Tailings Management in the Alberta Oil Sands: Mitigating the Risk of Pond Failure

by

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Abstract

Alberta has a prosperous oil industry with large reserves of oil sands. The oil sands are mined and produce substantial amounts of waste (tailings) needing to be stored in tailings ponds. With a growing number of tailings ponds across the province, the possibility of a pond failure increases. As such, there is a rising concern for the environment, surrounding communities and existing infrastructure. There is thus a need for Alberta to have strategies in place to mitigate the risk of a pond failure. Case studies analysis and a survey of academic literature identify key components and categories of successful tailings management from which three policy options are established and analyzed: dewatered tailings, risk assessment and hazard identifications, and publicly available emergency response plans. A final policy recommendation is made to implement emergency response plans, if it is only feasible to select one option. However, a second recommendation is made to implement all three policies as the most likely way of addressing the complex issue of tailings pond failures.

Keywords: Alberta; oil sands; tailings ponds; mitigating risk; pond failure

To my Amazing Loved Ones and Forever Support

System in Life

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Executive Summary

Alberta's natural resource industry is a prominent sector that shapes the province's economy. Since the commercialization of the oil sands in 1967, the extraction of oil has dominated economic development in the province. My research seeks to explore the negative environmental impacts associated with the oil sands. Given the vastness of this field of study, I exclusively examine the area of waste management and the pressing issue of tailings ponds. Specifically, this essay focuses on the qualities of successful tailings management and strategies for mitigating the risk of tailings pond failures.

As the number of ongoing mining projects in the oil sands has grown, there has been a corresponding increase in the number of tailings ponds across the provincial landscape. The majority of tailings ponds are situated in the northeastern region of the province, alongside oil sands projects. A major waterway, the Athabasca River, runs through this area. The risk of a failure and the need to avoid it are fueled by the understanding of the negative impacts that would ensue on the natural lands, adjoining waterways, biodiversity, and surrounding communities. Alberta's history is marked by three pond failures in the 1970s and while it has now been decades since the last accident, there is a large incentive to ensure that there are no pond failures in Alberta's future.

Alberta continues to engage in research and development of tailings management yet there remain areas in need of further improvement. This essay elaborates on some of those areas and provides recommendations on addressing areas of concern. A literature review provides a background on tailings ponds and details the mining process that leads to their existence. The literature elucidates the major issues that arise when a tailings pond fails and the importance of avoiding such an occurrence.

To determine policy options that Alberta could use to address the concern of pond failures, case studies analysis of three jurisdictions is completed. The cases that I examine are Western Australia, Australia; the United Kingdom; and Arizona, USA. From the cases, three key sub-categories of a successful tailings management strategy are

identified: having stable and secure tailings pond locations and construction, engaging in a risk assessment and hazard identification of the ponds prior to construction and throughout their lifespan, and of having emergency response plans prepared in case of a failure. The sub-categories are used to establish three policy options: the first is a policy of tailings dewatering – the reduction in the percentage of water contained in the tailings to achieve increased stability in the ponds. The chosen method of reducing the water content would be up to the discretion of each oil sands company so long as predetermined specifications, as set out by the regulator, are met; the second option is a risk assessment and hazard identification system – a process occurring at all stages of pond operation from design and construction through to site closure and reclamation of the land. This would direct elements such as the level of inspection, monitoring, reporting, construction and repair requirements depending on the level of risk associated with the pond; the third option is a publicly available emergency response plan – emergency response plans implemented by all oil sands companies for the preparation of a pond failure. These plans would need to be transparent and made available to employees, regulators, nearby communities, and on industry and government websites.

I evaluate the options with five criteria: effectiveness, security and protection, sustainability, cost, and stakeholder acceptance. The results of the analysis determine that implementing a publicly available emergency response plan scores the highest and thus is the most favorable option. The final recommendation is however to implement all three policies, if it is feasible, as this would be the most effective in successfully mitigating the risk of pond failures in the Alberta oil sands.

1. Introduction

In Alberta, Canada the economy is strongly driven by the natural resource sector. In particular, the oil and gas industry is a large contributor to employment, provincial GDP and the high standard of living associated with life in this Western province. Apart from a strong industry in conventional drilling for oil, Alberta is also the home of one of the world's largest reserves of oil sands. The exploration of oil sands is at present predominantly done through methods of mining and results in tailings ponds for the storage of leftover waste. These large bodies of water that contain toxic waste materials pose a hazard to the surrounding ecosystems.

This essay focuses on tailings ponds and the types of environmental impacts with which they are associated. An understanding of the causes of pond failures, the harms that can result, and the incentives for avoiding the failure of a tailings pond are established. I analyze three distinct jurisdictions to identify best practices for avoiding pond failures. I verify the results with a survey of academic literature and industry guidelines as presented by various international organizations. I then identify three policy options that can be implemented to help improve current tailings management strategies and reduce the risk of pond failure in Alberta. An evaluation of the options against five key criteria allows for a recommendation to be made to the Government of Alberta. If only one policy can be feasibly implemented at this time, the establishment of a publicly available emergency response plan is advised. The final recommendation is, however, that all three policy options should be implemented as this is most likely to achieve the objective of mitigating pond failure in Alberta's future of oil sands development.

2.

Tailings Ponds in Alberta, Canada

In this chapter I define tailings ponds, discuss their purpose and why they are readily used in the natural resource sector. I then explore the use of tailing ponds in the context of Alberta.

2.1. What are Tailings Ponds?

Tailings ponds[1] are the most common form of containing waste from the extraction of certain natural resources (Franks, 2011). Using ponds as an industry standard is in part because of the cost effectiveness of this option in comparison to other alternatives. A couple of oil sands companies in Alberta have begun using methods of tailings management that remove the water from the tailings (i.e., dewatered tailings) but it can be costly and is not yet a widely used practice.

A tailings pond is an artificially constructed enclosure that can resemble a lake or pond but that contains a toxic liquid with potentially harmful compounds. Tailings ponds are constructed alongside most mining operations that require the disposal or storage of the waste following an extraction process (Poveda and Lipsett, 2011). The pond isolates the waste from the surrounding environment (Franks, 2011). Given that extraction cannot be 100% efficient and not all of the solvents or chemicals added during the process can be fully reclaimed, there is a leftover byproduct called tailings (Engels, 2002a). In addition to any trace elements that cannot be extracted, any minerals or metals that do not provide an economic benefit to the company remain in the tailings.

