated hydrogen peroxide can cause explosions. Reacts with hypochlorous acid either in water solution or in mixed water/carbon tetrachloride solution to give methyl hypochlorite, which decomposes in the cold and may explode on exposure to sunlight or heat. Gives the same product with chlorine. Can react explosively with isocyanates under basic conditions. The presence of an inert solvent mitigates this reaction [Wischmeyer 1969]. A violent exothermic reaction occurred between methyl alcohol and bromine in a mixing cylinder [MCA Case History 1863. 1972]. A flask of anhydrous lead perchlorate dissolved in methanol exploded when it was disturbed [J. AChem. Soc. 52:2391. 1930]. P4O6 reacts violently with methanol. (Thorpe, T. E. et al., J. Chem. Soc., 1890, 57, 569-573). Ethanol or methanol can ignite on contact with a platinum-black catalyst. (Urben 1794).

Conditions to avoid: no data available

Incompatible materials: Distillation of mixtures with C1-C3 alcohols gives highly explosive alkyl perchlorates. Barium perchlorate

Hazardous decomposition products: When heated to decomposition it emits acrid smoke and irritating fumes.

Toxicological information

Acute toxicity

Oral: LD0 - rat - >= 2 528 mg/kg bw.

Remarks: Application as 50% aqueous solution.

Inhalation: LC50 - cat - 43.68 mg/L air.

Dermal: LD50 - rabbit - 17 100 mg/kg bw.

Ecological information

Toxicity

Toxicity to fish: LC50 - *Lepomis macrochirus* - 15 400 mg/L - 96 h.

Toxicity to daphnia and other aquatic invertebrates: EC50 - *Daphnia magna* - 18 260 mg/L - 96 h.

Toxicity to algae: EC50 - *Pseudokirchneriella subcapitata* (previous names: *Raphidocelis subcapitata, Selenastrum capricornutum*) - ca. 22 000 mg/L - 96 h.

Toxicity to microorganisms: IC50 - activated sludge from domestic and industrial sewage treatment plants - > 1 000 mg/L - 3 h.

Persistence and degradability

AEROBIC: The half-life for methanol applied to a sandy loam from Mississippi (68% sand, 23.4% silt, 8.6% clay, 0.94% organic carbon, pH 4.8) was 3.2 days. The half-life of methanol applied to a sandy silt loam from Texas (61.5% sand, 31.1% silt, 7.4% clay, 3.28% organic carbon, pH 7.8) was 1 day. The moisture content of each soil was maintained at approxim80% of its field capacity over the 64 day incubation period, and the half-lives did not account for any potential volatilization loss(1).

Bioaccumulative potential

Fish (golden ide (*Leuciscus idus melanotus*)) exposed to 0.05 mg/L of methanol for three days in an aquatic tank had measured BCF values of less than 10(1). According to a classification scheme(2), this BCF suggests the potential for bioconcentration in aquatic organisms is low(SRC).

Mobility in soil

The measured Koc for methanol is reported to be 2.75(1). According to a classification scheme(2), this estimated Koc value suggests that methanol is expected to have very high mobility in soil(SRC).

Methyl isobutyl carbinol (MIBC)

Listed at Pogo, Kensington, Greens Creek, and Red Dog

Extracts from ixom.com Safety Data Sheet (https://www.ixom.com/sds-search) for Methyl isobutyl carbinol

Classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for Transport by Road and Rail; DANGEROUS GOODS.
This material is hazardous according to Safe Work Australia; HAZARDOUS CHEMICAL.

Classification of the chemical:
Flammable liquids - Category 3
Eye Irritation - Category 2A
Specific target organ toxicity (single exposure) - Category 3

Signal word

Warning

Hazard statement(s)
H226 Flammable liquid and vapour.
H319 Causes serious eye irritation.
H335 May cause respiratory irritation.

Precautionary statement(s):
Prevention
P210 Keep away from heat, sparks, open flames, hot surfaces. No smoking.
P233 Keep container tightly closed.
P240 Ground or bond container and receiving equipment
P241 Use explosion-proof electrical, ventilating, lighting equipment.
P242 Use only non-sparking tools.
P243 Take precautionary measures against static discharge.
P261 Avoid breathing mist, vapours, spray.
P264 Wash hands thoroughly after handling.
P271 Use only outdoors or in a well-ventilated area.
P280 Wear protective gloves / protective clothing / eye protection / face protection.

Accidental Release Measures

Emergency procedures/Environmental precautions: Shut off all possible sources of ignition. Clear area of all unprotected personnel. If contamination of sewers or waterways has occurred advise local emergency services.

Personal precautions/Protective equipment/Methods and materials for containment and cleaning up: Slippery when spilt. Avoid accidents, clean up immediately. Wear protective equipment to prevent skin and eye contact and breathing in vapours. Work up wind or increase ventilation. Contain - prevent run off into drains and waterways. Use absorbent (soil, sand or other inert material). Collect and seal in properly labelled containers or drums for disposal. Use non-sparking tools.

Toxicological information

Ingestion: Swallowing can result in nausea, vomiting and central nervous system depression. If the victim is showing signs of central system depression (like those of drunkenness (*sic*)) there is greater likelihood of the patient breathing in vomit and causing damage to the lungs.

Eye contact: An eye irritant.

Skin contact: Contact with skin may result in irritation. Will have a degreasing action on the skin. Repeated or prolonged skin contact may lead to irritant contact dermatitis. Can be absorbed through the skin with resultant adverse effects.

Inhalation: Material is irritant to the mucous membranes of the respiratory tract (airways). Breathing in vapour can result in headaches, dizziness, drowsiness, and possible nausea. Breathing in high concentrations can produce central nervous system depression, which can lead to loss of co-ordination, impaired judgement and if exposure is prolonged, unconsciousness.

Ecological information

Ecotoxicity Avoid contaminating waterways.
Persistence/degradability: The material is readily biodegradable.
48hr EC50 (*Daphnia magna*): 337 mg/L (semi-static test)
96hr LC50 (rainbow trout): 359 mg/L (semi-static test)

Permanganate

Spilled at Kensington

For *Potassium permanganate*

From ixom.com Safety Data Sheet (https://www.ixom.com/sds-search)

Extracts from potassium permanganate SDS

> Classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for Transport by Road and Rail; DANGEROUS GOODS.
>
> This material is hazardous according to Safe Work Australia; HAZARDOUS CHEMICAL.
>
> *Classification of the chemical:*
> Oxidising solids - Category 2
> Acute Oral Toxicity - Category 4
> Skin Corrosion - Sub-category 1C
> Toxic to Reproduction - Category 2
>
> The following health/environmental hazard categories fall outside the scope of the Workplace Health and Safety Regulations:
> Acute Aquatic Toxicity - Category 1
> Chronic Aquatic Toxicity - Category 1
>
> SIGNAL WORD: DANGER
>
> *Hazard Statement(s):*
>
> H272 May intensify fire; oxidizer.
> H302 Harmful if swallowed.
> H314 Causes severe skin burns and eye damage.
> H361 Suspected of damaging fertility or the unborn child.
> H410 Very toxic to aquatic life with long lasting effects.
>
> *Precautionary Statement(s): Prevention:*
>
> P201 Obtain special instructions before use.
> P202 Do not handle until all safety precautions have been read and understood.
> P210 Keep away from heat, sparks, open flames, hot surfaces. No smoking.
> P220 Keep and store away from clothing, incompatible materials, combustible materials.
> P221 Take any precaution to avoid mixing with combustibles / incompatible materials.
> P260 Do not breathe dust.
> P264 Wash hands thoroughly after handling.
> P270 Do not eat, drink or smoke when using this product.
> P280 Wear protective gloves / protective clothing / eye protection / face protection.
> P281 Use personal protective equipment as required.
> P273 Avoid release to the environment.

Accidental release measures

Emergency procedures/Environmental precautions: Isolate spill or leak area immediately. Clear area of all unprotected personnel. Do not allow container or product to get into drains, sewers, streams or ponds. If contamination of sewers or waterways has occurred advise local emergency services.

Personal precautions/Protective equipment/Methods and materials for containment and cleaning up: Wear protective equipment to prevent skin and eye contact and breathing in dust. Work up wind or increase ventilation. Cover with damp absorbent (inert material, sand or soil). Sweep or vacuum up, but avoid generating dust. Collect and seal in properly labelled containers or drums for disposal. DO NOT return spilled material to original container for re-use. Wash area down with excess water. Recover the cleaning water for subsequent disposal.

Soluble in water

Toxicological information

Ingestion: Swallowing can result in nausea, vomiting, diarrhoea, abdominal pain and chemical burns to the gastrointestinal tract.

Eye contact: A severe eye irritant. Contamination of eyes can result in permanent injury.

Skin contact: Contact with skin will result in severe irritation. Corrosive to skin - may cause skin burns.

Inhalation: Breathing in dust may result in respiratory irritation.

Chronic effects: Available evidence from animal studies indicate that repeated or prolonged exposure to this material could result in effects on the central nervous system.

Ecological information

Ecotoxicity Avoid contaminating waterways.

Persistence/degradability: Biodegradation is not an applicable endpoint since the product is an inorganic chemical.

Bioaccumulative potential: May cause bioaccumulation.

Aquatic toxicity: Very toxic to aquatic organisms. May cause long lasting harmful effects to aquatic life

48hr EC50 (*Daphnia magna*): 0.084 mg/L

96hr LC50 (rainbow trout): 0.3-0.6 mg/L
96hr LC50 (bluegill sunfish): 2.3 mg/L

Potassium amyl xanthate (PAX)

Listed at Pogo and Kensington

Extracts from ixom.com Safety Data Sheet (https://www.ixom.com/sds-search)

Classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for Transport by Road and Rail; DANGEROUS GOODS.
This material is hazardous according to Safe Work Australia; HAZARDOUS CHEMICAL.

Classification of the chemical:
Self-heating substances and mixtures - Category 2
Acute Oral Toxicity - Category 4
Acute Dermal Toxicity - Category 4
Skin Irritation - Category 2
Eye Irritation - Category 2A
Specific target organ toxicity (single exposure) - Category 3
Toxic to Reproduction - Category 2
Specific target organ toxicity (repeated exposure) - Category 2

SIGNAL WORD: WARNING

Hazard Statement(s):
H252 Self-heating in large quantities; may catch fire.
H302+H312 Harmful if swallowed or in contact with skin.
H315 Causes skin irritation.
H319 Causes serious eye irritation.
H335 May cause respiratory irritation.
H361 Suspected of damaging fertility or the unborn child.
H373 May cause damage to organs through prolonged or repeated exposure.

Precautionary Statement(s):
Prevention:
P201 Obtain special instructions before use.
P202 Do not handle until all safety precautions have been read and understood.
P235+P410 Keep cool. Protect from sunlight.
P260 Do not breathe dust.
P264 Wash hands thoroughly after handling.
P270 Do not eat, drink or smoke when using this product.
P271 Use only outdoors or in a well-ventilated area.
P280 Wear protective gloves / protective clothing / eye protection / face protection.
P281 Use personal protective equipment as required.

Response:
P301+P312 IF SWALLOWED: Call a POISON CENTER or doctor/physician if you feel unwell.
P330 Rinse mouth.

P302+P352 IF ON SKIN: Wash with plenty of soap and water.
P321 Specific treatment (see First Aid Measures on Safety Data Sheet).
P322 Specific measures (see First Aid Measures on Safety Data Sheet).
P362 Take off contaminated clothing and wash before reuse.
P363 Wash contaminated clothing before re-use.
P332+P313 If skin irritation occurs: Get medical advice/attention.
P305+P351+P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P337+P313 If eye irritation persists: Get medical advice/attention.
P304+P340 IF INHALED: Remove person to fresh air and keep comfortable for breathing.
P312 Call a POISON CENTER or doctor/physician if you feel unwell.
P308+P313 IF exposed or concerned: Get medical advice/attention.
P314 Get medical advice/attention if you feel unwell.

Fire fighting measures

Specific hazards arising from the chemical:
Substance liable to spontaneous combustion.
Avoid all ignition sources.
In common with many organic chemicals, may form flammable dust clouds in air. For precautions necessary refer to Safety Data Sheet "Dust Explosion Hazards".

Special protective equipment and precautions for fire-fighters:
Heating can cause expansion or decomposition of the material, which can lead to the containers exploding. If safe to do so, remove containers from the path of fire. Decomposes on heating emitting toxic fumes, including those of carbon disulphide.
Fire fighters to wear self-contained breathing apparatus and suitable protective clothing if risk of exposure to products of decomposition.

Stability and reactivity

Reactivity: Reacts exothermically on dilution with water. Contact with acids liberates toxic gas.

Chemical stability: Stable under normal conditions of use. Hygroscopic: absorbs moisture or water from surrounding air.

Possibility of hazardous reactions: Hazardous polymerisation will not occur. Can react with water producing carbon disulfide.

Conditions to avoid: Avoid dust generation. Avoid exposure to heat, sources of ignition, and open flame. Avoid exposure to moisture. Avoid exposure to direct sunlight. Avoid electrostatic discharge.

Incompatible materials: Incompatible with oxidising agents, combustible materials, acids, water, phosgene, sulfur chlorides, copper, copper alloy.

Hazardous decomposition products: Carbon disulfide. Hydrogen sulfide. Oxides of sulfur. Oxides of carbon.

Toxicological information

Ingestion: Swallowing can result in nausea, vomiting, diarrhoea, abdominal pain, convulsions and loss of consciousness. Death may occur if large amounts are ingested.

Eye contact: An eye irritant.

Skin contact: Contact with skin will result in irritation. Will liberate carbon disulfide upon contact with moist skin. Carbon disulfide can be absorbed through the skin with resultant adverse effects.

Inhalation: Breathing in dust will result in respiratory irritation. Breathing in high concentrations can produce central nervous system depression, which can lead to loss of co-ordination, impaired judgement and if exposure is prolonged, unconsciousness. Breathing in high concentrations may result in an irregular heart beat and prove suddenly fatal.

Acute toxicity: Oral LD50 (rat): 500-2000 mg/kg

Chronic effects:

Mutagenicity: No information available.

Carcinogenicity: Not listed as carcinogenic according to the International Agency for Research on Cancer (IARC).

Reproductive toxicity: Suspected of damaging fertility or the unborn child.

Specific Target Organ Toxicity (STOT) - single exposure: May cause respiratory irritation.

Specific Target Organ Toxicity (STOT) - repeated exposure: May cause damage to organs through prolonged or repeated exposure.

Ecological information

Ecotoxicity Avoid contaminating waterways

Potassium ethyl xanthate (PEX)

Listed at Red Dog

Extracts from EChemi.com (http://www.echemi.com)

Hazard identification

Classification of the substance or mixture
Flammable solids, Category 1
Acute toxicity - Category 4, Oral
Acute toxicity - Category 4, Dermal
Skin irritation, Category 2
Eye irritation, Category 2
Specific target organ toxicity â..single exposure, Category 3

Hazard identification
Signal word: Danger

Hazard statement(s)
H228 Flammable solid
H302 Harmful if swallowed
H312 Harmful in contact with skin
H315 Causes skin irritation
H319 Causes serious eye irritation
H335 May cause respiratory irritation

Precautionary statement(s)
Prevention
P210 Keep away from heat, hot surfaces, sparks, open flames and other ignition sources. No smoking.
P240 Ground and bond container and receiving equipment.
P241 Use explosion-proof [electrical/ventilating/lighting/...] equipment.
P280 Wear protective gloves/protective clothing/eye protection/face protection/hearing protection/...
P264 Wash ... thoroughly after handling.
P270 Do not eat, drink or smoke when using this product.
P261 Avoid breathing dust/fume/gas/mist/vapours/spray.
P271 Use only outdoors or in a well-ventilated area.

Response
P370+P378 In case of fire: Use ... to extinguish.
P301+P317 IF SWALLOWED: Get medical help.
P330 Rinse mouth.
P302+P352 IF ON SKIN: Wash with plenty of water/...
P317 Get medical help.
P321 Specific treatment (see ... on this label).
P362+P364 Take off contaminated clothing and wash it before reuse.

P332+P317 If skin irritation occurs: Get medical help.
P305+P351+P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easyContinue rinsing.
P304+P340 IF INHALED: Remove person to fresh air and keep comfortable for breathing.
P319 Get medical help if you feel unwell.