[1] Throughout this essay ‘pond’ is used as a substitute for ‘tailings pond’.

The liquid in tailings ponds is predominantly water mixed with various naturally-occurring sediments, residual amounts of bitumen[2] (approximately 3%), and any remaining solvents used in the separation process (Poveda and Lipsett, 2011). According to BGC Engineering, approximately 86% of all tailings waste is water (2010). The tailings are highly acidic and extremely toxic to animals and other living organisms (Allen, 2008). The composition of tailings can be harmful to plant and animal life through physical contact by entering the water systems or if the toxins are ingested (Timoney and Ronconi, 2010). Due to the toxicity of the tailings, a zero discharge policy exists in Alberta. This requires all mining and oil sands companies to store the waste on site (Alberta Government, 2013b). The semiliquid mixture (slurry) of tailings must therefore be disposed of in a tailings pond (Engels, 2002a).

Tailings ponds may be constructed using hills and valleys from the natural geography or they can be entirely engineered and self-contained (Franks, 2009). Design depends on the location of the mining site and whether or not natural barriers are present and able to be used. If the site is mostly flat then a fully engineered pond will be built. There are four main types of tailings ponds: cross valley, valley bottom, valley side, and ring types (Ozkan and Ipekoglu, 2002). The cross valley type is the most basic structure where dam walls are constructed from side to side within a valley. The valley side tailings pond is built on a moderately sloping surface and requires dam walls on both sides as well as the front. With the valley bottom type, construction combines elements of both the cross valley and valley side structures. This type is used when the location is too flat or the valley is too wide to build a single wall (Ozkan and Ipekoglu, 2002). The ring type makes use of a pond-like foundation with a retaining wall around the entire parameter; this type is used when the landscape is primarily flat or mildly sloping.

An important factor for the location of a pond is the permeability of the underlying rock beds as this plays a role in natural water drainage. The cross valley pond for example is isolated within a valley and in the case of heavy rainfall there are limited options for natural water diversion, risking an overflow of the pond. Appropriate drainage

[2] Bitumen is the desired oily substance in the sands needed to produce crude oil.

or diversion systems are therefore essential for accommodating unexpected amount of extra water.

2.2. The Oil Sands Industry in Alberta

The province of Alberta is resource rich. The energy sector, which includes oil (both conventional and oil sands), gas, and mining accounted for more than 22% of AB's GDP in 2012. Alberta had the 3rd largest recorded reserves of oil in the world following Venezuela and Saudi Arabia. In the same year, the industry also employed roughly 121,500 individuals across the province. Exports rose by about 50% between 2002 and 2012 reaching a value of $95 billion; with increasing oil production $68 billion of total exports was from energy exclusively (Alberta Government, 2014). Commercial oil sands extraction began in AB in 1967 (Mamer, 2010) and there are now three main deposits, the largest of which is the Athabasca deposit. With nearly 170 billion barrels remaining to be extracted, almost 168 billion are from the oil sands. AB had 114 active oil sands projects underway in 2013 and the industry is steadily growing (Alberta Government, 2014).

As one of the largest energy developments in the world, the Alberta oil sands production has been progressively increasing and is predicted to continue growing for several decades. The 2009 level of bitumen production of 1.3 million barrels per day is expected to increase to 3 million barrels per day by the year 2018. As the rate of resource extraction increases so will the rate of waste produced and thus, the need for more tailings ponds will arise unless new policies are implemented. Between the years of 1992 and 2008, the presence of tailings ponds across northeastern Alberta grew by 422% (Timoney and Ronconi, 2010).

Alberta is a large producer of oil with growing oil sands operations. Given the present number and the forecast for future production, the potential risk for a pond failure should be addressed before it becomes an issue for the province.

3.

Oil Sands Extraction Methods

Oil sands are extracted in one of two manners: *in situ* drilling or surface mining. The method of *in situ* drilling injects steam into a well in the ground to loosen and release the bitumen from the oil sands. This type of extraction is for reaching oil sands that are below a depth of 75 meters from the surface. Over 80% of the recoverable oil sands reserves are well below the depths that can be extracted through mining. Currently however, the most widely used technique for excavating the oil sands is surface mining. This method is for oil sands that are less than 75m from the surface. Shallow oil sands deposits that can be mined account for only 18% of the total recoverable bitumen. Nonetheless, in 2008 this method accounted for 65% of all oil sands production (Allen, 2008). This essay focuses on surface mining, the resulting tailings ponds and makes references to other mining industries for comparative purposes.

The oil sands are mined to extract bitumen, the substance used in the production of oil. The oil sands also contain other naturally occurring minerals. Once the oil sands are extracted, the bitumen is separated from the sand and other undesirable materials. This process occurs with the use of hot water, mechanical energy and heat along with other chemicals added to assist the separation. The bitumen is then sent off to be developed into synthetic sweet crude oil (Allen, 2008). The remaining byproducts are pumped into a tailings pond. From this point, the solids begin to settle over time and the water can potentially be reused (Simieritsch et al., 2009). To illustrate the amount of waste that accumulates, it takes approximately one cubic meter of oil sands to produce a single barrel of oil (159 liters[3] or 0.159 cubic meters) (Allen, 2008). The large quantity of

[3] For comparative purposes there are 1000 liters of water in a cubic meter.

raw material that is excavated to produce one barrel of oil is why tailings ponds are used as large liquid storage facilities and why the number of ponds is steadily increasing.

Once the waste is contained in the pond several changes occur over time. The heaviest sand particles settle to the bottom first and the water rises to the surface. The liquid tailings consist of a mixture of water and fine particles throughout, initially resembling murky water. The content of the tailings is less than 30% solid at this stage and is referred to as thin fine tailings. Within three years the thin fine tailings begin solidifying into what is called mature fine tailings (MFT). MFT are denser with a higher solid content; at this stage the waste is approximately 30% solid, about the consistency of yogurt (Mamer, 2010). As the tailings evolve and become more solid and stable, the process of land reclamation[4] can begin. The long lifespan of the MFT however, can be problematic in advancing with the reclamation stage. It can take decades for MFT to solidify enough naturally to be reclaimable. As extraction continues and more waste accumulates, the more space that is occupied by ponds for long periods of time.

Various methods exist for treating the MFT. The technology used can alter the duration of the tailings lifespan but, some methods that dewater the tailings are still relatively new and can be costly. With the different methods there is a significant time variance for how long it will take the tailings to settle to the point of being reclaimed. In 2009, the most common tailings technology to solidify the tailings was consolidated tailing technology, which can take as long as 30 years to settle (Simieritsch et al., 2009). With another option, called tailings reduction operations, the MFT are mixed with chemicals and dried on shallow slopes so the tailings solidify more rapidly; the tailings may be suitable for reclamation within less than one month. This is however a newer technology approved in 2010 and has not yet been adopted across the industry. A lot of current research focuses on how to accelerate the solidification of MFT to reclaim the ponds within shorter time frames (Mamer, 2010).

[4] Reclamation is the desired end result of tailings management where the original landscape occupied by the tailings pond is restored to a natural ecosystem that is habitable (Mamer, 2010).

4.

Regulation and Legislation

The regulation of safety is a way of mitigating accidental risks. The higher the level of hazards associated with a given activity, the greater the level of regulation that is expected as a way of constraining potential accidents. Industries with lower levels of regulation are therefore more likely to experience a failure of some sort (Shavell, 1983). For this reason, natural resource industries are typically highly regulated. The greater the level of safety and security sought after, the more likely there will be strict regulations.

The governance of natural resources falls primarily under the jurisdiction of provincial governments; thus regulation specific to the oil sands and tailings management is established by the Government of Alberta. There are 19 provincial acts and regulations pertinent to the operation of the Alberta oil sands industry as a whole (Alberta Energy, 2015). Secondary sources of regulation are provided at the federal level by five agencies and government departments. The Canadian Environmental Assessment Agency manages environmental assessments, and Environment Canada is responsible for migratory birds, the quality of air and water across the country and species at risk. Fisheries and Oceans Canada has jurisdiction over fish and their habitats as well as species at risk, and Transport Canada has oversight on navigable waterways used for resource transportation. Finally, the National Energy Board regulates the use of interprovincial and export pipelines (Canadian Association of Petroleum Producers, 2015).

The regulation of Alberta's oil and gas industries has undergone significant changes over the last 75 years. In 1938, Alberta established the Petroleum and Natural Gas Conservation Board which in 1971 became known as the Energy Resource

Conservation Board. This resulted from the expanded reach of the board to now include coal, electricity, and pipelines (Breen, 2015). Prior to 2013, energy regulation in Alberta was under the jurisdiction of the Ministry of Alberta Environment and Sustainable Resource Development (ESRD) and the Energy Resources Conservation Board (ERCB). With new legislation passed in 2013 the Alberta Energy Regulator (AER) was formed as the sole regulator of energy development within the province, replacing the ESRD and the ERCB. Having a single regulator for the entire energy sector is an Alberta generated concept. This aims to simplify the access and understanding of energy regulation for the public and industry. A single regulator emphasizes the important connection between energy and environmental regulation. With the AER, a balance between economic and conservation goals can be achieved and regulation can occur without duplication from varying sources. Created along with the AER is the Policy Management Office who serves as a liaison between the regulator and the Government of AB (Alberta Government, 2015a). The responsibilities of the AER include application and exploration, construction and development, site closures as well as reclamation and remediation procedures. All of the regulatory responsibilities of the AER are drawn from six primary provincial statutes on the energy sector. While the AER is an independent body funded by industry, the Responsible Energy Development Act (REDA) allows the organization to function in close proximity to the Government of Alberta (Alberta Energy Regulator, 2014).

Over time, adjustments to regulation are needed to address industry shortcomings and to ensure that all companies adhere to certain standards of practice. A longstanding industry regulation is that all oil sands companies must reclaim their liquid tailings waste[5]. Industry practices however, are not properly addressing the long-term liability of tailings and the growing volume of ponds across the province. In response to this, in 2009, the Alberta Energy and Resources Conservation Board (ERCB) created new regulation specific to tailings reclamation. The new Directive 074 - that has since been suspended and replaced - aimed at redefining industry standards of waste reclamation focused on two main criteria: the quantity of fine particles remaining in the tailings and the strength of the tailings following reclamation, both of which need to occur

[5] All of the information in this paragraph and in the next is from (Simieritsch et al., 2009).

within set time parameters. For the density of the tailings to be considered sufficient, the tailings must meet a predetermined load-bearing capability referred to as trafficability, within a year of being deposited. The reclaimed tailings must be able to support a specific amount of weight before the land can be repurposed. Reclamation must occur within five years from the trafficability test at which point further strength testing is performed.

The Directive was implemented in phases to give the opportunity to individual companies to properly modify their respective methods. The expectation was that the total percentage of particles in the tailings must be reduced to 20% by 2011, 30% by 2012 and by 50% in 2013 and every year thereafter. An initial submission of tailings management plans were required in 2009 by each oil sands company as well as yearly compliance reports from 2011 onwards. A total of nine management plans were submitted with only two indicating that full compliance would be met. The other seven were determined to not be in compliance either in terms of meeting the time constraints or did not provide any empirical evidence on how the reductions and trafficability components would be met. The AER has the jurisdiction to enforce the directive but it was not clear how the organization should go about doing this.

In March of 2015, Directive 074 was suspended by the AER pending the implementation of new regulation expected to be in force in 2016. A bulletin was released informing the industry of this suspension and of the anticipated changes. The Tailings Management Framework for the Mineable Athabasca Oil Sands (TMF) was created by the Alberta Government and submitted to the AER. This framework is currently in effect and to be adhered to by all oil sands companies. The TMF is a policy framework from which the AER is now tasked with establishing new regulatory parameters on allowable liquid tailings volumes. This new regulation will cover the subject of tailings management specifically aimed at reducing the risks associated with the increasing buildup of liquid tailings across Alberta. In the interim, oil sands companies are expected to continue operating within the boundaries of other relevant legislation and refrain from making any changes that may conflict with the future regulation (Alberta Energy Regulator, 2015).

5.

Tailings Ponds Failures and Hazards

In this chapter the risks associated with tailings ponds and the potential failures that can occur are discussed. The threats that the issues present to the surrounding ecosystems and biodiversity are also presented.