Storage
P403+P233 Store in a well-ventilated place. Keep container tightly closed.
P405 Store locked up.

Disposal
P501 Dispose of contents/container to an appropriate treatment and disposal facility in accordance with applicable laws and regulations, and product characteristics at time of disposal.

Description of necessary first-aid measures

If inhaled: Move the victim into fresh air. If breathing is difficult, give oxygen. If not breathing, give artificial respiration and consult a doctor immediately. Do not use mouth to mouth resuscitation if the victim ingested or inhaled the chemical.

Following skin contact: Take off contaminated clothing immediately. Wash off with soap and plenty of water. Consult a doctor.

Following eye contact: Rinse with pure water for at least 15 minutes. Consult a doctor.

Following ingestion: Rinse mouth with water. Do not induce vomiting. Never give anything by mouth to an unconscious person. Call a doctor or Poison Control Center immediately.

Accidental release measures

Personal precautions, protective equipment and emergency procedures

Avoid dust formation. Avoid breathing mist, gas or vapours. Avoid contacting with skin and eye. Use personal protective equipment. Wear chemical impermeable gloves. Ensure adequate ventilation.Remove all sources of ignition. Evacuate personnel to safe areas. Keep people away from and upwind of spill/leak.

Environmental precautions

Prevent further spillage or leakage if it is safe to do so. Do not let the chemical enter drains. Discharge into the environment must be avoided.

Methods and materials for containment and cleaning up

Collect and arrange disposal. Keep the chemical in suitable and closed containers for disposal. Remove all sources of ignition. Use spark-proof tools and explosion-proof equipment. Adhered or collected material should be promptly disposed of, in accordance with appropriate laws and regulations.

Toxicological information

Acute toxicity

Oral: LD50 - rat (male/female) - 500 mg/kg bw.
Remarks: The findings of this study indicate that Sodium Isobutyl Xanthate produces adverse effects on the central nervous system and kidneys.
Inhalation: LC50 - rat (male/female) - 10.35 mg/L air (analytical).
Dermal: LD50 - rabbit (male) - < 1 000 mg/kg bw.

Ecological information

Toxicity

Toxicity to fish: LC50 - *Oncorhynchus mykiss* (previous name: *Salmo gairdneri*) - 76.55 mg/L - 96 h.
Toxicity to daphnia and other aquatic invertebrates: EC50 - *Daphnia magna* - 3.6 mg/L - 24 h.
Toxicity to algae: EC50 - *Chlorella pyrenoidosa* - 21 mg/L - 96 h.
Toxicity to microorganisms: EC50 - *Nitrosomonas* sp. - 50 mg/L - 3 h.

Potassium hydroxide: Liquid

Spilled at Kensington

From ixom.com Safety Data Sheet (https://www.ixom.com/sds-search)

HAZARDS IDENTIFICATION
Classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for Transport by
Road and Rail; DANGEROUS GOODS.
This material is hazardous according to Safe Work Australia; HAZARDOUS CHEMICAL.
Classification of the chemical:
Corrosive to Metals - Category 1
Acute Oral Toxicity - Category 4
Skin Corrosion - Sub-category 1A
Eye Damage - Category 1

SIGNAL WORD: DANGER

Hazard Statement(s):
H290 May be corrosive to metals.
H302 Harmful if swallowed.
H314 Causes severe skin burns and eye damage.

Precautionary Statement(s):
Prevention:
P234 Keep only in original container.
P260 Do not breathe dust / fume / gas / mist / vapours / spray.
P264 Wash hands thoroughly after handling.
P270 Do not eat, drink or smoke when using this product.
P280 Wear protective gloves / protective clothing / eye protection / face protection.

Response:
P301+P330+P331 IF SWALLOWED: Rinse mouth. Do NOT induce vomiting.
P301+P312 IF SWALLOWED: Call a POISON CENTER or doctor/physician if you feel unwell.
P303+P361+P353 IF ON SKIN (or hair): Take off immediately all contaminated clothing. Rinse skin with water/shower.
P321 Specific treatment (see First Aid Measures on Safety Data Sheet).
P363 Wash contaminated clothing before re-use.
P304+P340 IF INHALED: Remove person to fresh air and keep comfortable for breathing.
P310 Immediately call a POISON CENTER or doctor/physician.
P305+P351+P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P390 Absorb spillage to prevent material damage.

Storage:
P405 Store locked up.

P406 Store in corrosive resistant container with a resistant inner liner.

Disposal:
P501 Dispose of contents and container in accordance with local, regional, national, international regulations.

Fire Fighting Measures

Suitable Extinguishing Media: Not combustible, however, if material is involved in a fire use: Fine water spray, normal foam, dry agent (carbon dioxide, dry chemical powder).

Hazchem or Emergency Action Code: 2R

Specific hazards arising from the chemical: Non-combustible material. Corrosive substance. May evolve flammable hydrogen gas on contact with metals.

Physical And Chemical Properties

pH: 12-14

Stability And Reactivity

Reactivity: Reacts violently with acids. Reacts exothermically on dilution with water. Reacts with ammonium salts liberating ammonia gas. Corrosive to aluminium, tin, and zinc.

Chemical stability: Stable under normal ambient and anticipated storage and handling conditions of temperature and pressure. Absorbs carbon dioxide from the air.

Possibility of hazardous reactions: Hazardous polymerisation will not occur. Reacts vigorously with acids, and chlorinated hydrocarbons. Reacts readily with various reducing sugars (i.e., fructose, galactose, maltose, dry whey solids) to produce carbon monoxide. Take precautions including monitoring the tank atmosphere for carbon monoxide to ensure safety of personnel before vessel entry.

Conditions to avoid: Avoid contact with foodstuffs.

Incompatible materials: Incompatible with acids, chlorinated hydrocarbons, ammonium salts, many metals.

Toxicological Information

No adverse health effects expected if the product is handled in accordance with this Safety Data Sheet and the product label. Symptoms or effects that may arise if the product is mishandled and overexposure occurs are:

Ingestion: Swallowing can result in nausea, vomiting, diarrhoea, abdominal pain and chemical burns to the gastrointestinal tract.

Eye contact: A severe eye irritant. Corrosive to eyes; contact can cause corneal burns. Contamination of eyes can result in permanent injury.

Skin contact: Contact with skin will result in severe irritation. Corrosive to skin - may cause skin burns.

Inhalation: Breathing in mists or aerosols may produce respiratory irritation.

Acute toxicity: No LD50 data available for the product. For the constituent Potassium hydroxide:

Oral LD50 (rat): 273 mg/kg
Skin corrosion/irritation: Severe irritant (human).
Serious eye damage/irritation: Moderate irritant (rabbit).

Ecological Information

Ecotoxicity: Avoid contaminating waterways.
Persistence/degradability: Biodegradation is not an applicable endpoint since the product is an inorganic chemical.

Transport Information

Road and Rail Transport
Classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for Transport by Road and Rail; DANGEROUS GOODS.

Marine Transport
Classified as Dangerous Goods by the criteria of the International Maritime Dangerous Goods Code (IMDG Code) for transport by sea; DANGEROUS GOODS.

Air Transport
Classified as Dangerous Goods by the criteria of the International Air Transport Association (IATA) Dangerous Goods Regulations for transport by air; DANGEROUS GOODS.

Potassium hydroxide: Solid

From ixom.com Safety Data Sheet (https://www.ixom.com/sds-search)

HAZARDS IDENTIFICATION
Classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for Transport by
Road and Rail; DANGEROUS GOODS.
This material is hazardous according to Safe Work Australia; HAZARDOUS CHEMICAL.
Classification of the chemical:
Corrosive to Metals - Category 1
Acute Oral Toxicity - Category 4
Skin Corrosion - Sub-category 1A
Eye Damage - Category 1

SIGNAL WORD: DANGER

Hazard Statement(s):
H290 May be corrosive to metals.
H302 Harmful if swallowed.
H314 Causes severe skin burns and eye damage.

Precautionary Statement(s):
Prevention:
P234 Keep only in original container.
P260 Do not breathe dust / fume / gas / mist / vapours / spray.
P264 Wash hands thoroughly after handling.
P270 Do not eat, drink or smoke when using this product.
P280 Wear protective gloves / protective clothing / eye protection / face protection.

Response:
P301+P330+P331 IF SWALLOWED: Rinse mouth. Do NOT induce vomiting.
P301+P312 IF SWALLOWED: Call a POISON CENTER or doctor/physician if you feel unwell.
P303+P361+P353 IF ON SKIN (or hair): Take off immediately all contaminated clothing. Rinse skin with water/shower.
P321 Specific treatment (see First Aid Measures on Safety Data Sheet).
P363 Wash contaminated clothing before re-use.
P304+P340 IF INHALED: Remove person to fresh air and keep comfortable for breathing.
P310 Immediately call a POISON CENTER or doctor/physician.
P305+P351+P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P390 Absorb spillage to prevent material damage.

Storage:
P405 Store locked up.
P406 Store in corrosive resistant container with a resistant inner liner.

Disposal:

P501 Dispose of contents and container in accordance with local, regional, national, international regulations.

Physical And Chemical Properties

pH: 14 (10g/100 mL water)

Stability And Reactivity

Reactivity: Reacts violently with acids. Reacts with ammonium salts liberating ammonia gas.

Chemical stability: Stable under normal conditions of use. Deliquescent. Absorbs carbon dioxide from the air.

Possibility of hazardous reactions: Corrosive to metals in the presence of moisture. Corrosive to aluminium, tin, and zinc, liberating flammable hydrogen gas.

Conditions to avoid: Avoid exposure to moisture. Avoid exposure to air. Avoid exposure to humidity. Avoid contact with organic materials.

Incompatible materials: Incompatible with acids, ammonium salts, chlorinated hydrocarbons, water, many metals.

Hazardous decomposition products: Oxides of potassium.

Toxicological Information

No adverse health effects expected if the product is handled in accordance with this Safety Data Sheet and the product label. Symptoms or effects that may arise if the product is mishandled and overexposure occurs are:

Ingestion: Swallowing can result in nausea, vomiting, diarrhoea, abdominal pain and chemical burns to the gastrointestinal tract.

Eye contact: A severe eye irritant. Corrosive to eyes; contact can cause corneal burns. Contamination of eyes can result in permanent injury.

Skin contact: Contact with skin will result in severe irritation. Corrosive to skin - may cause skin burns.

Inhalation: Breathing in dust may result in respiratory irritation.

Acute toxicity:

Oral LD50 (rat): 273 mg/kg

Skin corrosion/irritation: Severe irritant (rabbit).

Serious eye damage/irritation: Corrosive (rabbit).

Ecological Information

Ecotoxicity: Avoid contaminating waterways.
Persistence/degradability: Biodegradation is not an applicable endpoint since the product is an inorganic chemical.

Transport Information

Road and Rail Transport
Classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for Transport by Road and Rail; DANGEROUS GOODS.

Marine Transport
Classified as Dangerous Goods by the criteria of the International Maritime Dangerous Goods Code (IMDG Code) for transport by sea; DANGEROUS GOODS.

Air Transport
Classified as Dangerous Goods by the criteria of the International Air Transport Association (IATA) Dangerous Goods Regulations for transport by air; DANGEROUS GOODS.

Propylene glycol

Spilled at Pogo, Fort Knox/True North, and Red Dog

Extracts from ixom.com Safety Data Sheet (https://www.ixom.com/sds-search) for propylene glycol

> Not classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for transport by Road and Rail; NON-DANGEROUS GOODS.
> Based on available information, not classified as hazardous according to Safe Work Australia; NON-HAZARDOUS CHEMICAL.
>
> *Stability and reactivity*
>
> Conditions to avoid: Avoid exposure to heat, sources of ignition, and open flame. Avoid temperatures above 40°C. Avoid exposure to direct sunlight.
>
> Incompatible materials: Incompatible with strong oxidising agents, strong acids, isocyanates.
>
> Hazardous decomposition products: Oxides of carbon. Aldehydes. Alcohols. Ethers. Organic acids.
>
> *Ecological information*
>
> Ecotoxicity 96hr LC50 (rainbow trout): 40,613 mg/L

Soda ash

Listed among fluxes for Pogo and Fort Knox/True North

From ixom.com Safety Data Sheet (https://www.ixom.com/sds-search)

Extracts from the soda ash solution 10% SDS

Not classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for transport by Road and Rail; NON-DANGEROUS GOODS.
This material is hazardous according to Safe Work Australia; HAZARDOUS CHEMICAL.

Classification of the chemical:
Eye Irritation - Category 2A

SIGNAL WORD: WARNING

Hazard Statement(s):
H319 Causes serious eye irritation.

Precautionary Statement(s):
Prevention:
P264 Wash hands thoroughly after handling.
P280 Wear protective gloves / protective clothing / eye protection / face protection.

Accidental release measures

Emergency procedures/Environmental precautions: Clear area of all unprotected personnel. If contamination of sewers or waterways has occurred advise local emergency services.

Personal precautions/Protective equipment/Methods and materials for containment and cleaning up: Slippery when spilt. Avoid accidents, clean up immediately. Contain - prevent run off into drains and waterways. Use absorbent (soil, sand or other inert material). Collect and seal in properly labelled containers or drums for disposal. Wash area down with excess water.

Physical and chemical properties

Solubility: Miscible in water.
pH: >10.5

Toxicological information

Ingestion: No adverse effects expected, however, large amounts may cause nausea and vomiting. May cause irritation to the mouth, throat and digestive tract.

Eye contact: An eye irritant.

Skin contact: Contact with skin may result in irritation. Repeated or prolonged skin contact may lead to irritant contact dermatitis.

Inhalation: Breathing in mists or aerosols may produce respiratory irritation.

Ecological information

Ecotoxicity Avoid contaminating waterways.

Sodium carbonate

Listed in the plan of operations for Greens Creek

Extracts from the Fisher Scientific Material Safety Data Sheet for sodium carbonate (https://fscimage.fishersci.com/msds/21080.htm)

Hazards Identification

EMERGENCY OVERVIEW

Warning! Harmful if inhaled. Causes eye and skin irritation. May cause respiratory tract irritation. Hygroscopic (absorbs moisture from the air).

Target Organs: Eyes, skin.

Potential Health Effects
Eye: Causes eye irritation. Lachrymator (substance which increases the flow of tears).
Skin: Causes skin irritation. May be harmful if absorbed through the skin.
Ingestion: May cause irritation of the digestive tract. May be harmful if swallowed.
Inhalation: Harmful if inhaled. May cause respiratory tract irritation.
Chronic: Adverse reproductive effects have been reported in animals.

First Aid Measures

Eyes: Immediately flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower eyelids. Get medical aid.

Skin: Get medical aid. Immediately flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes.

Ingestion: Do not induce vomiting. Get medical aid.

Inhalation: Remove from exposure and move to fresh air immediately. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical aid.

Notes to Physician: Treat symptomatically and supportively.

Accidental Release Measures

Spills/Leaks: Vacuum or sweep up material and place into a suitable disposal container. Wear a self contained breathing apparatus and appropriate personal protection. (See Exposure Controls, Personal Protection section). Avoid generating dusty conditions. Provide ventilation. Do not let this chemical enter the environment.

Stability and Reactivity

Chemical Stability: Hygroscopic: absorbs moisture or water from the air.

Conditions to Avoid: Incompatible materials, dust generation, excess heat, moist air.

Incompatibilities with Other Materials: Acids, strong oxidizing agents, metals, fluorine, hydrogen peroxide, phosphorus pentoxide, 2,4,6-trinitrotoluene, 2,-4-dinitrotoluene.

Hazardous Decomposition Products: Carbon monoxide, carbon dioxide, toxic fumes of sodium oxide.

Hazardous Polymerization: Has not been reported.

Toxicological Information

LD50/LC50:

CAS# 497-19-8:

Draize test, rabbit, eye: 100 mg/24H Moderate;
Draize test, rabbit, eye: 50 mg Severe;
Draize test, rabbit, skin: 500 mg/24H Mild;
Inhalation, mouse: LC50 = 1200 mg/m3/2H;
Inhalation, rat: LC50 = 2300 mg/m3/2H;
Oral, mouse: LD50 = 6600 mg/kg;
Oral, mouse: LD50 = 6600 mg/kg;
Oral, rat: LD50 = 4090 mg/kg;

Ecological Information

Ecotoxicity: Fish: Bluegill/Sunfish: LC50 = 320 mg/L; 96 Hr.; Static Conditions No data available.