The purpose of tailings ponds is to ensure that hazardous waste is not released into the environment but problems can arise. The primary environmental hazard of the mining industry is the failure of tailings ponds (Franks, 2011). Pond failures can be a result of poor tailings management (Fourie, 2009). However, more frequently failures are caused by the unexpected displacement of water resulting from earthquakes, heavy rainfall, and flooding (Ozkan and Ipekoglu, 2002). Storing large bodies of tailings waste over long periods of time creates a high level of risk (Joint Expert Group on Water and Industrial Accidents, 2008) and is the main factor behind structural failures. As such, most pond failures are the direct result of the presence and movement of water. This includes seeping of water through pond walls, the erosion of the foundation, and overtopping or spilling of water over the edges of a pond (Fourie, 2009). It is the long term structural stability of the ponds and the need to control the level and movement of the water that can be difficult to manage. The chemical stability of the liquid tailings is also a crucial factor to be managed to avoid issues such as erosion and seepage (Franks, 2011). The liquefaction of settled tailings deposits is a potential problem and it can be caused by a large vibration or shifting in the foundation, a dyke collapse, or as a result of flooding and the development of slime layers. Liquefaction is when non-solidified[6] and saturated sediments in a pond are shaken up which causes them to mix into the water again. In this state the tailings can pass more readily through spall spaces

[6] Unconsolidated is the term used in technical documents.

and flow for long distances (US Environmental Protection Agency). Liquefaction is especially problematic as it often occurs without any warning (Ozkan and Ipekoglu, 2002).

Many complications are inherent to all ponds regardless of the structural type. There are however certain issues which are common to specific types. For example, the cross-valley type is at risk for flooding and overflowing[7]. If there is excessive rainfall or flash flooding it needs to be ensured that the water diversion systems are fully functioning[8]. The valley side type is at less risk from flash floods but is at risk of increased pressure on the front wall causing a breach and release of tailings liquid. The valley bottom type used in wide/flat valleys runs the hazard of eroding if one of the walls is too close to the fall of the flowing liquids. Other potential pond failures are foundation breakdowns including but not limited to the failure of dykes and pipes, breached or eroded retaining walls, and embankment failures. For instance, foundation malfunctions where a weak layer of soil deteriorates can compromise the entire structure. Anything that creates an unstable slope or disproportionate pressure on the structure can lead to pond failures; there are a number of reasons that may cause this issue from a small leak to a complete collapse of a dam wall. When a pond's walls are increased in height but the base is not widened to compensate for the added pressure, failures may also result.

Regarding pond failures, in 2000 there were approximately 3,500 tailings ponds across the world and, globally, there are on average two to five major pond failures per year with around 35 minor failures per year (Grant et al., 2010). So there is roughly a two percent probability of a yearly accident with waste being spilled into the surrounding environments (United Nations Environment Programme, 2001). This may appear small but tailings ponds are ten times more likely to fail than a conventional dam (such as a hydropower dam) and due to the toxic nature of the tailings, the consequences of a failure are much more serious (Grant et al., 2010).

[7] Overflowing referred to as overtopping in technical documents.
[8] All of the information in this paragraph is from (Ozkan and Ipekoglu, 2002).

Periodic pond failures, especially those of a disastrous nature, perpetuate the public concern of an accident occurring (Fourie, 2009). The probability of a failure may be relatively low; nevertheless, the severity of the consequences can be quite grave. For this reason the environmental impacts of tailings ponds must be taken seriously. A major concern with structural failings of ponds is that there can be a substantial amount of liquid released into the environment in a very short time (Ozkan and Ipekoglu, 2002). This makes it difficult to manage as it is happening which can lead to severe damage. The substantial flood of liquid waste can inundate ecosystems downstream (Franks, 2011), cause ground water-contamination which can harm vegetation (Ozkan and Ipekoglu, 2002) and lead to damage of communities and infrastructure.

6.

Policy Problem and Stakeholders

The policy problem that I address is: with the increase in number of tailings ponds across Alberta, there is a growing risk to the nearby communities, the environment and infrastructure and thus a need for tailings management reform. As the number of ponds increases across the province, the probability of a pond failure also increases. For this reason, it is important to identify ways of avoiding a failure in the future. The research question that I ask is: how can the risk of a tailings pond failure be mitigated both in terms of reducing the likelihood of a failure and of decreasing the severity of the consequences?

When a pond fails due to a breached wall allowing toxic liquid to flow into the surrounding area, numerous threats arise. The threat to personal safety as a result of the immediate release of liquid can lead to injury and even death. After the initial sudden rush of tailings there is a threat to human health through contact with the waste. There is also a threat to infrastructure such as houses and schools as a result of flood damage. There is therefore a need to enhance public safety and to protect the local environment from a large scale spill of tailings. In addition, pond failures can have high financial costs for companies (United Nations Environment Programme, 2001); this is another incentive for mitigating future risks. A major pond failure has not occurred in the oil sands industry since the 1970s and action should be taken to ensure that a failure is not in Alberta's future. Further efforts need to be directed at decreasing the probability of a failure and at reducing the severity of the potential consequences.

Policies directed at the oil sands tailings ponds impact other sectors, groups, and individuals. Given the policy problem, there are numerous stakeholders to consider; those who are legally entitled and those without a legal right but who will be affected by the change. Primary stakeholders are the most directly involved in the process of implementing a new policy or are the most heavily affected by the outcome. Secondary stakeholders are those that contribute to the process but play a minor general role. The Oil Sands Companies are a primary stakeholder as they are responsible for generating the tailings ponds and carrying out the policy directive. Communities located near tailings ponds are another primary stakeholder as a pond failure can have a direct impact on the population as well as the infrastructure. Lastly, the provincial Government of Alberta is also a primary stakeholder as it is in charge of the legislation and regulation that governs natural resources.

The municipal governments of communities near tailings ponds are considered secondary stakeholders because they are the governing authorities of potentially affected residents. The Federal Government is also a secondary stakeholder because it is not involved in the regular management of natural resources but it plays a role in cross-jurisdictional resource issues. Environmental concerns are a key constraint to economic growth and an urgent factor in promoting environmental sustainability and the conservation of biodiversity. Environmental interest groups and NGOs do not have a direct influence on policy; however, an indirect impact on the implementation outcomes of policies makes them a secondary stakeholder.

With the policy problem in mind, the rest of this essay analyzes possible ways of addressing the issue. From the results, policy options that could be implemented in Alberta are suggested.

7.

Methodology for Analysis

In this chapter I discuss the primary and secondary methods of analysis for evaluating the qualities of successful tailings management practices for mitigating the risk of a pond failure. Case studies analysis from various jurisdictions is the primary methodology used to establish a set of categories and measures for successful pond strategies. The secondary methodology is using academic literature to verify that these categories are best practices for pond management to implement in Alberta. A description of the chosen case studies is provided followed by a description of the framework of analysis used to evaluate the cases.

7.1. Case Study Selection

I examine three cases: Western Australia, Australia; the United Kingdom (UK); and Arizona, USA. There are many other cases around the world that could be examined. Due to time constraints however, only three are analyzed in this research. Improving tailings management is a global issue and currently no industry stands out as 'doing everything right'. Since tailings ponds are managed by private companies, it can be difficult to locate publicly available information that is needed for doing a thorough case study. A basic requirement for the chosen cases is therefore that they have publicly available information and well-developed government and industry websites for collecting data. Cases with complete data and that align with the basic industry framework in Alberta are selected. In order to select the cases, countries or regions with similar functional characteristics as Alberta are used. Jurisdictions engaged in large scale disposal or storage of liquid tailings waste are considered. The three main characteristics that are used to select the case studies are whether they have industries that create tailings ponds, the type of economy they have (which can be an indicator of technological capabilities), and the type of government in place (indicating whether or not tailings management practices are regulated). Western Australia, the UK, and Arizona all have prominent mining industries that provide a comparative assessment of industries with tried-and-tested techniques and methods of operation. While some Canadian case studies would have comparable frameworks to Alberta, they are not used for a few reasons. First, many metals and minerals mined in Canada produce solid waste and not liquid waste so the type of storage and the associated issues are different than those with oil sands tailings. Second, certain industries that produce liquid waste are currently trying to manage their own set of problems and do not serve as good case studies. For example, the mining of copper and gold in British Columbia results in a liquid waste but with recent major pond failures cannot serve as a model for best practices. Likewise, the potash industry in Saskatchewan uses tailings ponds to store liquid waste but it is currently engaged in solving similar issues as Alberta with respect to growing volumes of tailings waste. Table 1 provides a summary of the characteristics used for choosing each case study.

Table 1. Characteristics for Choice of Case Studies

	Industry resulting in Tailings Waste	Method of Tailings Storage	Economy	Type of Government
Western Australia	Copper, Iron Ore	Pond – semi solid and liquid state.	High income-OECD member	Federal Parliamentary Democracy; State Government
United Kingdom	Copper, Coal	Pond – semi solid and liquid state.	High income-OECD member	Parliamentary Democracy
Arizona, USA	Copper	Pond – semi solid and liquid state.	High income -OECD member	Federal Parliamentary Democracy; State Government

Western Australia

Western Australia, a state in Australia, is one of the world's leading mineral producers. Western Australia's regulatory framework is readily accessible to the public and is thus used as a state level example of industry practices. Australia as a whole is responsible for the large scale production of 19 minerals supplied from over 400 mine sites across the country (Australian Government, n.d.b). As a primary industry, mining is a key contributor to the Australian economy (Australian Government, n.d.a). Australia is the world's largest producer of bauxite, ilmenite, iron ore, rutile, and zircon. It's the second largest producer of gold, lead, lithium, manganese ore, and zinc. It is the third largest producer or uranium and fourth largest producer in the world of black coal, nickel, and silver. It is also the fifth largest producer of cobalt, copper, and diamond (Australian Government, n.d.b). Of these numerous resources, several result in the presence of tailings waste, such as copper, coal, and iron. Australia is a high income member of the Organization for Economic Co-Operation and Development (OECD) and as of 2013 it had a GDP per capita of $67,458.4 in current US dollars (World Bank Data, n.d). There are large global resource companies, such as BHP Billiton and Citi Gold, operating in Australia with similar technological capabilities as large companies working within Canada's resource sectors making it easier for successful practices used in in the country of Australia to be duplicated in Canada. Australia is a parliamentary democracy and each state and territory also has its own government (Australian Government, n.d.c). The Government derives its authority from a written constitution, as is the case in Canada. The six states of Australia have their own constitution, legislature, executive and judiciary (Australian Government, n.d.d).

The United Kingdom

Natural resources in the UK include coal, petroleum, natural gas, iron ore, lead, zinc, gold, tin, limestone, salt, clay, chalk, gypsum, potash, silica sand, slate (Infoplease, 2013b). As a result of the extraction of various minerals, liquid tailings are produced and ponds are used for containing the waste. The UK is a high income OECD country and according to 2013 values the per capita GDP in the UK was $41,787.5 in current US dollars (World Bank Data, n.d). The UK has a Parliamentary democracy (Infoplease, 2013b) and has an executive branch, a legislative branch, and a judicial branch, as does Canada. The UK derives its authority from a written constitution and has a common law legal system in place which is also the legal framework used in Canada (Central Intelligence Agency, 2015a).

Arizona, USA

Minerals and metals in the US state of Arizona are copper, gold, silver, molybdenum, lead, sand, gravel, crushed stone, clay, cement, gypsum, lime, perlite, pumice, salt, turquoise, peridot, petrified wood, azurite, and malachite (Arizona Geological Survey, n.d.a). Arizona is the provider of approximately 65% of all of the United States' copper (Arizona Geological Survey, n.d.b); as such copper is the state's most valuable mineral. Copper is of particular use as a case study in comparing waste management methods to oil sands tailings as its extraction generates large amounts of waste rock and sludge requiring containment (U.S. Environmental Protection Agency, 2012). As a state within the US, Arizona is a member of a high income country OECD member that had a GDP per capita of $53,042.0 in current US dollars as of 2013 (World Bank Data, n.d). The US as a whole is thus a comparable economy to Canada and Arizona is a specific location within the country with comparable mining and waste management needs as Alberta. Arizona is within the federal parliamentary democracy of the United States (Central Intelligence Agency, 2015b). Arizona does however have its own written Constitution apart from that of the United States. It also has a Governor and a bicameral parliament made up of a Senate and a House of Representatives (Infoplease, 2013a).

7.2. Framework of Analysis

I now outline the framework of analysis that is used to compare and evaluate the case studies. Many categories of successful tailings management principles relevant to the oil sands industry exist throughout the relevant literature, most of which suggest the significance of similar factors. The type of technology used at each site and the processes that are in place, the infrastructure used, and all of the pertinent regulatory mechanisms and standards are essential (Poveda and Lipsett, 2011). These factors are crucial from the start of a project through to the disposal of the tailings. The framework in Table 2 provides a list of categories specific to pond management. The sub-categories are explained with the measures for each.