Sodium cetylsulfonate

Listed for Red Dog

Extracts from ThermoFisher Scientific Safety Data Sheet for n-hexadecyl sulfate, sodium salt

(https://www.fishersci.com/store/msds?partNumber=AC385000010&productDescription=N-HEXADECYL+SULFATE%2C+SOD+1GR&vendorId=VN00032119&countryCode=US&language=en)

Hazard(s) identification

This chemical is considered hazardous by the 2012 OSHA Hazard Communication Standard (29 CFR 1910.1200)

Skin Corrosion/Irritation: Category 2
Serious Eye Damage/Eye Irritation: Category 2
Specific target organ toxicity (single exposure): Category 3
Target Organs - Respiratory system.

Signal Word WARNING

Hazard Statements
Causes skin irritation
Causes serious eye irritation
May cause respiratory irritation
Causes eye irritation

Precautionary Statements
Prevention
Wash face, hands and any exposed skin thoroughly after handling
Wear protective gloves/protective clothing/eye protection/face protection
Avoid breathing dust/fume/gas/mist/vapors/spray
Use only outdoors or in a well-ventilated area
Inhalation: IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing
Skin: IF ON SKIN: Wash with plenty of soap and water. If skin irritation occurs: Get medical advice/attention. Take off contaminated clothing and wash before reuse
Eyes: IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. If eye irritation persists: Get medical advice/attention.

Storage
Store in a well-ventilated place. Keep container tightly closed
Store locked up

Disposal
Dispose of contents/container to an approved waste disposal plant

First-aid measures

Eye Contact: Rinse immediately with plenty of water, also under the eyelids, for at least 15 minutes. Get medical attention.
Skin Contact: Get medical attention. Wash off immediately with plenty of water for at least 15 minutes.
Inhalation: Remove to fresh air. Get medical attention. If not breathing, give artificial respiration.
Ingestion: Do NOT induce vomiting. Get medical attention.
Most important symptoms and effects: No information available.
Notes to Physician: Treat symptomatically

Fire-fighting measures

Specific Hazards Arising from the Chemical: Thermal decomposition can lead to release of irritating gases and vapors.
Hazardous Combustion Products: Carbon monoxide (CO). Carbon dioxide (CO2). Sulfur oxides.

Accidental release measures

Environmental Precautions: Should not be released into the environment.
Methods for Containment and Clean Up: Sweep up and shovel into suitable containers for disposal. Do not let this chemical enter the environment.

Stability and reactivity

Incompatible Materials: Bases, Strong oxidizing agents
Hazardous Decomposition Products: Carbon monoxide (CO), Carbon dioxide (CO_2), Sulfur oxides

Sodium hydroxide

Listed for Pogo, Greens Creek, and Fort Knox/True North

Extracts from ixom.com Safety Data Sheet (https://www.ixom.com/sds-search) for caustic soda – liquid (46-50%) (Data sheet for 5-45% also available.)

Classified as a Dangerous Good according to NZS 5433:2012 Transport of Dangerous Goods on Land.
Classified as hazardous according to criteria in the Hazardous Substances (Minimum Degrees of Hazard) Notice 2017 and the Hazardous Substances (Classification) Notice 2017.

SIGNAL WORD: DANGER

Subclasses:
Subclass 6.1 Category D - Substances which are acutely toxic.
Subclass 8.1 Category A - Substances that are corrosive to metals.
Subclass 8.2 Category B - Substances that are corrosive to dermal tissue.
Subclass 8.3 Category A - Substances that are corrosive to ocular tissue.
Subclass 9.1 Category D - Substances that are slightly harmful to the aquatic environment or are otherwise designed for biocidal action.

Hazard Statement(s):
H290 May be corrosive to metals.
H302 Harmful if swallowed.
H313 May be harmful in contact with skin.
H314 Causes severe skin burns and eye damage.
H402 Harmful to aquatic life.

Precautionary Statement(s):
Prevention:
P102 Keep out of reach of children.
P103 Read label before use.
P234 Keep only in original container.
P260 Do not breathe mist/vapours/spray.
P264 Wash hands thoroughly after handling.
P270 Do not eat, drink or smoke when using this product.
P273 Avoid release to the environment.
P280 Wear protective gloves/protective clothing/eye protection/face protection.

Response:
P301+P330+P331 IF SWALLOWED: Rinse mouth. Do NOT induce vomiting.
P303+P361+P353 IF ON SKIN (or hair): Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower.
P304+P340 IF INHALED: Remove to fresh air and keep at rest in a position comfortable for breathing.

P305+P351+P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P310 Immediately call a POISON CENTER or doctor/physician.
P321 Specific treatment (see First Aid Measures on the Safety Data Sheet).
P363 Wash contaminated clothing before re-use.
P390 Absorb spillage to prevent material damage.

Physical and chemical properties

Physical state: Liquid
Colour: Colourless
Odour: Odourless
Solubility: Miscible with water.
Specific Gravity: 1.48-1.52 @20°C
pH: 14 (literature)

Stability and reactivity

Reactivity: Reacts violently with acids. Reacts exothermically on dilution with water.

Chemical stability: Stable under normal ambient and anticipated storage and handling conditions of temperature and pressure. Absorbs carbon dioxide from the air.

Possibility of hazardous reactions: Reacts with ammonium salts, evolving ammonia gas. Reacts readily with various reducing sugars (i.e. fructose, galactose, maltose, dry whey solids) to produce carbon monoxide. Take precautions including monitoring the tank atmosphere for carbon monoxide to ensure safety of personnel before vessel entry.

Conditions to avoid: Avoid exposure to moisture. Avoid exposure to direct sunlight.

Incompatible materials: Incompatible with acids, ammonium salts, aluminium, tin, zinc, brass.

Toxicological information

Ingestion: Swallowing can result in nausea, vomiting, diarrhoea, abdominal pain andchemical burns to the gastrointestinal tract.

Eye contact: A severe eye irritant. Corrosive to eyes; contact can cause corneal burns.

Contamination of eyes can result in permanent injury. May cause blindness.

Skin contact: Contact with skin will result in severe irritation. Corrosive to skin - may cause skin burns.

Inhalation: Breathing in mists or aerosols may produce respiratory irritation.

Acute toxicity: No LD50 data available for the product.

For the constituent Sodium hydroxide: Skin corrosion/irritation: Severe irritant (rabbit).

Specific Target Organ Toxicity (STOT) - single exposure: May cause respiratory irritation.
Serious eye damage/irritation: Severe irritant (rabbit).

Ecological information

Ecotoxicity Avoid contaminating waterways.

Sodium hypochlorite

Listed at Red Dog as a chemical for treating spills; spilled at Kensington, Fort Knox/True North, and Red Dog

Extracts from ixom.com Safety Data Sheet (https://www.ixom.com/sds-search) for sodium hypochlorite solution (10-15% solution)

Hazards identification

Classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for Transport by Road and Rail; DANGEROUS GOODS.
This material is hazardous according to Safe Work Australia; HAZARDOUS CHEMICAL.

Classification of the chemical:
Skin Corrosion - Sub-category 1B
Eye Damage - Category 1
Specific target organ toxicity (single exposure) - Category 3
The following health/environmental hazard categories fall outside the scope of the Workplace Health and Safety Regulations:
Acute Aquatic Toxicity - Category 1
Chronic Aquatic Toxicity – Category 1

SIGNAL WORD: DANGER

Hazard Statement(s):
H314 Causes severe skin burns and eye damage.
H335 May cause respiratory irritation.
H410 Very toxic to aquatic life with long lasting effects.

Precautionary Statement(s):
Prevention:
P260 Do not breathe mist, vapours, spray.
P264 Wash hands thoroughly after handling.
P271 Use only outdoors or in a well-ventilated area.
P280 Wear protective gloves / protective clothing / eye protection / face protection.
P273 Avoid release to the environment.

Response:
P301+P330+P331 IF SWALLOWED: Rinse mouth. Do NOT induce vomiting.
P303+P361+P353 IF ON SKIN (or hair): Take off immediately all contaminated clothing. Rinse skin with water/shower.
P321 Specific treatment (see First Aid Measures on Safety Data Sheet).
P363 Wash contaminated clothing before re-use.
P304+P340 IF INHALED: Remove person to fresh air and keep comfortable for breathing.
P312 Call a POISON CENTER or doctor/physician if you feel unwell.
P305+P351+P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P310 Immediately call a POISON CENTER or doctor/physician.

Other Hazards:
AUH031 Contact with acids liberates toxic gas.

Physical and chemical properties

pH: 12.5 (1% w/w)

Stability and reactivity

Possibility of hazardous reactions: Hazardous polymerisation will not occur. Reacts exothermically with acids. Reacts with ammonia, amines, or ammonium salts to produce chloramines. Decomposes on heating to produce chlorine gas.

Conditions to avoid: Avoid contact with foodstuffs. Avoid exposure to heat, sources of ignition, and open flame. Avoid exposure to light. Avoid contact with other chemicals. Avoid contact with acids.

Incompatible materials: Incompatible with acids, metals, metal salts, peroxides, reducing agents, ethylene diamine tetra-acetic acid, methanol, aziridine, urea. Incompatible with ammonia and ammonium compounds such as amines and ammonium salts.

Hazardous decomposition products: Chlorine.

Toxicological information

Ingestion: Swallowing can result in nausea, vomiting, diarrhoea, abdominal pain and chemical burns to the gastrointestinal tract.

Eye contact: A severe eye irritant. Corrosive to eyes; contact can cause corneal burns. Contamination of eyes can result in permanent injury.

Skin contact: Contact with skin will result in severe irritation. Corrosive to skin - may cause skin burns.

Inhalation: Breathing in mists or aerosols will produce respiratory irritation. Delayed (up to 48 hours) fluid build up in the lungs may occur.

Acute toxicity: No LD50 data available for the product.

For the constituent SODIUM HYPOCHLORITE:
Oral LD50 (mice): 5800 mg/kg
Serious eye damage/irritation: Moderate irritant (rabbit). Standard Draize test

Ecological information

Ecotoxicity: Avoid contaminating waterways.

Persistence/degradability: This material is biodegradable.

Bioaccumulative potential: Does not bioaccumulate.

Mobility in soil: No information available.

Aquatic toxicity: Very toxic to aquatic life with long lasting effects.
96hr LC50 (fish): 0.065 mg/L (for sodium hypochlorite)

Sodium isobutyl xanthate (SIBX)

Listed at Red Dog

Extracts from ixom.com Safety Data Sheet (https://www.ixom.com/sds-search)

HAZARDS IDENTIFICATION
Classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for Transport by
Road and Rail; DANGEROUS GOODS.
This material is hazardous according to Safe Work Australia; HAZARDOUS CHEMICAL.

Classification of the chemical:
Self-heating substances and mixtures - Category 2
Acute Oral Toxicity - Category 4
Acute Dermal Toxicity - Category 4
Skin Irritation - Category 2
Eye Irritation - Category 2A
Specific target organ toxicity (single exposure) - Category 3
Toxic to Reproduction - Category 2
Specific target organ toxicity (repeated exposure) - Category 2

SIGNAL WORD: WARNING

Hazard Statement(s):
H252 Self-heating in large quantities; may catch fire.
H302+H312 Harmful if swallowed or in contact with skin.
H315 Causes skin irritation.
H319 Causes serious eye irritation.
H335 May cause respiratory irritation.
H361 Suspected of damaging fertility or the unborn child.
H373 May cause damage to organs through prolonged or repeated exposure.

Precautionary Statement(s):
Prevention:
P201 Obtain special instructions before use.
P202 Do not handle until all safety precautions have been read and understood.
P235+P410 Keep cool. Protect from sunlight.
P260 Do not breathe dust.
P264 Wash hands thoroughly after handling.
P270 Do not eat, drink or smoke when using this product.
P271 Use only outdoors or in a well-ventilated area.
P280 Wear protective gloves / protective clothing / eye protection / face protection.
P281 Use personal protective equipment as required.

Response:
P301+P312 IF SWALLOWED: Call a POISON CENTER or doctor/physician if you feel unwell.
P330 Rinse mouth.
P302+P352 IF ON SKIN: Wash with plenty of soap and water.

P321 Specific treatment (see First Aid Measures on Safety Data Sheet).
P322 Specific measures (see First Aid Measures on Safety Data Sheet).
P362 Take off contaminated clothing and wash before reuse.
P363 Wash contaminated clothing before re-use.
P332+P313 If skin irritation occurs: Get medical advice/attention.
P305+P351+P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P337+P313 If eye irritation persists: Get medical advice/attention.
P304+P340 IF INHALED: Remove person to fresh air and keep comfortable for breathing.
P308+P313 IF exposed or concerned: Get medical advice/attention.
P312 Call a POISON CENTER or doctor/physician if you feel unwell.

Storage:
P403+P233 Store in a well-ventilated place. Keep container tightly closed.
P405 Store locked up.
P407 Maintain air gap between stacks/pallets.
P420 Store away from other materials.

Disposal:
P501 Dispose of contents and container in accordance with local, regional, national, international regulations.

Other Hazards:
AUH031 Contact with acids liberates toxic gas.
Poisons Schedule (SUSMP): S5 Caution.

Inhalation: Remove victim from area of exposure - avoid becoming a casualty. Remove contaminated clothing and loosen remaining clothing. Allow patient to assume most comfortable position and keep warm. Keep at rest until fully recovered. If patient finds breathing difficult and develops a bluish discolouration of the skin (which suggests a lack of oxygen in the blood - cyanosis), ensure airways are clear of any obstruction and have a qualified person give oxygen through a face mask. Apply artificial respiration if patient is not breathing. Seek immediate medical advice.

Skin Contact: If skin or hair contact occurs, immediately remove any contaminated clothing and wash skin and hair thoroughly with running water and soap. If swelling, redness, blistering or irritation occurs seek medical assistance.

Eye Contact: If in eyes, hold eyelids apart and flush the eye continuously with running water. Continue flushing until advised to stop by a Poisons Information Centre or a doctor, or for at least 15 minutes.

Ingestion: Rinse mouth with water. If swallowed, give a glass of water to drink. If vomiting occurs give further water. Seek immediate medical assistance.

Fire fighting measures

Suitable Extinguishing Media: Coarse water spray, fine water spray, normal foam, dry agent (carbon dioxide, dry chemical powder).

Hazchem or Emergency Action Code: 1Y

Specific hazards arising from the chemical: Substance liable to spontaneous combustion. Avoid all ignition sources. In common with many organic chemicals, may form flammable dust clouds in air. For precautions necessary refer to Safety Data Sheet "Dust Explosion Hazards".

Special protective equipment and precautions for fire-fighters: Heating can cause expansion or decomposition of the material, which can lead to the containers exploding. If safe to do so, remove containers from the path of fire. Decomposes on heating emitting toxic fumes, including those of carbon disulphide . Fire fighters to wear self-contained breathing apparatus and suitable protective clothing if risk of exposure to products of decomposition.

Accidental release measures

Emergency procedures/Environmental precautions: Shut off all possible sources of ignition. Clear area of all unprotected personnel. If contamination of sewers or waterways has occurred advise local emergency services.

Personal precautions/Protective equipment/Methods and materials for containment and cleaning up: Wear protective equipment to prevent skin and eye contact and breathing in vapours/dust. DO NOT allow material to get wet. Air-supplied masks are recommended to avoid inhalation of toxic material. Vacuum solid spills instead of sweeping. Collect and seal in properly labelled containers or drums for disposal. Use non-sparking tools. After cleaning, flush away any residual traces with water.

Stability and reactivity

Reactivity: Reacts exothermically on dilution with water. Contact with acids liberates toxic gas.

Chemical stability: Stable under normal conditions of use. Hygroscopic: absorbs moisture or water from surrounding air.

Possibility of hazardous reactions: Hazardous polymerisation will not occur. Can react with water producing carbon disulfide.

Conditions to avoid: Avoid dust generation. Avoid exposure to heat, sources of ignition, and open flame. Avoid exposure to moisture.

Incompatible materials: Incompatible with oxidising agents, combustible materials, acids, water, phosgene, sulfur chlorides, copper, copper alloys.

Hazardous decomposition products: Carbon disulfide. Hydrogen sulfide.

Toxicological information

No adverse health effects expected if the product is handled in accordance with this Safety Data Sheet and the product label. Symptoms or effects that may arise if the product is mishandled and overexposure occurs are:

Ingestion: Swallowing can result in nausea, vomiting, diarrhoea, abdominal pain, convulsions and loss of consciousness. Death may occur if large amounts are ingested.

Eye contact: An eye irritant.

Skin contact: Contact with skin will result in irritation. Will liberate carbon disulfide upon contact with moist skin. Carbon disulfide can be absorbed through the skin with resultant adverse effects.

Inhalation: Breathing in dust will result in respiratory irritation. Breathing in high concentrations can produce central nervous system depression, which can lead to loss of co-ordination, impaired judgement and if exposure is prolonged, unconsciousness. Breathing in high concentrations may result in an irregular heart beat and prove suddenly fatal.

Acute toxicity: Oral LD50 (rat): 500-2000 mg/kg

Chronic effects:

Mutagenicity: No information available.

Carcinogenicity: Not listed as carcinogenic according to the International Agency for Research on

Cancer (IARC).

Reproductive toxicity: Suspected of damaging fertility or the unborn child.

Specific Target Organ Toxicity (STOT) - single exposure: May cause respiratory irritation.

Specific Target Organ Toxicity (STOT) - repeated exposure: May cause damage to organs through prolonged or repeated exposure.

Aspiration hazard: No information available.

Ecological information

Ecotoxicity Avoid contaminating waterways.

Transport information

Road and Rail Transport
Classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for Transport by
Road and Rail; DANGEROUS GOODS.
Transport Hazard Class: 4.2 Spontaneously Combustible
Packing Group: III
Proper Shipping Name or Technical Name: XANTHATES
Hazchem or Emergency Action Code: 1Y

Marine Transport
Classified as Dangerous Goods by the criteria of the International Maritime Dangerous Goods Code (IMDG Code) for transport by sea; DANGEROUS GOODS.
UN No: 3342
Transport Hazard Class: 4.2 Spontaneously Combustible
Packing Group: III
Proper Shipping Name or Technical Name: XANTHATES
IMDG EMS Fire: F-A
IMDG EMS Spill: S-J

Air Transport
Classified as Dangerous Goods by the criteria of the International Air Transport Association (IATA) Dangerous Goods
Regulations for transport by air; DANGEROUS GOODS. TRANSPORT PROHIBITED under the International Air Transport Association (IATA) Dangerous Goods Regulations for transport by air in Passenger and Cargo Aircraft; may be transported by Cargo Aircraft Only.
UN No: 3342
Transport Hazard Class: 4.2 Spontaneously Combustible
Packing Group: III
Proper Shipping Name or Technical Name: XANTHATES

Sodium isopropyl xanthate (SIPX)

Listed for Greens Creek and Red Dog

Extracts from ixom.com Safety Data Sheet (https://www.ixom.com/sds-search)

Hazards identification
Classified as dangerous goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for transport by road and rail; dangerous goods.
This material is hazardous according to Safe Work Australia; HAZARDOUS CHEMICAL.

Classification of the chemical:
Self-heating substances and mixtures - category 1
Acute oral toxicity - category 4
Acute dermal toxicity - category 4
Skin irritation - category 2
Eye irritation - category 2a
Toxic to reproduction - category 2
Specific target organ toxicity (repeated exposure) - category 2
The following health/environmental hazard categories fall outside the scope of the workplace health and safety regulations:
Acute aquatic toxicity - category 2
Chronic aquatic toxicity - category 2

SIGNAL WORD: DANGER

Hazard statement(s):
H251 self-heating; may catch fire.
H302+H312 harmful if swallowed or in contact with skin.
H315 causes skin irritation.
H319 causes serious eye irritation.
H361 suspected of damaging fertility or the unborn child.
H373 may cause damage to organs through prolonged or repeated exposure.
H411 toxic to aquatic life with long lasting effects.

Precautionary statement(s):
Prevention:
P102 keep out of reach of children.
P201 obtain special instructions before use.
P202 do not handle until all safety precautions have been read and understood.
P235+P410 keep cool. Protect from sunlight.
P260 do not breathe dust.
P264 wash hands thoroughly after handling.
P270 do not eat, drink or smoke when using this product.
P273 avoid release to the environment.
P280 wear protective gloves / protective clothing / eye protection / face protection.
P281 use personal protective equipment as required.

Response:
P301+P312 if swallowed: call a poison center or doctor/physician if you feel unwell.
P330 rinse mouth.
P302+P352 if on skin: wash with plenty of soap and water.
P312 call a poison center or doctor/physician if you feel unwell.
P321 specific treatment (see first aid measures on safety data sheet).
P322 specific measures (see first aid measures on safety data sheet).
P332+P313 if skin irritation occurs: get medical advice/attention.
P362 take off contaminated clothing and wash before reuse.
P363 wash contaminated clothing before re-use.
P308+P313 if exposed or concerned: get medical advice/attention.
P305+P351+P338 if in eyes: rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P337+P313 if eye irritation persists: get medical advice/attention.
P314 get medical advice/attention if you feel unwell.
P391 collect spillage.

Storage:
P405 store locked up.
P407 maintain air gap between stacks/pallets.
P420 store away from other materials.

Disposal:
P501 dispose of contents and container in accordance with local, regional, national, international regulations.

Other hazards:
Auh031 contact with acids liberates toxic gas.
Poisons schedule (susmp): none allocated.

First aid measures

Inhalation: Remove victim from area of exposure - avoid becoming a casualty. Remove contaminated clothing and loosen remaining clothing. Allow patient to assume most comfortable position and keep warm. Keep at rest until fully recovered. If patient finds breathing difficult and develops a bluish discolouration of the skin (which suggests a lack of oxygen in the blood - cyanosis), ensure airways are clear of any obstruction and have a qualified person give oxygen through a face mask. Apply artificial respiration if patient is not breathing. Seek immediate medical advice.

Skin contact: If skin or hair contact occurs, immediately remove any contaminated clothing and wash skin and hair thoroughly with running water and soap. If swelling, redness, blistering or irritation occurs seek medical assistance.

Eye contact: If in eyes, hold eyelids apart and flush the eye continuously with running water. Continue flushing until advised to stop by a poisons information centre or a doctor, or for at least 15 minutes.

Ingestion: Rinse mouth with water. If swallowed, do not induce vomiting. Give a glass of water. Never give anything by the mouth to an unconscious patient. Seek immediate medical assistance.

Indication of immediate medical attention and special treatment needed: Treat symptomatically.

Fire fighting measures

Suitable extinguishing media: Coarse water spray, fine water spray, normal foam, dry agent (carbon dioxide, dry chemical powder).

Hazchem or emergency action code: 1y

Specific hazards arising from the chemical: Substance liable to spontaneous combustion. Environmentally hazardous.

Special protective equipment and precautions for fire-fighters: Heating can cause expansion or decomposition of the material, which can lead to the containers exploding. If safe to do so, remove containers from the path of fire. Decomposes on heating emitting toxic fumes, including those of carbon disulphide . Fire fighters to wear self-contained breathing apparatus and suitable protective clothing if risk of exposure to products of decomposition.

Accidental release measures

Emergency procedures/environmental precautions: Shut off all possible sources of ignition. Clear area of all unprotected personnel. Do not allow container or product to get into drains, sewers, streams or ponds. If contamination of sewers or waterways has occurred advise local emergency services.

Personal precautions/protective equipment/methods and materials for containment and cleaning up: Wear protective equipment to prevent skin and eye contact and breathing in vapours/dust. Do not allow material to get wet. Air-supplied masks are recommended to avoid inhalation of toxic material. Vacuum solid spills instead of sweeping. Collect and seal in properly labelled containers or drums for disposal.

Physical and chemical properties

pH: >12

Stability and reactivity

Reactivity: reacts with moisture liberating highly flammable carbon disulfide vapours.

Chemical stability: stable under normal ambient and anticipated storage and handling conditions of temperature and pressure.

Possibility of hazardous reactions: Reacts exothermically with water . Reacts with acids liberating toxic gas.

Conditions to avoid: avoid exposure to moisture. Avoid exposure to heat. Avoid dust generation.

Incompatible materials: incompatible with acids , oxidising agents, moisture.

Hazardous decomposition products: Carbon disulfide. Oxides of carbon.

Toxicological information

Ingestion: swallowing may result in irritation of the gastrointestinal tract.

Eye contact: An eye irritant

Skin contact: contact with skin will result in irritation. Will liberate carbon disulfide upon contact with moist skin. Carbon disulfide can be absorbed through the skin with resultant adverse effects.

Inhalation: breathing in dust may result in respiratory irritation. May cause coughing and shortness of breath.

Acute toxicity: Oral ld50 (rat): 1500 mg/kg.

Ecological information

Ecotoxicity avoid contaminating waterways.

Transport information

Road and rail transport
Classified as dangerous goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for transport by road and rail; dangerous goods.
Un no: 3342
Transport hazard class: 4.2 spontaneously combustible
Packing group: II
Version: 7
Proper shipping name or technical name: Xanthates
Hazchem or emergency action code:1y

Marine transport
Classified as dangerous goods by the criteria of the International Maritime Dangerous Goods Code (IMDG Code) for transport by sea; dangerous goods.
UN No: 3342
Transport Hazard Class: 4.2 Spontaneously Combustible
Packing Group: II
Proper Shipping Name Or Technical Name: XANTHATES
IMDG EMS Fire: F-A
IMDG EMS Spill: S-J

Air transport
Classified as dangerous goods by the criteria of The International Air Transport Association (IATA) dangerous goods
Regulations for transport by air; dangerous goods. Transport prohibited under the International Air Transport Association (IATA) dangerous goods regulations for transport by air in passenger and cargo aircraft; may be transported by cargo aircraft only.
UN no: 3342
Transport Hazard Class: 4.2 Spontaneously Combustible
Packing Group: II
Proper Shipping Name Or Technical Name: XANTHATES

Sodium meta bisulfite (SMBS)

Listed for Pogo and Red Dog

Extracts from ixom.com Safety Data Sheet (https://www.ixom.com/sds-search)

Hazards identification
Not classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for transport by Road and Rail; NON-DANGEROUS GOODS.
This material is hazardous according to Safe Work Australia; HAZARDOUS CHEMICAL.
Classification of the chemical:
Acute Oral Toxicity - Category 4
Eye Damage - Category 1

SIGNAL WORD: DANGER

Hazard Statement(s):
H302 Harmful if swallowed.
H318 Causes serious eye damage.

Precautionary Statement(s):
Prevention:
P102 Keep out of reach of children.
P264 Wash hands thoroughly after handling.
P270 Do not eat, drink or smoke when using this product.
P280 Wear protective gloves / protective clothing / eye protection / face protection.

Response:
P301+P312 IF SWALLOWED: Call a POISON CENTER or doctor/physician if you feel unwell.
P330 Rinse mouth.
P305+P351+P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P310 Immediately call a POISON CENTER or doctor/physician.

Other Hazards:
AUH031 Contact with acids liberates toxic gas.

First aid measures

Inhalation: Remove victim from area of exposure - avoid becoming a casualty. Remove contaminated clothing and loosen remaining clothing. Allow patient to assume most comfortable position and keep warm. Keep at rest until fully recovered. Seek medical advice if effects persist.

Skin Contact: If skin contact occurs, remove contaminated clothing and wash skin with running water. If irritation occurs seek medical advice.

Eye Contact: Immediately wash in and around the eye area with large amounts of water for at least 15 minutes. Eyelids to be held apart. Remove clothing if contaminated and wash skin. Urgently seek medical assistance. Transport promptly to hospital or medical centre.

Ingestion: Rinse mouth with water. If swallowed, do NOT induce vomiting. Give a glass of water. Seek immediate medical assistance.

Fire fighting measures

Suitable Extinguishing Media: Not combustible, however, if material is involved in a fire use: Fine water spray, normal foam, dry agent (carbon dioxide, dry chemical powder).

Specific hazards arising from the chemical: Non-combustible material.

Special protective equipment and precautions for fire-fighters: Decomposes on heating emitting toxic fumes, including those of sulfur dioxide. Fire fighters to wear self-contained breathing apparatus and suitable protective clothing if risk of exposure to products of decomposition.

Physical and chemical properties

pH: 4.0-5.0 (50g/water, 20°C)

Stability and reactivity

Reactivity: Contact with acids liberates toxic gas.

Chemical stability: Slowly oxidized on exposure to air and moisture.

Possibility of hazardous reactions: None known.

Conditions to avoid: Avoid exposure to heat.

Incompatible materials: Incompatible with acids, oxidising agents.

Hazardous decomposition products: Sulfur dioxide.

Toxicological information

Ingestion: Swallowing can result in nausea, vomiting, diarrhoea, and abdominal pain.

Eye contact: A severe eye irritant. Contamination of eyes can result in permanent injury.

Skin contact: Contact with skin may result in irritation. May cause skin sensitisation in sensitive individuals. Repeated or prolonged skin contact may lead to allergic contact dermatitis.

Inhalation: Breathing in dust may result in respiratory irritation. May cause respiratory sensitisation in sensitive individuals, producing asthma-like symptoms.

Acute toxicity:
Oral LD50 (rat): 1131 mg/kg
Chronic effects: Sodium metabisulfite can sensitise the respiratory tract of allergic persons.

Ecological information

Ecotoxicity Avoid contaminating waterways.
96hr LC50 (fish): 150-220 mg/L (*S. gairdnerii*)

Sodium nitrate

Listed in plans of operation among fluxes for Pogo and Fort Knox/True North

Extracts from ixom.com Safety Data Sheet (https://www.ixom.com/sds-search)

Classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for Transport by Road and Rail; DANGEROUS GOODS.
This material is hazardous according to Safe Work Australia; HAZARDOUS CHEMICAL.
Classification of the chemical: Oxidising solids - Category 3
Acute Oral Toxicity - Category 4
Eye Irritation - Category 2A

SIGNAL WORD: WARNING

Hazard Statement(s):
H272 May intensify fire; oxidizer.
H302 Harmful if swallowed.
H319 Causes serious eye irritation.

Precautionary Statement(s):
Prevention:
P102 Keep out of reach of children.
P210 Keep away from heat, sparks, open flames, hot surfaces. No smoking.
P220 Keep and store away from clothing, incompatible materials, combustible materials.
P221 Take any precaution to avoid mixing with combustibles / incompatible materials.
P264 Wash hands thoroughly after handling.
P270 Do not eat, drink or smoke when using this product.
P280 Wear protective gloves / protective clothing / eye protection / face protection.

Response:
P301+P312 IF SWALLOWED: Call a POISON CENTER or doctor/physician if you feel unwell.
P330 Rinse mouth.
P305+P351+P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P337+P313 If eye irritation persists: Get medical advice/attention.
P370+P378 In case of fire: Use extinguishing media as outlined in Section 5 of this Safety Data Sheet to extinguish.

FIRST AID MEASURES

Indication of immediate medical attention and special treatment needed:
Clinical findings: The smooth muscle relaxant effect of nitrate salts may lead to headache, dizziness and marked hypotension.
Cyanosis is clinically detectable when approximately 15% of the haemoglobin has been converted to methaemoglobin (ie. ferric iron).
Symptoms such as headache, dizziness, weakness and dyspnoea occur when methaemoglobin concentrations are 30% to 40%; at levels of about 60%, stupor,

convulsions, coma and respiratory paralysis occur and the blood is a chocolate brown colour. At higher levels death may result. Spectrophotometric analysis can determine the presence and concentration of methaemoglobin in blood.

Treatment:
1. Give 100% oxygen.
2. In cases of (a) ingestion: use gastric lavage, (b) contamination of skin (unburnt or burnt): continue washing to remove salts.
3. Observe blood pressure and treat hypotension if necessary.
4. When methaemoglobin concentrations exceed 40% or when symptoms are present, give methylene blue 1 to 2 mg/kg body weight in a 1% solution by slow intravenous injection. If cyanosis has not resolved within one hour a second dose of 2 mg/kg body weight may be given. The total dose should not exceed 7 mg/kg body weight as unwanted effects such as dyspnoea, chest pain, vomiting, diarrhoea, mental confusion and cyanosis may occur. Without treatment methaemoglobin levels of 20-30% revert to normal within 3 days.
5. Bed rest is required for methaemoglobin levels in excess of 40%.
6. Continue to monitor and give oxygen for at least two hours after treatment with methylene blue.
7. Consider transfer to centre where haemoperfusion can be performed to remove the nitrates from the blood if the condition of the patient is unstable.
8. Following inhalation of oxides of nitrogen the patient should be observed in hospital for 24 hours for delayed onset of pulmonary oedema. Further observation for 2-3 weeks may be required to detect the onset of the inflammatory changes of bronchiolitis fibrosa obliterans. Treat with toluonium chloride to reverse methaemoglobinanaemia.