Table 2. Framework of Analysis

Category	Sub-Category	Measure
Design and Construction	Location/Foundation	Where will the pond be built? What factors are considered in choosing a location?
	Stability/Safety/Security	Are any steps taken to verify the stability of the pond location prior to construction?
	Size/Capacity of Pond	What considerations are made for the size and storage capacity of a pond?
Management and Usage	Regulation	At what government level is tailings management regulated?
	Monitoring/Inspection/Review	What type and frequency of inspections/monitoring/review is required for ponds and by whom?
	Emergency Response Plan	Is there a requirement to have an emergency plan in case of a pond failure?
Closure and Reclamation	Site Closure/Emergency Fund	Is there a financial guarantee for completing reclamation of the land at the end of mining projects?
	Closure Strategy	What closure strategy is required as per regulation (consistency of soil, landscape, usability, etc)?

Azapagic (2004), Davies and Rice (2000), Franks et al. (2011), and Fourie (2009) outline numerous principles for safe and sustainable tailings management. The three main categories that I use to evaluate the case studies are design and construction, management and usage, and closure and reclamation. Within design and construction there are three sub-categories examined: the location and foundation of a pond looks at what factors influence where a pond is built; stability, safety and security looks at what factors are considered to ensure the stability/safety/security of the location and of the pond throughout its lifespan; the size and capacity of the pond considers what factors determine the size of a pond. Within management and usage there are three more sub-categories examined: regulation determines what level of government regulates the industry; monitoring, inspections and review looks at the type and frequency of inspections/monitoring/review on ponds; and emergency response plans asks whether or not each case requires an emergency plan to be in place in case a pond failure occurs. Lastly, within closure and reclamation there are two sub-categories examined: site closure and emergency response funds determines whether or not the cases require a financial guarantee by the mine operator in case of a failure or for a future reclamation; closure strategy looks at what is required at the end of a mining project in terms of reclamation of the land, water etc.

In the following chapter the categories of sustainability measures for successful tailings management and pond failure mitigation will be systematically analyzed in Western Australia, the UK, and Arizona.

8.

Analysis

In this chapter I evaluate each case study with the set of categories for successful tailings management. From there I identify the sub-categories that appear in most (2) or all (3) of the cases to determine which are essential to a successful tailings management strategy to avoid a pond failure. Table 3 shows the results of the analysis.

Table 3. Case Study Tailings Pond Summary

Category	Sub-Category	Western Australia	United Kingdom	Arizona
Design and Construction	Location/ Foundation	-Location chosen where hazards can be eliminated. -Location where Negative impacts on people, environment, and existing infrastructure can be mitigated.	-Competent person must draw up report that approves land as being “acceptable” and “suitably located”. -Must adhere to regulations pertinent to local communities and national requirements.	-Location’s capacity for water drainage must be assessed. -Lands with water drainage problems or geologic hazards, such as landslides, are unsuitable.
	Stability/Safety/ Security of Location and of Pond	-The pond must be safe, stable, erosion-resistant and non-polluting according to legislation. -Requires that all ponds undergo hazard identification and are categorized according to level of risk. This determines the level of scrutiny that will be required across the pond’s lifespan.	-Any potential issues of security/stability of the land and of the pond must be verified prior to operation. -Construction must be done to ensure ponds are stable, do not pollute or contaminate the surrounding water, land, or air.	-Evaluation of location stability with current conditions and with the probability of earthquakes/other ground instabilities calculated. -If pond capacity is surpassed, the construction must be done in way that mitigates erosion.

	Size/Capacity of Pond	NA	NA	Size of ponds can vary but capacity requirements are threefold. Must be able to contain: 1) expected amount of tailings 2) any precipitation that will enter the pond and 3) have additional room for unanticipated storage needs.
Management and Usage	Level of Regulation	State	EU, Federal	Federal, State
	Inspection and Reporting	-Daily inspections by mine operators. -Periodic technical reviews by third party. -Annual performance reviews by geotechnical engineer.	-Regular inspections by competent person. - Reports made for any defects and remedial action taken. -If an event occurs that jeopardizes the stability of the pond or a hazardous environmental impact is detected, the mine operator has 48 hours to notify the regulator. -Regardless of incidences, a minimum of one inspection report per year must be submitted to the regulator. -The regulator may decide to issue an external expert inspection.	-Initial inspection at time of construction. -Throughout the lifespan of the pond, inspections must occur four times a year. -Following any storm an inspection must take place. -Inspection records must be kept on site for reference purposes, as required by the regulator.
	Emergency Response Plan	Yes	Yes	Yes

Closure and Reclamation	Site Closure/ Emergency Fund	NA	-Regulation requires that a financial guarantee be in place by the mine operator prior to commencing operation to ensure all requirements are met and that funding is available for reclamation after the project is complete.	NA
	Closure Strategy	- Pond closure plan is an essential part of overall mine closure plan. - Closure plan must start before the pond is built and continue developing over lifespan of pond to increase likelihood of successful closure. -Goal is to leave location safe, stable, erosion-resistant, non-polluting and needing no further maintenance. -Review and assessment of closure required by competent person to ensure land remains a self-sustaining ecosystem.	-Pond site must be rehabilitated. -Even after closure of the site, the operator is responsible for any monitoring, maintenance, and corrective measures. -In certain cases, operator responsible for ensuring the physical and chemical stability of the site including minimizing negative environmental impacts. -For issues pertaining to mine waste, after a site closure, that go beyond the responsibility of the operator there are agencies tasked with managing the damages.	-Site closure plan must be given to the regulator prior to ending the mining operation and before reclamation starts. -Closure must ensure that the pond: 1) Does not allow for any future discharge of tailings. 2) Is stabilized and dried in a way that allows for heavy machinery to drive on it. 3) Is flattened and covered so that liquids cannot filter through. -Any leftover tailings waste must be either physically removed and relocated or stored and evaporated.

8.1. Western Australia, Australia

Design and construction

A tailings pond must be safe, stable, erosion-resistant and non-polluting. The Code of Practice for Tailings Storage Facilities in Western Australia provides a thorough outline of how a pond operator may achieve these elements. Regarding the selected location to build a pond, it must be where the hazards can be eliminated or where the possibility of negative impacts on people, the environment and existing infrastructure are mitigated. Before operation commences, a pond's construction needs to be certified by a competent person, as defined by the legislation, and recorded as meeting all required design specifications (Government of Western Australia, 2013).