After inhalation of decomposition products: Pulmonary oedema prophylaxis.

Fire fighting measures

Special protective equipment and precautions for fire-fighters: Nitrate salts on their own are not combustible, however, they will support the combustion of other materials.

Decomposes on heating emitting irritating white fumes and/or brown fumes. Brown fumes indicate the presence of toxic oxides of nitrogen.

On detection of fire the compartment(s) should be opened up to provide maximum ventilation. Fire-fighters to wear self-contained breathing apparatus and suitable protective clothing if there is a risk of exposure to products of combustion/decomposition. Fires should be fought from a protected location. Keep containers and adjacent areas cool with water spray. If safe to do so, remove containers from path of fire. If safe to do so, prevent molten material from being confined in drains, pipes etc.

A major fire may involve a risk of explosion. An adjacent detonation may also involve the risk of explosion.

Stability and reactivity

Reactivity: Reacts with oxidising agents. Reacts with reducing agents. Hygroscopic: absorbs moisture or water from surrounding air.

Chemical stability: Sodium nitrate is a powerful oxidising agent. Organic materials may become highly combustible when contaminated with sodium nitrate.

Possibility of hazardous reactions: Reacts with oxidising agents , reducing agents .

Conditions to avoid: Avoid dust generation. Avoid exposure to heat. Avoid exposure to moisture.

Incompatible materials: Incompatible with oxidising agents , reducing agents , ammonium compounds .

Hazardous decomposition products: Oxides of nitrogen. Disodium oxide. Oxygen, which will support combustion.

Toxicological information

No adverse health effects expected if the product is handled in accordance with this Safety Data Sheet and the product label. Symptoms or effects that may arise if the product is mishandled and overexposure occurs are:

Ingestion: Swallowing can result in nausea, vomiting, diarrhoea, and abdominal pain. Swallowing large amounts may result in headaches, dizziness and a reduction in blood pressure (hypotension).

Eye contact: An eye irritant.

Skin contact: Repeated or prolonged skin contact may lead to irritation.

Inhalation: Breathing in dust may result in respiratory irritation.

Acute toxicity:
Oral LD50 (rat): 1267 mg/kg
Skin corrosion/irritation: Non-irritant (rabbit).
Serious eye damage/irritation: Irritant.
Respiratory or skin sensitisation: Not a skin sensitiser (mouse).
Chronic effects: No carcinogenic effects were observed in animal studies. Under certain circumstances nitrosamines can form in contact with nitrosating agents. Some nitrosamines were found to cause cancer in animal experiments.

Reproductive toxicity: No evidence of reproductive effects.

NITRATES: Ingestion of large quantities will cause methaemaglobinemia with headaches, heart beat irregularities, blood pressure loss, cramps and breathing difficulties. Cyanosis will occur. Nephritis can result from chronic exposure. There is a risk of damage to the blood (methomoglobinemia) after a single uptake of large quantities.

Ecological information

Ecotoxicity Avoid contaminating waterways.

Persistence/degradability: Inhibition of degradation activity in activated sludge is not to be anticipated during correct introduction of low concentrations.

96hr LC50 (fish): 7950 mg/L (*Oncorhynchus tschawytscha*; static)

Transport information

Road and Rail
Transport Classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for Transport by Road and Rail; DANGEROUS GOODS.

Marine Transport
Classified as Dangerous Goods by the criteria of the International Maritime Dangerous Goods Code (IMDG Code) for transport by sea; DANGEROUS GOODS.

Air Transport
Classified as Dangerous Goods by the criteria of the International Air Transport Association (IATA) Dangerous Goods Regulations for transport by air; DANGEROUS GOODS.

Sodium sulfide

Listed for Red Dog

Extracts from ixom.com Safety Data Sheet (https://www.ixom.com/sds-search)

Classified as dangerous goods in accordance with the Australian Code for the Transport of Dangerous Goods by Road and Rail (ADG).
Classified as a hazardous chemical in accordance with the criteria of Safe Work Australia - Globally Harmonized System (GHS).
Acute toxicity - Oral Category 3
Acute toxicity - Dermal Category 3
Skin corrosion/irritation Category 1 Sub-category B
Serious eye damage/eye irritation Category 1

SIGNAL WORD Danger

Hazard statements
H301 - Toxic if swallowed
H311 - Toxic in contact with skin
H314 - Causes severe skin burns and eye damage

Precautionary Statements - Prevention
Do not breathe fume, gas, mist, vapours, spray
Wash face, hands and any exposed skin thoroughly after handling
Do not eat, drink or smoke when using this product
Wear protective gloves / protective clothing / eye protection / face protection
Avoid release to the environment

Precautionary Statements - Response
Specific treatment (see First aid on this SDS)
IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. Immediately call a POISON CENTER or doctor/physician
IF ON SKIN (or hair): Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower. Wash contaminated clothing before reuse
IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing. Call a POISON CENTER or doctor/physician if you feel unwell
IF SWALLOWED: Rinse mouth. DO NOT induce vomiting
IF SWALLOWED: Call a POISON CENTER or doctor/physician if you feel unwell
Collect spillage

Precautionary Statements - Storage
Store locked up

Precautionary Statements - Disposal
Dispose of contents/container in accordance with local, regional, national, and international regulations as applicable

Other hazards which do not result in classification
AUH031 - Contact with acids liberates toxic gas
Very toxic to aquatic life

First aid measures

Inhalation Remove to fresh air. If breathing is difficult, (trained personnel should) give oxygen. If breathing has stopped, give artificial respiration. Get medical attention immediately. Do not use mouth-to-mouth method if victim ingested or inhaled the substance; give artificial respiration with the aid of a pocket mask equipped with a one-way valve or other proper respiratory medical device.

Eye contact Rinse thoroughly with plenty of water for at least 15 minutes, lifting lower and upper eyelids. Consult a physician.

Skin contact Wash skin with soap and water. IF ON SKIN (or hair): Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower Immediately call a POISON CENTER or doctor/physician.

Ingestion Rinse mouth thoroughly with water. Do NOT induce vomiting. Drink 1 or 2 glasses of water. Never give anything by mouth to an unconscious person. Get immediate medical advice/attention.

Most important symptoms and effects, both acute and delayed
Symptoms Irritation/Corrosion.
Indication of any immediate medical attention and special treatment needed
Note to physicians Treat symptomatically. Can cause corneal burns. Effects may be delayed.

Fire fighting measures

Specific hazards arising from the chemical
Corrosive hazard. Wear protective gloves/clothing and eye/face protection.
Special protective actions for fire-fighters

Stability and reactivity

Reactivity: Contact with acids liberates toxic gas. Hygroscopic.

Chemical stability: Stable under normal conditions.

Possibility of hazardous reactions: Can react with acids evolving flammable and toxic hydrogen sulphide gas.

Conditions to avoid: Exposure to light. Exposure to air. Heat. Moisture.
Incompatible materials: Acids. Carbon. Diazonium salts. Strong oxidizing agents. Strong reducing agents. Moisture. Metals.

Hazardous decomposition products: Oxides of sulfur. Hydrogen sulfide.

Toxicological information

Acute toxicity
Information on likely routes of exposure
Product Information No adverse health effects expected if the chemical is handled in accordance with this
Safety Data Sheet and the chemical label. Symptoms or effects that may arise if the chemical is mishandled and overexposure occurs are:
Inhalation May cause irritation.
Eye contact Corrosive to the eyes and may cause severe damage including blindness.
Skin contact Contact causes severe skin irritation and possible burns.
Ingestion Can burn mouth, throat, and stomach.
Symptoms Irritation/Corrosion.

Numerical measures of toxicity - Component Information

Chemical name	Oral LD50	Dermal LD50	Inhalation LC50
Water of crystallisation	> 90 mL/kg (Rat)	-	-
Sodium sulphide	= 208 mg/kg (Rat)	< 340 mg/kg (Rabbit)	-

Delayed and immediate effects as well as chronic effects from short and long-term exposure
Skin corrosion/irritation Causes burns. Classification is based on mixture calculation methods based on component data.
Serious eye damage/eye irritation Causes serious eye damage. Classification is based on mixture calculation methods based on component data.

Ecological information

Ecotoxicity

Ecotoxicity Keep out of waterways. Toxic to aquatic life.

Chemical name	Algae/ aquatic plants	Fish	Toxicity to micro-organisms	Crustacea
Sodium sulphide	-	LC50: 7.7 - 29.1mg/L (96h, *Poecilia reticulata*)	-	EC50: =2.1mg/L (48h,*Daphnia magna*)

Transport information

ADG Classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for Transport by Road and Rail; DANGEROUS GOODS.
UN number 1849
Proper shipping name SODIUM SULPHIDE, HYDRATED
Hazard class 8
Packing group II
Hazchem code 2X

IATA Classified as Dangerous Goods by the criteria of the International Air Transport Association (IATA) Dangerous Goods Regulations for transport by air; DANGEROUS GOODS.
UN number 1849
UN proper shipping name SODIUM SULPHIDE, HYDRATED
Transport hazard class(es) 8
Packing group II

IMDG Classified as Dangerous Goods by the criteria of the International Maritime Dangerous Goods Code (IMDG Code) for transport by sea; DANGEROUS GOODS.

Sodium sulfite

Listed in the plan of operations for Greens Creek

Extracts from the ThermoFisher Scientific Safety Data Sheet for **sodium sulfite** (https://www.fishersci.com/msds?productName=AC219270010&productDescription=..)

Synonyms Sulfurous acid, disodium salt.

Hazard(s) identification

This chemical is not considered hazardous by the 2012 OSHA Hazard Communication Standard (29 CFR 1910.1200)

First-aid measures

Eye Contact: Rinse immediately with plenty of water, also under the eyelids, for at least 15 minutes. Get medical attention.

Skin Contact: Wash off immediately with plenty of water for at least 15 minutes. Get medical attention immediately if symptoms occur.

Inhalation: Remove to fresh air. Get medical attention immediately if symptoms occur.

Ingestion: Clean mouth with water and drink afterwards plenty of water. Get medical attention if symptoms occur.

Most important symptoms and effects: None reasonably foreseeable.

Notes to Physician: Treat symptomatically

Fire-fighting measures

Suitable Extinguishing Media: Water spray, carbon dioxide (CO2), dry chemical, alcohol-resistant foam.

Specific Hazards Arising from the Chemical: Non-combustible, substance itself does not burn but may decompose upon heating to produce corrosive and/or toxic fumes.

Hazardous Combustion Products: Sulfur oxides. Sodium oxides.

Accidental release measures

Environmental Precautions: Should not be released into the environment.

Stability and reactivity

Conditions to Avoid: Avoid dust formation. Incompatible products. Excess heat. Exposure to air or moisture over prolonged periods.

Incompatible Materials: Strong oxidizing agents, Acids

Hazardous Decomposition Products: Sulfur oxides, Sodium oxides

Toxicological information

Acute Toxicity

Component	LD50 Oral	LD50 Dermal	LC50 Inhalation
Sodium sulfite	2610 mg/kg (Rat)	>2000 mg/kg	>22 mg/L (Rat) 1 h >5.5 mg/L (Rat) 4 h

Delayed and immediate effects as well as chronic effects from short and long-term exposure

Irritation: May cause skin, eye, and respiratory tract irritation

Ecological information

Ecotoxicity: Do not empty into drains. Do not flush into surface water or sanitary sewer system.

Component	Freshwater Algae	Freshwater Fish	Microtox	Water Flea
Sodium sulfite	Not listed	LC50: 220 - 460 mg/L, 96h static (*Leuciscus idus*)	EC50 = 770 mg/L 17 h	LC50: = 330 mg/L, 24h (*Psammechinus miliaris*)

Mobility: Will likely be mobile in the environment due to its water solubility.

Tetrachloroethene

Spilled at Fort Knox/True North

Extracts from National Institute of Standards and Technology Material Safety Data Sheet for tetrachloroethene (https://www-s.nist.gov/m-srmors/msds/3010-MSDS.pdf)

Hazards identification

Major Health Hazards: Skin, eye, and/or respiratory tract irritation, central nervous system depression, blood disorders, liver damage, aspiration hazard, and nerve damage. Tetrachloroethene is a known cancer hazard (in humans).

Physical Hazards: Flammable liquid and vapor. Vapor may cause flash fire. Electrostatic charges may be generated by flow or agitation.

Potential Health Effects (Acute and Chronic)

Inhalation: Methanol may cause irritation, cough, ringing in the ears, constipation, headache, drowsiness, dizziness, tingling sensation, pain in extremities, tremors, loss of coordination, blood disorders, and nerve damage. Tetrachloroethene can cause irritation, nausea, vomiting, chest pain, difficulty breathing, irregular heartbeat, headache, drowsiness, dizziness, disorientation, mood swings, loss of coordination, blurred vision, lung congestion, kidney damage, liver damage, and cancer.

Skin Contact: Methanol can cause irritation, absorption may occur, headache, drowsiness, dizziness, loss of coordination, and blood disorders. Tetrachloroethene can cause irritation to the skin (possibly severe).

Eye Contact: Methanol and tetrachloroethene vapors may cause irritation and eye damage. Repeated or prolonged contact may cause conjunctivitis.

Ingestion: Ingestion of methanol may result in mild and transient inebriation and subsequent drowsiness. Liver, kidney, heart, stomach, intestine and pancreatic damage may also occur. Death may occur due to respiratory failure. As little as 15 mL has caused blindness; the usual fatal dose is 60 mL to 240 mL. Tetrachloroethene can cause the same effects reported in short term inhalation.

First aid measures

Inhalation: If adverse effects occur, remove to uncontaminated area. If not breathing, give artificial respiration or oxygen by qualified personnel. Seek medical attention if needed.

Eye Contact: Immediately flush eyes with copious amounts of water for at least 15 minutes.

Skin Contact: Wash exposed skin with copious amounts of water for at least 15 minutes. Remove contaminated clothing and shoes. Thoroughly clean and dry contaminated clothing and shoes before reuse.

Ingestion: Ingestion of this material is not likely under normal conditions of use. Potential aspiration hazard if ingested. If swallowed, seek medical attention.

Fire fighting measures

Fire and Explosion Hazards: Severe fire hazard. Vapor/air mixtures are explosive. The vapor is heavier than air. Vapors or gases may ignite at distant ignition sources and flash back. Electrostatic discharges may be generated by flow or agitation resulting in ignition or explosion.
Extinguishing Media: Alcohol-resistant foam, carbon dioxide, regular dry chemical, water.
Fire Fighting: Avoid inhalation of material or combustion by-products. Wear full protective clothing and NIOSH-approved self-contained breathing apparatus (SCBA).

Accidental release measures

Occupational Release: Remove sources of ignition. Do not touch spilled material. Absorb small spills with sand or other non-combustible material. Collect spilled material in appropriate container for proper disposal. Disposal: Refer to … "Disposal Considerations".

Stability and reactivity

Conditions to Avoid: Avoid heat, flames, sparks, and other sources of ignition. Ampoules may rupture or explode if exposed to heat. Keep out of water supplies and sewers. Avoid inhalation of material or combustion by-products. Avoid contact with incompatible materials.
Incompatible Materials: Halo carbons, combustible materials, metals, oxidizing materials, halogens, metal carbide, bases, acids, amines, and metal salts.
Fire/Explosion Information: See Section 5, "Fire Fighting Measures".
Hazardous Decomposition: Phosgene, chlorides, oxides of carbon.
Hazardous Polymerization: Will Not Occur

Toxicological information

Routes of Entry: Inhalation, Skin, Ingestion
Toxicity Data: End points listed by Registry of Toxic Effects of Chemical Substances (RTECS).
Rat,
Oral LD50: 2629 mg/kg
Rat,
Inhalation LC50: 4000 ppm (4 h)
Mouse,
Dermal LD50: 2800 mg/kg

Irritation Data: Rabbit, eyes: 500 mg (24 h), mild
Rabbit,
skin: 500 mg (24 h), mild

Target Organs: Central nervous system.

Mutagen/Teratogen: The components of this material have been reviewed and the Registry of Toxic Effects of Chemical Substances (RTECS) publishes the following endpoints.

Tumorigenic: Rat, Inhalation TC: 200 ppm (6 h)

Mutagenic: Rat: 500 ppm, 97 µmol/L; Human: 100 mg/L, 2.4 ppm (1 year)

Reproductive: Rat, Inhalation TCLo: 250 ppm (pregnant 6 d to 19 d)

Ecotoxicity Data

Fish Toxicity: Bluegill (*Lepomis macrochirus*) LC50 (static): 11.0 mg/L to 15.0 mg/L (96 h)

Algae Toxicity: *Pseudokirchneriella subcapitata* EC50: >500 mg/L (96 h)

Disposal considerations

Waste Disposal: Dispose in accordance with all applicable federal, state, and local requirements. Subject to disposal regulations: U.S. EPA 40 CFR 262; Hazardous Waste Number(s): U210 (tetrachloroethene, 0.7 mg/L regulatory level).

Regulatory information

European Regulations

EC Classification: Xn – Harmful, D – Dangerous for the environment

EC Risk Phrases:

R40 – Limited evidence of a carcinogenic effect.

R51/53 – Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.

EC Safety Phrases:

S23 – Do not breathe vapor.

S36/37 – Wear suitable protective clothing and gloves.

S61 – Avoid release to the environment. Refer to special instructions/Safety data sheets.

Urea (solid)

Listed in the plan of operations for Greens Creek; spilled at Kensington

Extracts from ixom.com Safety Data Sheet (https://www.ixom.com/sds-search)

Hazards identification

Not classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for transport by Road and Rail; NON-DANGEROUS GOODS.
Based on available information, not classified as hazardous according to Safe Work Australia; NON-HAZARDOUS CHEMICAL.

Fire fighting measures

Suitable Extinguishing Media: Not combustible, however, if material is involved in a fire use: Extinguishing media appropriate to surrounding fire conditions.
Specific hazards arising from the chemical: Non-combustible material.
Special protective equipment and precautions for fire-fighters: Decomposes on heating emitting toxic fumes, including those of oxides of nitrogen, and ammonia. Fire fighters to wear self-contained breathing apparatus and suitable protective clothing if risk of exposure to products of decomposition.

Stability and reactivity

Reactivity: Reacts with strong oxidising agents.
Chemical stability: Stable under normal conditions of use.
Possibility of hazardous reactions: Dust explosion hazard. Hazardous polymerisation will not occur.
Conditions to avoid: Avoid dust generation. Avoid exposure to moisture. Avoid exposure to heat, sources of ignition, and open flame.
Incompatible materials: Incompatible with strong oxidising agents, hypochlorites , phosphorous pentachloride, chromyl chloride.
Hazardous decomposition products: Oxides of nitrogen. Ammonia.

Toxicological information

No adverse health effects expected if the product is handled in accordance with this Safety Data Sheet and the product label. Symptoms or effects that may arise if the product is mishandled and overexposure occurs are:
Ingestion: Swallowing can result in nausea, vomiting, diarrhoea, and gastrointestinal irritation. Swallowing large amounts may result in dizziness, drowsiness, excessive urine, weakness and confusion.
Eye contact: May be an eye irritant. Exposure to the dust may cause discomfort due to particulate nature. May cause physical irritation to the eyes.
Skin contact: Contact with skin may result in irritation.
Inhalation: Breathing in dust may result in respiratory irritation.
Acute toxicity:

Oral LD50 (rat): 8471 mg/kg
Skin corrosion/irritation: Mild irritant (human).

Ecological information

Ecotoxicity Avoid contaminating waterways

Zinc

Spilled at Red Dog

Extracts from Teck safety data sheet for zinc metal (https://www.teck.com/media/Zinc-Metal-SDS.pdf)

Hazards identification

Classification

Health
Acute Toxicity (Oral, Inhalation) – Does not meet criteria
Skin Corrosion/Irritation – Does not meet criteria
Eye Damage/Eye Irritation – Does not meet criteria
Respiratory or Skin Sensitization – Does not meet criteria
Mutagenicity – Does not meet criteria
Carcinogenicity – Does not meet criteria
Reproductive Toxicity – Does not meet criteria
Specific Target Organ Toxicity: Acute Exposure – Does not meet criteria
Chronic Exposure – Does not meet criteria

Physical
Does not meet criteria for any Physical Hazard

Environmental
Aquatic Toxicity – (Short Term/Long Term) Does not meet any criteria

Emergency Overview: A lustrous bluish-silver metal that does not burn in bulk but may form explosive mixtures if dispersed in air as a fine powder. Zinc oxide fume is formed when zinc metal is heated to or near the boiling point, or is burned. Contact with acids or alkalis generates flammable hydrogen gas which can accumulate in poorly ventilated areas. Do NOT use water or foam on burning zinc metal. Apply dry chemical, sand or special powder extinguishing media. Zinc is relatively non-toxic and poses little immediate hazard to the health of emergency response personnel or to the environment in an emergency situation.

Potential Health Effects: Zinc is essentially non-toxic to humans. However, zinc oxide fumes may cause mild local irritation to eyes, nose, throat and upper airways. Acute over-exposure to zinc oxide fume may cause metal fume fever, characterized by flu-like symptoms such as chills, fever, nausea, and vomiting which may be delayed 3 – 10 hours in onset. In most cases, dermal exposure to zinc or zinc compounds does not result in any noticeable toxic effects. Zinc is not listed as a carcinogen by OSHA, NTP, IARC, ACGIH or the EU (see Toxicological Information).

Potential Environmental Effects: Zinc metal has relatively low bioavailability and poses no immediate ecological risks. Depending on physico-chemical characteristics (e.g., pH, water hardness), compounds of zinc metal can be toxic, particularly in the aquatic environment. Zinc also has the potential to bioaccumulate in plants and animals in both aquatic and terrestrial environments (see Ecological Information).

First aid measures

Eye Contact: Symptoms: Mild eye irritation, redness. Do not rub eye(s). Let the eye(s) water naturally for a few minutes. Look right and left, then up and down. If particle/dust does not come out, cautiously rinse eye(s) with lukewarm, gently flowing water for 5 minutes or until particle/dust is removed, while holding eyelid(s) open. If eye irritation persists, get medical advice/attention. DO NOT attempt to manually remove anything from the eye.

Skin Contact: Symptoms: Soiling of skin. No health effects expected. If irritation does occur, rinse with lukewarm, gently flowing water for 5 minutes or until the product is removed. If skin irritation occurs or you feel unwell, get medical advice/attention. Molten Metal: Flush contact area to solidify and cool but do not attempt to remove encrusted material or clothing. Cover burns and seek medical attention immediately.

Inhalation: Symptoms: Coughing and irritation in heavy dust clouds. If symptoms are experienced remove source of contamination or move victim from exposure area to fresh air immediately and obtain medical advice. NOTE: Metal fume fever may develop 3-10 hours after exposure to zinc oxide fumes. If symptoms of metal fume fever (flu-like symptoms) develop, obtain medical attention.

Ingestion: Symptoms: Stomach upset, nausea, diarrhea. If swallowed, no specific intervention is indicated as this material is not likely to be hazardous by ingestion. However, if you are concerned or you feel unwell, obtain medical advice.

Accidental release measures

Procedures for Cleanup: Control source of release if possible to do so safely. Clean up spilled material immediately observing precautions in Section 8, Personal Protection. Molten metal should be allowed to cool and harden before cleanup. Once solidified wear gloves, pick up and return to process. Powder or dust should be cleaned up by sweeping/shoveling, etc. Solid metal is recyclable. Return uncontaminated spilled material to the process if possible. Place contaminated material in clean, dry, suitably labelled containers for later recovery or disposal. Treat or dispose of waste material in accordance with all local, state/provincial, and national requirements.

Personal Precautions: Protective clothing, gloves, and a respirator are recommended for persons responding to an accidental release (see also Section 8). Close-fitting safety goggles may be necessary in some circumstances to prevent eye contact with zinc dust and fume. Where molten metal is involved, wear heat-resistant gloves and suitable clothing for protection from hot-metal splash.

Environmental Precautions: Zinc metal has relatively low bioavailability and poses no immediate ecological risks. Depending on physico-chemical characteristics (e.g., pH, water hardness), compounds of zinc metal can be toxic, particularly in the aquatic environment. Zinc also has the potential to bioaccumulate in plants and animals in both aquatic and terrestrial environments. Releases of the product to water and soil should be prevented.

Stability and reactivity

Stability & Reactivity: Fine, condensed zinc dust or powder may heat spontaneously and ignite on exposure to air when damp. Zinc metal will react with acids and strong alkalis to generate hydrogen gas. A violent, explosive reaction may occur when powdered zinc is heated with sulphur. Powdered zinc will become incandescent or ignite in the presence of fluorine, chlorine, bromine or interhalogens (e.g., chlorine trifluoride). Powdered zinc can also react explosively with halogenated hydrocarbons if heated. Mixtures with potassium chlorate or fused ammonium nitrate may explode on impact.

Incompatibilities: Contact with acids and alkalis will generate highly flammable hydrogen gas. Contact with acidic solutions of arsenic and antimony compounds may evolve highly toxic ARSINE or STIBINE gas. Incompatible with strong oxidizing agents such as chlorine, fluorine, bromine, sodium, potassium or barium peroxide, sodium or potassium chlorate, chromium trioxide and fused ammonium nitrate. Also incompatible with elemental sulphur dust, halogenated hydrocarbons or chlorinated solvents, chlorinated rubber, and ammonium sulphide or calcium disulphide.

Hazardous Decomposition Products: High temperature operations such as oxy-acetylene cutting, electric arc welding or overheating a molten bath will generate zinc oxide fume which, on inhalation in sufficient quantity, can produce metal fume fever, a transient influenza-like illness.

Toxicological information

General: Zinc, especially in the metal form, is relatively non-toxic. However, it can react with other materials, such as oxygen or acids, to form compounds that can be potentially toxic. The primary route of exposure would be through the generation and inhalation of zinc oxide fume.

Acute:

Skin/Eye: In most cases, dermal exposure to zinc or zinc compounds does not result in any noticeable toxic effects. Zinc metal is not chemically irritating to the eyes.

Inhalation: If excessive quantities of zinc oxide fume are inhaled, it can result in the condition called metal fume fever. The symptoms of metal fume fever will occur within 3 to 10 hours, and include immediate dryness and irritation of the throat, tightness of the chest and coughing, which may later be followed by flu-like symptoms of fever, malaise, perspiration, frontal headache, muscle cramps, low back pain, occasionally blurred vision, nausea, and vomiting. The symptoms are temporary and generally disappear, without medical intervention, within 24 to 48 hours of onset. There are no recognized complications, after affects, or chronic affects that result from this condition.

Ingestion: Zinc is not expected to be harmful if ingested. When ingested in excessive quantities, zinc can irritate the stomach resulting in nausea, vomiting, abdominal pain and diarrhea. Ingestion is not a typical route of occupational exposure.

Chronic: There is no chronic form of metal fume fever but in rare instances an acute incident may be followed by complaints such as bronchitis or pneumonia. Some workers may develop a short-term immunity (resistance) so that repeated exposure to zinc oxide fumes does not cause metal fume fever. This immunity (resistance) however is quickly lost after short absences from work (weekends or vacations). Workers exposed to finely-divided metallic zinc for up to 35 years revealed no acute or chronic illnesses attributable to zinc. Prolonged or repeated skin contact with zinc dust or powder may cause dryness, irritation and cracking (dermatitis) since zinc is astringent and may tend to draw moisture from the skin. Zinc is not listed as a human carcinogen by the Occupational Safety and Health Administration (OSHA), the National Toxicology Program (NTP), the International Agency for Research on Cancer (IARC), the American Conference of Governmental Industrial Hygienists (ACGIH) or the European Union (EU).

Animal Toxicity:

Ingredient:	Acute Oral Toxicity:	Acute Dermal Toxicity:	Acute Inhalation Toxicity:
Zinc	>5,000 mg/kg†	No data	No data

† LD50, Mouse, Oral,

Ecological information

Zinc metal is relatively insoluble; however, processing of the product or extended exposure in aquatic and terrestrial environments may lead to the release of zinc compounds in bioavailable forms. Zinc is highly mobile, and can be toxic in the aquatic environment with water hardness, pH and dissolved organic carbon content being major regulating factors. Zinc also has the potential to bioaccumulate in plants and animals in both aquatic and terrestrial environments. In soils, zinc is moderately mobile in accordance with soil properties (e.g., cation exchange capacity, pH, redox potential, chemical species); these properties also influence its bioavailability to terrestrial plants.

Extracts from ThermoFisher Scientific Safety Data Sheet for **zinc metal powder** (https://www.fishersci.com/msdsproxy%3FproductName%3DZ5500%26productDescription%3DZINC%2BMETAL%2BPOWDER%2BCERTIF%2B500G%26catNo%3DZ5-500%26vendorId%3DVN00033897%26storeId%3D10652)

Hazard(s) identification

Classification: This chemical is considered hazardous by the 2012 OSHA Hazard Communication Standard (29 CFR 1910.1200)

Substances/mixtures which, in contact with water, emit flammable gases: Category 1
Pyrophoric solids: Category 1
Combustible dust: Yes

Signal Word DANGER

Hazard Statements

May form combustible dust concentrations in air
In contact with water releases flammable gases which may ignite spontaneously
Catches fire spontaneously if exposed to air

Precautionary Statements

Prevention

Keep away from heat/sparks/open flames/hot surfaces. - No smoking
Do not allow contact with air
Wear protective gloves/protective clothing/eye protection/face protection
Keep away from any possible contact with water, because of violent reaction and possible flash fire
Handle under inert gas.
Protect from moisture

Skin

Brush off loose particles from skin. Immerse in cool water/wrap with wet bandages

Fire

In case of fire: Use CO_2, dry chemical, or foam for extinction

Storage

Store under an inert atmosphere Store in a dry place. Store in a closed container Store in a well-ventilated place. Keep container tightly closed

Disposal
Dispose of contents/container to an approved waste disposal plant

Hazards not otherwise classified (HNOC)
Very toxic to aquatic life with long lasting effects

First-aid measures

Eye Contact: Rinse immediately with plenty of water, also under the eyelids, for at least 15 minutes. Get medical attention.
Skin Contact: Wash off immediately with plenty of water for at least 15 minutes. Get medical attention if symptoms occur.
Inhalation: Move to fresh air. If breathing is difficult, give oxygen. Get medical attention if symptoms occur.
Ingestion: Do not induce vomiting. Obtain medical attention.
Most important symptoms and effects: No information available.
Notes to Physician: Treat symptomatically

Fire-fighting measures

Unsuitable Extinguishing Media DO NOT USE WATER, Carbon dioxide (CO_2), Dry chemical, Foam

Specific Hazards Arising from the Chemical
Flammable. Fine dust dispersed in air may ignite. Pyrophoric: Spontaneously flammable in air. Water reactive. Contact with water liberates extremely flammable gases. Thermal decomposition can lead to release of irritating gases and vapors. Keep product and empty container away from heat and sources of ignition.

Hazardous Combustion Products
Hydrogen

Accidental release measures

Environmental Precautions: Should not be released into the environment. See [Ecological information] for additional ecological information.

Stability and reactivity

Reactive Hazard: Yes
Stability: Water reactive. Moisture sensitive. Air sensitive. Pyrophoric: Spontaneously flammable in air.

Conditions to Avoid: Avoid dust formation. Incompatible products. Exposure to air. Exposure to moist air or water. Keep away from open flames, hot surfaces and sources of ignition.
Incompatible Materials: Strong oxidizing agents, Strong acids, Strong bases, Amines
Hazardous Decomposition Products: Hydrogen
Hazardous Polymerization: Hazardous polymerization does not occur.
Hazardous Reactions: Contact with water liberates extremely flammable gases. Pyrophoric: Spontaneously flammable in air.