Regarding the stability and safety of a pond, all tailings ponds in Western Australia require hazard identifications to be completed. Ponds are categorized according to level of potential risk prior to construction and throughout their life. This assesses the different risks of individual ponds to determine the impact of varying types of pond failure. The hazard assessment is used throughout the life of the pond to determine what is necessary for design and construction, management of the pond, and degree of monitoring. This practice acknowledges that each pond is unique, with different levels of risks and can have varying degrees of complications. Hazard identifications allow regulators and operators to provide the appropriate level of attention and maintenance to different ponds (Government of Western Australia, 2013). A pond rated as a high risk will not only require more strict construction, management of operations and reclamation but will also need more stringently designed emergency plans for if a failure occurs. Ponds that are a high risk in all of Australia can be subjected to government audit by regulatory agencies (Australian Government, 2007).

Regarding the size and capacity requirements of tailings ponds in Western Australia, no information could be found at this time. While this does not indicate that the information does not exist or that the state does not have specifications for the sub-category, it indicates that it could not be readily located at the time of this research.

Management and Usage

Regarding the level of regulation, in Australia mining activities are regulated by individual states and within each state there are different government departments that uphold the regulations. For example, in the state of Western Australia the regulation of tailings management is in the Mining Act of 1978, the Mining Act Regulations of 1981, the Mines Safety and Inspection Act of 1994, and the Mine Safety and Inspection Regulations of 1995. Two Australian states, Tasmania and Southern Australia, do not have a specific legislation on tailings management but Southern Australia does draw guidelines from the state of Western Australia and the state of Victoria (Engels, 2002b).

The ponds in Western Australia do not all need to meet the same specifications but they do need to achieve certain pre-determined outcomes as laid out in the various Acts (Government of Western Australia, 2013).

Regarding inspection and reporting of ponds, a technical review needs to be completed on a periodic basis to ensure that ponds are operating according to design specifications of the original construction report. This verifies that all regulatory requirements are being met. The review must be done by a third party that is not the designer or operator of the mine site and pond, as required by regulation (Government of Western Australia, 2013). Additionally, annual performance reviews need to be done by qualified geotechnical engineers specialized in dealing with tailings ponds. The annual review, similarly to the technical reviews, has the purpose of comparing current operations with the original design specifications. The aim is to use this to make recommendations for eliminating potential risks. The requirement of a performance review is often mandated by an industry regulator (Australian Government, 2007). While the Australian government also encourages a set of best practices stating that all ponds, their pipeline and pumping systems need to be inspected, at the very least, on a daily basis. These inspections need to include thorough observations and the recording of any unusual or notable discoveries. It is necessary to follow up on these observations with any maintenance or modification to parts (Australian Government, 2007).

Regarding emergency response plans, Western Australia requires emergency response plans for a pond failure to be part of the mine operation plans. This improves the odds that the operator will be prepared and ready to act and address the situation in a prompt manner. While this does not help to avoid a pond failure it can make a big difference in the severity of the outcome of a failure. Immediately following a failure, improvements need to be made and recommendations to avoid a similar incident in the future should be noted (Government of Western Australia, 2013).

Closure and reclamation

Regarding an emergency or closure fund, no information could be found at this time. While this does not indicate that the information does not exist or that the state does not have specifications for the sub-category, it indicates that it could not be readily located at the time of this research.

Regarding a closure strategy, a pond closure plan must be prepared in conjunction with the closure plan for the entire mine operation. This plan is to be made prior to building the pond and should be amended as changes in technology, regulation, and the overall functioning of the mine occur. Part of the initial pond design and the role of inspections are to ensure that a closure plan is successful and well developed according to the specific pond. When closing a pond, the goal is to leave the location in a safe, stable, erosion-resistant, and non-polluting state. The aim is for the location to require no further maintenance following a closure. A review and assessment is required by a competent person to determine if the closure is acceptably completed (Government of Western Australia, 2013).

8.2. The United Kingdom

Design and Construction

Regarding the location of ponds, detailed plans must be drawn up and approved according to national requirements. As outlined in the Mines and Quarries (Tips) Act, this must occur before mine operation and waste disposal can begin[9]. Prior to operation, the mine operator must have a report completed by a competent person that approves the proposed method of waste containment. This report must also ensure that the proposed land on which the pond is to be built is acceptable. Ponds must be suitably located, as defined by the regulator, and take into account any regulations specific to the local communities and national requirements.

Regarding safety, stability, and security of ponds, the security and stability of the waste containment need to be verified prior to usage. The construction must ensure the ponds are stable, do not pollute or contaminate the surrounding water, land, and air

[9] All of the information in this paragraph on the United Kingdom is from (United Kingdom Secretary of State, 1971)

(European Parliament and the Council of the European Union, 2006). According to EU law, which also governs UK ponds, member states must ensure that a competent person oversees the construction of ponds and the training of staff.

Regarding the size and capacity requirements of tailings ponds in the UK, no information could be found at this time. While this does not indicate that the information does not exist or that the state does not have specifications for the sub-category, it indicates that it could not be readily located at the time of this research.

Management and Usage

In the UK, ponds are submitted to national and European Union (EU) regulations. Nationally, the management of tailings are regulated under the Environmental Protection Act of 1990, the Water Act of 1989, and the Mines and Quarries (Tips) Act of 1971. For any ponds that contain more than 25,000 cubic meters of water above the surrounding natural land, then the Reservoirs Act of 1976 is also applicable (Engels, 2002b). In 2006, the Directive 2006/21/EC of the EU on the management of waste from the extractive industries was established. All member states of the EU must have waste management plans reviewed every five years. Reports from the member states must also be provided to the European Commission every three years detailing the implementation of the Directive and following this, the European Commission must publish a follow up report within nine months of receiving the submissions (European Parliament and the Council of the European Union, 2006).

Regarding inspections and reporting, all active mines must have a designated competent person in charge of supervision and operation of the pond (United Kingdom Secretary of State, 1971). There must be regular monitoring and inspections of ponds by the competent person. Throughout the lifespan of a pond, any erosion caused by wind or water needs to be reduced by as much as is financially and technically possible (European Parliament and the Council of the European Union, 2006). With the regular inspections of the premises, the competent person must complete a report on any defects that are found and a record must be kept of any remedial action taken to correct the defect (United Kingdom Secretary of State, 1971). If an event occurs that could jeopardize the stability of the pond or if any hazardous environmental impacts are discovered, the pond operator has 48 hours to notify the authorities. The operator must then implement an emergency plan at its own expense and follow any additional instructions given by the authorities to correct the situation. Regardless of any incidences, a minimum of one inspection report must be submitted each year by the operator whereby the competent authority may decide to issue an external expert inspection be completed as well (European Parliament and the Council of the European Union, 2006).