Toxicological information

LD50 Oral: LD50 = 630 mg/kg (Rat)

Ecological information

Freshwater Algae
EC50: 0.09 - 0.125 mg/L, 72h static (*Pseudokirchneriella subcapitata*)
EC50: 0.11 - 0.271 mg/L, 96h static (*Pseudokirchneriella subcapitata*)

Freshwater Fish
LC50: 0.211 - 0.269 mg/L, 96h semi-static (*Pimephales promelas*)
LC50: = 2.66 mg/L, 96h static (*Pimephales promelas*)
LC50: = 30 mg/L, 96h (*Cyprinus carpio*)
LC50: = 0.45 mg/L, 96h semi-static (*Cyprinus carpio*)
LC50: = 7.8 mg/L, 96h static (*Cyprinus carpio*)
LC50: = 3.5 mg/L, 96h static (*Lepomis macrochirus*)
LC50: = 0.24 mg/L, 96h flow-through (*Oncorhynchus mykiss*)
LC50: = 0.59 mg/L, 96h semi-static (*Oncorhynchus mykiss*)
LC50: 2.16 - 3.05 mg/L, 96h flow-through (*Pimephales promelas*)
LC50: = 0.41 mg/L, 96h static (*Oncorhynchus mykiss*)

Water Flea
EC50: 0.139 - 0.908 mg/L, 48h Static (*Daphnia magna*)

Zinc sulfate

Listed at Red Dog

Extracts from ixom.com Safety Data Sheet (https://www.ixom.com/sds-search)

Classified as dangerous goods in accordance with the Australian Code for the Transport of Dangerous Goods by Road and Rail (ADG).
Environmentally Hazardous Substances meeting the descriptions of UN 3077 or UN 3082 are not subject to the provisions of the Australian Code for the Transport of Dangerous Goods by Road and Rail when transported by road or rail in: packagings that do not incorporate a receptacle exceeding 500 kg(L); or IBCs.
Classified as a hazardous chemical in accordance with the criteria of Safe Work Australia-Globally Harmonized System (GHS).

SIGNAL WORD Danger

Hazard statements
H302 - Harmful if swallowed
H318 - Causes serious eye damage

The following health/environmental hazard categories fall outside the scope of the Workplace Health and Safety Regulations:
H410 - Very toxic to aquatic life with long lasting effects

Precautionary Statements - Prevention
Wash hands thoroughly after handling
Do not eat, drink or smoke when using this product
Wear eye/face protection
Avoid release to the environment
IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. Immediately call a POISON CENTER or doctor/physician
IF SWALLOWED: Call a POISON CENTER or doctor/physician if you feel unwell. Rinse mouth
Collect spillage

Fire fighting measures

Specific hazards arising from the chemical:
Environmentally hazardous. Fire residues and contaminated fire extinguishing water must be disposed of in accordance with local regulations.

Stability and reactivity

Incompatible materials
Incompatible materials Strong reducing agents.
Hazardous decomposition products
Hazardous decomposition products Oxides of sulfur. Zinc oxides.

Toxicological information

Inhalation: May cause irritation.

Eye contact: Causes serious eye damage.

Skin contact: May cause irritation.

Ingestion: Ingestion may cause gastrointestinal irritation, nausea, vomiting and diarrhoea. Symptoms Irritation. May cause redness and tearing of the eyes.

Delayed and immediate effects as well as chronic effects from short and long-term exposure

Serious eye damage/eye irritation: Causes serious eye damage

Ecological information

Ecotoxicity: Keep out of waterways. Very toxic to aquatic life with long lasting effects.

Mobility in soil: Harmful to the soil environment.

Disposal considerations

Waste treatment methods: Waste from residues/unused products should not be released into the environment.

Transport information

ADG Classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for Transport by Road and Rail; DANGEROUS GOODS.
Environmentally Hazardous Substances meeting the descriptions of UN 3077 or UN 3082 are not subject to the provisions of the Australian Code for the Transport of Dangerous Goods by Road and Rail when transported by road or rail in: packagings that do not incorporate a receptacle exceeding 500 kg(L); or IBCs.
UN number 3077
Proper shipping name ENVIRONMENTALLY HAZARDOUS SUBSTANCE, SOLID, N.O.S. (ZINC SULPHATE MONOHYDRATE)
Hazard class 9
Packing group III
Hazchem code 2Z

IATA Classified as Dangerous Goods by the criteria of the International Air Transport Association (IATA) Dangerous Goods Regulations for transport by air; DANGEROUS GOODS.
UN number 3077

UN proper shipping name ENVIRONMENTALLY HAZARDOUS SUBSTANCE, SOLID, N.O.S. (ZINC SULPHATE MONOHYDRATE)
Transport hazard class(es) 9
Packing group III

IMDG Classified as Dangerous Goods by the criteria of the International Maritime Dangerous Goods Code (IMDG Code) for transport by sea; DANGEROUS GOODS.
UN number 3077
UN proper shipping name ENVIRONMENTALLY HAZARDOUS SUBSTANCE, SOLID, N.O.S. (ZINC SULPHATE MONOHYDRATE)
Transport hazard class(es) 9
Packing group III
IMDG EMS Fire F-A
IMDG EMS Spill S-F
Marine pollutant Yes

Non-crude oil

Creosote

Spilled at Greens Creek

Extracts from EChemi for Coal tar creosote

Hazard identification
Classification of the substance or mixture
Carcinogenicity, Category 1B

Signal word DANGER

Hazard statement(s)
H350 May cause cancer

Precautionary statement(s)
Prevention
P203 Obtain, read and follow all safety instructions before use.
P280 Wear protective gloves/protective clothing/eye protection/face protection/hearing protection/...

Response
P318 IF exposed or concerned, get medical advice.

Storage
P405 Store locked up.

Disposal
P501 Dispose of contents/container to an appropriate treatment and disposal facility in accordance with applicable laws and regulations, and product characteristics at time of disposal.

Stability and reactivity

Possibility of hazardous reactions: On combustion, forms toxic fumes.

Diesel fuel

Listed and spilled at Pogo, Kensington, Greens Creek, Fort Knox/True North, and Red Dog; spill risk from truck accidents modeled at Pogo and Kensington

Extracts from ixom.com Safety Data Sheet (https://www.ixom.com/sds-search) for fuel oil.

> Classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for Transport by Road and Rail; DANGEROUS GOODS.
>
> This material is hazardous according to Safe Work Australia; HAZARDOUS CHEMICAL.
>
> *Classification of the chemical:*
> Flammable liquids - Category 4
> Aspiration hazard - Category 1
> Skin Irritation - Category 2
> Acute Inhalation Toxicity - Category 4
> Carcinogenicity - Category 2
> Specific target organ toxicity (repeated exposure) - Category 2
> Acute Aquatic Toxicity - Category 2
> Chronic Aquatic Toxicity - Category 2
>
> SIGNAL WORD: DANGER
>
> *Hazard Statement(s):*
>
> H227 Combustible liquid.
> H304 May be fatal if swallowed and enters airways.
> H315 Causes skin irritation.
> H332 Harmful if inhaled.
> H351 Suspected of causing cancer.
> H373 May cause damage to organs through prolonged or repeated exposure.
> H411 Toxic to aquatic life with long lasting effects.
>
> *Precautionary Statement(s): Prevention:*
>
> P201 Obtain special instructions before use.
> P202 Do not handle until all safety precautions have been read and understood.
> P210 Keep away from heat, sparks, open flames, hot surfaces. No smoking.
> P260 Do not breathe mist, vapours, spray.
> P264 Wash hands thoroughly after handling.
> P271 Use only outdoors or in a well-ventilated area.
> P273 Avoid release to the environment.
> P280 Wear protective gloves / protective clothing / eye protection / face protection.
>
> *Accidental release measures*

Emergency procedures/Environmental precautions: Shut off all possible sources of ignition. Clear area of all unprotected personnel. Shut off leak if possible without risk. Work up wind. Use water spray to disperse vapour. Do not allow container or product to get into drains, sewers, streams or ponds. If contamination of sewers or waterways has occurred advise local emergency services.

Toxicological information

Ingestion: Swallowing can result in nausea, vomiting and central nervous system depression. If the victim is showing signs of central system depression (like those of drunkeness) there is greater likelihood of the patient breathing in vomit and causing damage to the lungs. Breathing in vomit may lead to aspiration pneumonia (inflammation of the lung).

Eye contact: May be an eye irritant. Overexposure to diesel exhaust fumes may result in eye irritation.

Skin contact: Contact with skin may result in irritation. Will have a degreasing action on the skin. Repeated or prolonged skin contact may lead to irritant contact dermatitis. Repeated exposure may cause skin dryness or cracking.

Inhalation: Breathing in vapour may produce respiratory irritation. Breathing in vapour can result in headaches, dizziness, drowsiness, and possible nausea. Breathing in high concentrations can produce central nervous system depression, which can lead to loss of co-ordination, impaired judgement and if exposure is prolonged, unconsciousness. Overexposure to diesel exhaust fumes may result in headaches, nausea and respiratory irritation.

Ecological information

Ecotoxicity Avoid contaminating waterways.

Aquatic toxicity: Toxic to aquatic organisms. May cause long lasting harmful effects to aquatic life. Material floats on water. Films formed on water may affect oxygen transfer between the water and the atmosphere and cause adverse effects on aquatic organisms. Prevent entry of the material into waterways, sewers, basements or confined areas.

Kerosene

Spilled at Kensington and Greens Creek

Extracts from echemi.com Safety Data Sheet (https://www.echemi.com/sds/kerosene-pid_Rock27024.html) for kerosene

Hazard identification
Classification of the substance or mixture
Aspiration hazard, Category 1

Signal word DANGER

Hazard statement(s)
H304 May be fatal if swallowed and enters airways

Precautionary statement(s)
Prevention

Response
P301+P316 IF SWALLOWED: Get emergency medical help immediately.
P331 Do NOT induce vomiting.

Storage
P405 Store locked up.

Disposal
P501 Dispose of contents/container to an appropriate treatment and disposal facility in accordance with applicable laws and regulations, and product characteristics at time of disposal.

Stability and reactivity
Possibility of hazardous reactions: As a result of flow, agitation, etc., electrostatic charges can be generated. Reacts with oxidants.

Propane

Listed at Pogo

Extracts from ixom.com Safety Data Sheet (https://www.ixom.com/sds-search) for propane.

Classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for Transport by Road and Rail; DANGEROUS GOODS.

This material is hazardous according to Safe Work Australia; HAZARDOUS CHEMICAL.

Classification of the chemical:
Flammable Gases - Category 1
Gases under pressure - Liquefied Gas

SIGNAL WORD: DANGER

Hazard Statement(s):

H220 Extremely flammable gas.
H280 Contains gas under pressure; may explode if heated.

Precautionary Statement(s):
Prevention:
P210 Keep away from heat, sparks, open flames, hot surfaces. No smoking.

Response:
P377 Leaking gas fire: Do not extinguish, unless leak can be stopped safely.
P381 Eliminate all ignition sources if safe to do so.

Storage:
P410+P403 Protect from sunlight. Store in a well-ventilated place.
P403 Store in a well-ventilated place.

Accidental release measures

Emergency procedures/Environmental precautions: Shut off all possible sources of ignition. Clear area of all unprotected personnel. Increase ventilation.

Personal precautions/Protective equipment/Methods and materials for containment and cleaning up: If safe to do so, isolate the leak. Small spills are allowed to evaporate provided there is adequate ventilation. Wear protective equipment to prevent skin and eye contact and breathing in vapours. Avoid breathing in vapours. Work up wind or increase ventilation. Contain - prevent run off into drains and waterways. Use absorbent (soil, sand or other inert material). Collect and seal in properly labelled containers or drums for disposal. Use non-sparking tools.

Exposure controls/personal protection

Propane: Asphyxiant

Asphyxiant - gases which can lead to reduction of oxygen concentration by displacement or dilution. The minimum oxygen content in air should be 18% by volume under normal atmospheric pressure.

Stability and reactivity

Possibility of hazardous reactions: Can react violently with chlorine, pool chlorine, or nitric acid.

Conditions to avoid: Avoid exposure to heat, sources of ignition, and open flame. Avoid exposure to direct sunlight. Avoid exposure to extremes of temperature.

Incompatible materials: Incompatible with strong oxidising agents.

Hazardous decomposition products: Carbon monoxide. Carbon dioxide.

Toxicological information

Ingestion: Swallowing can result in nausea, vomiting and central nervous system depression. If the victim is showing signs of central system depression (like those of drunkeness) there is greater likelihood of the patient breathing in vomit and causing damage to the lungs.

Eye contact: Vapour from product may irritate eyes. Liquid splashes or spray may cause freeze burns to the eye.

Skin contact: Contact with skin may result in irritation. Liquid splashes or spray may cause freeze burns.

Inhalation: Vapours may cause drowsiness and dizziness. Intentional misuse by deliberately concentrating and breathing the contents can be harmful or fatal. An asphyxiant; exposure to high concentrations can eventually lead to a lack of oxygen in the blood, which may cause death.

Ecological information

Ecotoxicity: Avoid contaminating waterways.

Unleaded fuel (Gasoline)

Listed at Fort Knox/True North; spilled at Pogo, Greens Creek, Fort Knox/True North, and Red Dog

Extracts from Hess Corporation 1 Hess Plaza Woodbridge, NJ 07095-0961; Internet Website www.hess.com

EMERGENCY OVERVIEW

DANGER!

EXTREMELY FLAMMABLE
- EYE AND MUCOUS MEMBRANE IRRITANT
- EFFECTS CENTRAL NERVOUS SYSTEM
- HARMFUL OR FATAL IF SWALLOWED
- ASPIRATION HAZARD

High fire hazard. Keep away from heat, spark, open flame, and other ignition sources.

If ingested, do NOT induce vomiting, as this may cause chemical pneumonia (fluid in the lungs). Contact may cause eye, skin and mucous membrane irritation. Harmful if absorbed through the skin. Avoid prolonged breathing of vapors or mists. Inhalation may cause irritation, anesthetic effects (dizziness, nausea, headache, intoxication), and respiratory system effects.

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

Hazards Identification

EYES Moderate irritant. Contact with liquid or vapor may cause irritation. SKIN Practically non-toxic if absorbed following acute (single) exposure. May cause skin irritation with prolonged or repeated contact. Liquid may be absorbed through the skin in toxic amounts if large areas of skin are exposed repeatedly.

INGESTION The major health threat of ingestion occurs from the danger of aspiration (breathing) of liquid drops into the lungs, particularly from vomiting. Aspiration may result in chemical pneumonia (fluid in the lungs), severe lung damage, respiratory failure and even death. Ingestion may cause gastrointestinal disturbances, including irritation, nausea, vomiting and diarrhea, and central nervous system (brain) effects similar to alcohol intoxication. In severe cases, tremors, convulsions, loss of consciousness, coma, respiratory arrest, and death may occur.

INHALATION Excessive exposure may cause irritations to the nose, throat, lungs and respiratory tract. Central nervous system (brain) effects may include headache, dizziness, loss of balance and coordination, unconsciousness, coma, respiratory failure, and death.

WARNING: the burning of any hydrocarbon as a fuel in an area without adequate ventilation may result in hazardous levels of combustion products, including carbon monoxide, and inadequate oxygen levels, which may cause unconsciousness, suffocation, and death.

CHRONIC EFFECTS and CARCINOGENICITY Contains benzene, a regulated human carcinogen. Benzene has the potential to cause anemia and other blood diseases, including leukemia, after repeated and prolonged exposure. Exposure to light hydrocarbons in the same boiling range as this product has been associated in animal studies with systemic toxicity. See also Section 11 - Toxicological Information.

MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE Irritation from skin exposure may aggravate existing open wounds, skin disorders, and dermatitis (rash). Chronic respiratory disease, liver or kidney dysfunction, or pre-existing central nervous system disorders may be aggravated by exposure.

Fire fighting measures

FIRE AND EXPLOSION HAZARDS Vapors may be ignited rapidly when exposed to heat, spark, open flame or other source of ignition. Flowing product may be ignited by self-generated static electricity. When mixed with air and exposed to an ignition source, flammable vapors can burn in the open or explode in confined spaces. Being heavier than air, vapors may travel long distances to an ignition source and flash back. Runoff to sewer may cause fire or explosion hazard.

Stability and reactivity

CONDITIONS TO AVOID Avoid high temperatures, open flames, sparks, welding, smoking and other ignition sources INCOMPATIBLE MATERIALS Keep away from strong oxidizers. HAZARDOUS DECOMPOSITION PRODUCTS Carbon monoxide, carbon dioxide and non-combusted hydrocarbons (smoke). Contact with nitric and sulfuric acids will form nitrocresols that can decompose violently.

Toxicological properties

ACUTE TOXICITY

Acute Dermal LD50 (rabbits): > 5 ml/kg Acute Oral LD50 (rat): 18.75 ml/kg Primary dermal irritation (rabbits): slightly irritating Draize eye irritation (rabbits): non-irritating Guinea pig sensitization: negative

CHRONIC EFFECTS AND CARCINOGENICITY

Carcinogenicity: OSHA: NO IARC: YES - 2B NTP: NO ACGIH: YES (A3) IARC has determined that gasoline and gasoline exhaust are possibly carcinogenic in humans. Inhalation exposure to completely vaporized unleaded gasoline caused kidney cancers in male rats and liver tumors in female mice. The U.S. EPA has determined that the male kidney tumors are species-specific and are irrelevant for human health risk assessment. The significance of the tumors seen in female mice is not known. Exposure to light hydrocarbons in the same boiling range as this product has been associated in animal studies with effects to the central and peripheral nervous systems, liver, and kidneys. The significance of these animal models to predict similar human response to gasoline is uncertain. This product contains benzene. Human health studies indicate that prolonged and/or repeated overexposure to benzene may cause damage to the blood-forming system (particularly bone marrow), and serious blood disorders such as aplastic anemia and leukemia. Benzene is listed as a human carcinogen by the NTP, IARC, OSHA and ACGIH.

This product may contain methyl tertiary butyl ether (MTBE): animal and human health effects studies indicate that MTBE may cause eye, skin, and respiratory tract irritation, central nervous system depression and neurotoxicity. MTBE is classified as an animal carcinogen (A3) by the ACGIH

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Appendix B
Excel files with ADEC spill records from 1995-2020 for the five mines in the case studies

There are five Excel workbooks in this appendix, one for each of the case study mines:

Appendix B1. Pogo ADEC spills 1995-2020.xlsx

Appendix B2. Kensington ADEC spills 1995-2020.xlsx

Appendix B3. Greens Creek ADEC spills 1995-2020.xlsx

Appendix B4. Fort Knox and True North ADEC spills 1995-2020.xlsx

Appendix B5. Red Dog ADEC spills 1995-2020.xlsx

All five workbooks contain one sheet with all the spills from the ADEC records from July 1995-December 2020 and one sheet with the transportation spills from all causes.

The Fort Knox/True North workbook also contains sheets listing spills just for Fairbanks Gold Mining Inc., Fort Knox, Alaska West Express, and Lynden Transport. The combined contents of those four sheets form the list of all spills at Fort Knox/True North as analyzed in this report.

The spills are sorted chronologically within the sheets.

The column headings are from the ADEC database.

Spill incident fields in the ADEC spill database.

Spill ID	Source type	Location	Affiliate role
Spill name	Address 1	Substance type	Responsible party
Spill number	Address 2	Substance subtype	Facility name
Spill date	City	Quantity released	Latitude
Case closed date	ZIP code	Substance unit	Longitude
Response	Area	Quantity potential	Location data
Facility type	Subarea	Cause subtype	
Facility subtype	Region	Cause type	

Appendix C
Excel file of other *mining operations* spills ADEC 1995-2020

There is one Excel workbook in this appendix, Appendix C. Other mining operations spills ADEC 1995-2020.xlsx, which contains a single sheet of the *mining operations* spill incidents that were not attributed to the five case study mines in this report. The spill incidents are from ADEC records from 1995-2020 and are sorted chronologically.

The column headings are from the ADEC database.

Spill incident fields in the ADEC spill database.

Spill ID	Source type	Location	Affiliate role
Spill name	Address 1	Substance type	Responsible party
Spill number	Address 2	Substance subtype	Facility name
Spill date	City	Quantity released	Latitude
Case closed date	ZIP code	Substance unit	Longitude
Response	Area	Quantity potential	Location data
Facility type	Subarea	Cause subtype	
Facility subtype	Region	Cause type	

Appendix D
NRC/PHMSA spill records

There is one Excel workbook in this Appendix, Appendix D. NRC and PHMSA Alaska Spills.xlsx, which contains seven sheets:

NRC Alaska all

NRC Alaska Mining

PHMSA portal

Accident_hazardous_liquid_pre19

Accident_hazardous_liquid_1986

Accident_hazardous_liquid_2002

Accident_hazardous_liquid_2009

NRC Alaska all has 15,474 incident entries extracted from the NRC database with LOCATION-STATE = Alaska. It is sorted chronologically and has columns A-R.

NRC Alaska Mining has 197 incident entries that are associated with Alaskan mines. They are sorted chronologically by mine. This sheet has columns A-U. The columns largely match those in the NRC Alaska all sheet with the addition of Mine, Standard unit quantity, and Standard unit.

PHMSA portal is a compilation of the annual records from the PHMSA spill portal for Alaskan pipeline incidents from 2001 to 2020. Incident cause types and subtypes, fatalities, injuries, amounts spilled, and associated costs are shown for each year.

The remaining four sheets also contain data from PHMSA.

Accident_hazardous_liquid_pre19 contains 4,733 records for spills prior to 1986. This sheet has columns A-BI and is sorted by Accident_State. There are three spills that occurred in Alaska.

Accident_hazardous_liquid_1986 contains 3,094 records for spills from 1986-2001. This sheet has columns A-BK and is sorted by ACSTATE. There are 13 spills that occurred in Alaska.

Accident_hazardous_liquid_2002 contains 3,030 records for spills from 2002-2008. This sheet has columns A-IY and is sorted by ACSTATE. There are six spills that occurred in Alaska.

Accident_hazardous_liquid_2009 contains 4,470 records for spills from 2009-2008. This sheet has columns A-VP and is sorted by ONSHORE_STATE_ABBREVIATION. There are 14 spills that occurred in Alaska.

Appendix E
Statement of Qualifications

SUMMARY

Environmental statistician interested in the intersections of science and policy, with specific focus and experience in analysis of regulatory science used in decision-making

Areas of expertise include:

- Experimental design, linear and nonlinear regression, bootstrap methods, mixed effects models, longitudinal models, non-parametric multiplicative regression, fault trees, risk analysis
- Statistical software, especially R Studio
- Communication of research results to both specialists and non-specialists, either in small groups or large audiences

RECENT EXPERIENCE

Independent analyst— June 2015-present

- Research the data sets, assumptions, and statistical models contracted by and used within environmental impact statements for on- and offshore fossil fuel development in the Arctic (spill risk models), Sea Port Oil Terminal Project Offshore Brazoria County, Texas (spill risk models), Pebble Mine (transportation corridor spill risks, tailings storage facility failure models, fish habitat models), Gulf of Mexico Oil and Gas (spill risk models), Stibnite Gold Project (hazardous materials routing along the transportation corridor)
- Client list (paid and *pro bono*) includes Advocates for the West, Alaska Wilderness League, Cook Inletkeeper, Defenders of Wildlife, Earth Justice, Idaho Conservation League, Trustees for Alaska, and Wild Salmon Center

Executive Director: Terra Nostra, a multi-media symphony about climate change— July 2013-April 2020

- Commissioned a symphony about climate change from Christophe Chagnard, which was performed by the Lake Union Civic Orchestra in June of 2015 at Meany Hall, University of Washington
- Laid the groundwork for starting *Terra Nostra* as a non-profit, showing the effectiveness of using music and images to illustrate the contemporary and local effects of climate change
- Led a successful $55,000 fundraising effort to professionally record the revised version of the score in January 2019 and create the film version

- Oversaw getting the film version of *Terra Nostra* produced and submitted to film festivals around the country. Honors include *Best Original Score* (Top Shorts, October 2019), *Honorable Mention - Experimental Film* (Independent Shorts, November 2019), *Award of Merit - Nature/Environment/Wildlife* (Best Shorts Competition, December 2019), *Award of Merit - Documentary Short* (Impact DOCS, January 2020), inclusion in the American Documentary and Animation Film Festival (Palm Springs, California, March 2020; rescheduled to September 2020), finalist (Deep Focus Film Festival, April 2020), *Award of Merit Special Mention: Nature/Environment/Wildlife* (Accolade Global Film Festival, August 2020), Official Selection (Nature Without Borders International Film Festival, August 2020), *Best Documentary Short* and *Best Music* (Global Shorts Competition, September 2020)

Instructor, University of Washington—January-December 2014

- Nomination for a Distinguished Teaching Award, December 2014, University of Washington
- Quantitative Science (QSci) 482: Statistical Inference in Applied Research I: Hypothesis Testing and Estimation for Ecologists and Resource Managers (Fall 2014, Summers 1999, 2000)
- Quantitative Ecology and Resource Management (QERM) 514: Analysis of Ecological and Environmental Data (Spring 2014)
- QSci 486: Analysis of Designed Experiments (Winter 2014)

RESEARCH POSITIONS

September 2011 – February 2013 Seattle, Washington
University of Washington

Post-doctoral research assistantship with Evelyn Lessard (School of Oceanography) using nonparametric multiplicative regression to characterize the environmental variables best for predicting harmful algal blooms of *Pseudo-nitzschia* spp. and the production of domoic acid in the Pacific northwest.

September 2008 – May 2010 Seattle, Washington
University of Washington

Post-doctoral research assistantship with Judith Zeh (Department of Statistics) modeling bowhead whale baleen length and body length at age with several canonical growth models. This involved fitting nonlinear models to multivariate data and using bootstrapping procedures to then estimate the ages of whales with known baleen and/or body lengths.

September 1997- June 1998 Seattle, Washington
National Oceanographic and Atmospheric Administration

Research assistantship with Sarah Hinckley modeling nutrient-phytoplankton-zooplankton dynamics along the coastal Gulf of Alaska

EDUCATION

2008 University of Washington — Seattle, Washington

Ph.D., Quantitative Ecology and Resource Management (QERM): Using annual cycles of stable carbon isotope ratios with baleen and body length data from bowhead whales (*Balaena mysticetus*) to estimate whale age and explore anomalous years

My dissertation was focused on modeling the growth of bowhead whales, using stable isotope patterns in non-linear mixed effects (NLME) models and nonlinear regression techniques.

1997 University of Washington — Seattle, Washington

M.S., QERM: Multi-source mixing models: food web determination using stable isotope tracers

I developed a model to use stable isotopes to estimate primary production and other nutrient flows through estuarine food webs.

1994 Harvey Mudd College — Claremont, California

B.S., Biology

PUBLICATIONS

Peer reviewed articles and book chapters

George, J.C., S. C. Lubetkin, J. E. Zeh, J. G. M. Thewissen, D. Wetzel, and G. Givens. 2021. Chapter 21 - Age estimation. Pp. 309-322 in J. C. George and J. G. M. Thewissen, eds., *The Bowhead Whale* Balaena mysticetus: *Biology and Human Interactions*. Academic Press.

Lubetkin, S.C. 2020. The tip of the iceberg: three case studies of spill risk assessments used in environmental impact statements. *Marine Pollution Bulletin.* Available online January 31, 2020. https://doi.org/10.1016/j.marpolbul.2019.110613

Lubetkin, S. C., Zeh, J. E., and George, J. C. 2012. Statistical modeling of baleen and body length at age in bowhead whales (*Balaena mysticetus*). *Canadian Journal of Zoology*. 90: 915-931.

Lubetkin, S. C., Zeh, J. E., Rosa, C., and George, J. C. 2008. Age estimation for young bowhead whales (*Balaena mysticetus*) using annual baleen growth increments. *Canadian Journal of Zoology*. 86: 525-538.

Lubetkin, S. C. and Simenstad, C. A. 2004. Two multi-source mixing models using conservative tracers to estimate food web sources and pathways. *Journal of Applied Ecology 41*: 996-1008.

Schindler, D. E. and Lubetkin, S. C. 2004. Using stable isotopes to quantify material transport through food webs. Pp. 25-42 in Gary A. Polis, Mary E. Power, and Gary R. Huxel, eds., *Food Webs at the Landscape Level*. University of Chicago Press.

Schindler, D.E., Chang, G. C., Lubetkin, S. C., Abella, S. E. B., and Edmondson, W. T. 2002. Rarity and functional importance in a phytoplankton community. Pp. 206-220 in Peter Kareiva and Simon A. Levin, eds., *The Importance of Species*. Princeton University Press.

In preparation

Lubetkin, S. C., Zeh, J. E., Rosa, C., and George, J. C. Evidence of a decadal scale shift in the carbon sources for the Beaufort and Bering Seas from stable isotopic records in bowhead whale (*Balaena mysticetus*) baleen.

Lubetkin, S. C., Zeh, J. E., Rosa, C., and George, J. C. Bowhead whale (*Balaena mysticetus*) migration pattern changes in response to changing ice dynamics in the Arctic.

Lubetkin, S. C., Zeh, J. E., Rosa, C., and George, J. C. Stable isotopic evidence of bowhead whales (*Balaena mysticetus*) not migrating from the Bering Sea to the Beaufort Sea: frequency, characteristics, and ecological implications.

MEETING PRESENTATIONS, WORKSHOPS

Lubetkin, S.C. 2020. The tip of the iceberg: three case studies of spill risk assessments used in environmental impact statements. Poster at the Alaska Marine Sciences Symposium, January 27-30, 2020.

September 22-23, 2016, Washington, DC. Science and Tools for Developing Arctic Marine Protected Area Networks: Understanding Connectivity and Identifying Management Tools. Invited participant to the Arctic Council, Protection of the Arctic Marine Environment (PAME) scientific working group.

Lubetkin, S. C., and Lessard, E. J. 2013. Habitat modeling of *Pseudo-nitzschia* distribution and toxicity in the coastal waters of the northwest Pacific using non-parametric multiplicative regression. Poster at the 7th Annual Harmful Algal Bloom Symposium, Sarasota, Florida, October 2013.

Lubetkin, S. C., and Lessard, E. J. 2013. Habitat modeling of *Pseudo-nitzschia* distribution and toxicity in the coastal waters of the northwest Pacific using non-parametric multiplicative regression. Oral presentation at the Association for the Sciences of Limnology and Oceanography meeting, New Orleans, Louisiana, February 2013.

Lubetkin, S. C., and Zeh, J. E. 2006. Deriving age-length relationships for bowhead whales (*Balaena mysticetus*) using a synthesis of age estimation techniques. Paper SC/58/BRG14 presented to the International Whaling Commission Scientific Committee, June 2006.

Lubetkin, S. C., Zeh, J. E., Rosa, C., and George, J. C. 2004. Deriving von Bertalanffy age-length relationships for bowhead whales (*Balaena mysticetus*) using a synthesis of age estimation techniques. Paper SC/56/BRG3 presented to the IWC SC, June 2004.

Lubetkin, S. C. 2000. Bowhead whale age determination: extending estimates from baleen stable isotope signatures. Oral presentation at the 4th Meeting of the Society of Marine Mammalogy Northwest Student Chapter. University of Washington, Seattle, Washington, April 29, 2000.

Lubetkin, S. C. and Simenstad, C. A. 1997. Food web determination using a multiple stable isotope mixing model. Poster at the 14th Biennial Estuarine Research Federation International Conference: The State of Our Estuaries. Providence, Rhode Island, October 12-16, 1997.

November 7-9, 1996, Savannah, Georgia. Land Margin Ecosystems Research Program Workshop. (Participant with Charles Simenstad.)

February 3-6, 1996, Woods Hole, Massachusetts. Land Margin Ecosystems Research Program Workshop. (Participant with Charles Simenstad.)

COMMUNITY INVOVLEMENT AND SERVICE

Earth Creative Board of Directors (February 2021-present)

Alaska Wilderness League Leadership Council (charter member, January 2019-present)

Social Venture Partners (partner from 2005-present)

- Inaugural cohort of the Conservation Philanthropy Fellowship Program in Autumn 2013
- Service on the Environment Collective Action Team (EnviroCAT) (October 2015-June 2019, co-chair June 2017-June 2019)

Lake Union Civic Orchestra (cello, 1995-present)

Sustainable Seattle Board of Directors (October 2015-October 2017)