The EU requires emergency plans to be put into place prior to the operation of a pond to ensure appropriate measures can be taken in the case of a pond failure (European Parliament and the Council of the European Union, 2006).

Closure and reclamation

Regarding an emergency fund, Directive 2006/21/EC requires a financial guarantee from mine operators before a project begins to ensure all Directives requirements are met and that after operation is complete there are funds for the reclamation of the site (European Parliament and the Council of the European Union, 2006).

Regarding a closure strategy, before a mine site can be closed, the operator needs to ensure that the pond site has been rehabilitated. Even after the closure of the site, the operator remains responsible for any monitoring, maintenance and further corrective measures of the land and affected waterways. In certain instances the operator will also be responsible for ensuring the physical and chemical stability of the site after closure which can include the minimization of any negative environmental impacts (European Parliament and the Council of the European Union, 2006). For issues pertaining to mine waste following the closure of a site, that go beyond the responsibility of the operator, there are agencies tasked with managing the damages. For example, the UK has the Coal Authority which is a public body operating under the purview of the Department of Energy and Climate Change. The Coal Authority deals with issues caused by past coal mining activities such as pollution and other legacy problems and manages damages claims (United Kingdom Government, n.d).

8.3. Arizona, USA

Design and construction

Regarding a pond's location, before a pond is established the site's capacity for surface water drainage must be assessed. Any areas with surface water problems or possible geologic hazards, such as the potential for landslides or instability in the ground, need to be marked as unsuitable for building the pond[10]. The presence of any shallow waters will change the construction of the pond so it is important to be aware of it in advance.

Regarding pond stability and security, the ponds must be built following an evaluation of site stability according to present conditions and as well as calculated with the probability of earthquakes.

Regarding the size and capacity of a pond, while the size of a given pond may vary the storage capacity must be enough to hold the tailings that result from the mineral extraction. The capacity needs to be able to contain any precipitation that enters the pond and have extra room for unanticipated additional capacity needs. The pond must also be constructed in a way that mitigates erosion in case the capacity is surpassed.

Management and usage

Regarding the level of regulation of ponds, according to the Arizona Revised Statute, all mining activities including the management of tailings must align with the Arizona Mining Guideline Manual Best Available Demonstrated Control Technology (BADCT). The statute requires all mining facilities to have permits and adhere to the BADCT for design, construction, and operation of all mining activities. While each individual US state has its own laws and regulations on mining, according to the National Mining Association there are also over 36 Federal statutes that apply to the extraction industries (n.d).

[10] All the information for the analysis of Arizona, USA is from (Arizona Department of Environmental Quality (n.d)), unless otherwise specified.

Regarding inspections and reporting, all ponds must be inspected initially when constructed and four times a year there after. Inspections must take place following the occurrence of a storm. This is done with the aim of detecting any damage done to the site or to the ponds to avoid or mitigate a pond failure. Inspection records are required to be kept on site for reference purposes for a period of time determined by the regulator.

Regarding emergency response plans, the operator must prepare a contingency plan and provide it to the regulator so that in the case of a pond failure an emergency response is ready for implementation. This plan includes steps such as identification of the spill/leak source, clean up procedures, notifications and reporting mechanisms, and solutions testing to identify the chemical make-up of spilled substances.

Closure and reclamation

Regarding an emergency or closure fund, no information could be found at this time with respect to Arizona, USA. While this does not indicate that the information does not exist or that the state does not have specifications for the sub-category, it indicates that it could not be readily located at the time of this research.

A site closure plan must be provided to the statute administrator prior to the end of the mining operation and the reclamation of the site. The mine operator must, to its greatest ability, close the pond so that it does not allow any future discharge of tailings. The pond must be stabilized and dried in a way that makes it safe for heavy machinery to drive on. The surface must be flattened and covered so it stops liquids from filtering through. Lastly, any tailings waste left over must be either physically removed and relocated or stored and evaporated.

8.4. Summary of Case Study Analysis

Within the categories, six out of the eight sub-categories are found to be common to all three cases. In the category of construction and design, all three cases consider pond location and stability and security to be necessary. In the category of management and usage, all three cases have regulated industries and require frequent inspections and reporting, as well as the inclusion of an emergency response plan in case of a pond failure. In the category of closure and reclamation, all three cases require a closure strategy to achieve land reclamation. The six sub-categories exist at the broadest level in all three cases however, there are large variances in how each is implemented. The two sub-categories that are not common to all three cases are the pond size and capacity as well as of site closure/ emergency funds; both are only present in one case.

Elaborating on the role of regulation helps establish a sense of tailings management across the cases. The sub-category on regulation finds that the level of government that regulates mining varies in all three cases. Regardless of whether it is federal or state level governments that act as the regulator, in all of the cases there is heavy regulation on the industry. So while it is clear that regulation is essential to the industry, it is not apparent that the level of government that acts as the regulator is of much importance. The requirements of the industry are stringent, but the regulations seek to control the outcomes rather than the means for avoiding a pond failure; regulations do not dictate specific requirements such as type of ponds that must be used, consistency of tailings required, type of construction materials used, nor length of time reclamation must occur within. This is because each pond presents different challenges and requires different levels of attention. There are outcomes that the regulators expect but how each mining operator achieves them is broadly up to their discretion. This is an important basis for applying any future policies to the industry practices.

Though the involvement of competent persons was not directly analyzed, it is a concept that emerges across all of the cases and is a crucial component to all of the categories. It is the idea that transparency, non-biased observation and review, along with third party involvement and decision making are a necessary part to the successful tailings management process.

In summary, the sub-categories of primary importance to the successful tailings management practices in Western Australia, the UK, and Arizona are: the pond location, the stability and security of the location and construction, the presence of regulation –

but not the level of government in charge of regulating, frequent inspections and reporting, and having a closure strategy.

8.5. Features in Alberta

Alberta's oil sands industry is large and very active so the province has to be at the forefront of tailings management to keep up with production and ensure continued success and public support. While there remains room for improvement, this Canadian province is already engaged in many of the best practices in other jurisdictions. Given the vastness of the industry and the large number of ponds in Alberta, little is found in the three case studies that is not already being done in Alberta. As such, I look to the finer details of the sub-categories to suggest options that could be implemented in Alberta. In particular, I discuss three notable practices present in the case studies that could be incorporated into Alberta's tailings management.

Design and construction

Prior to constructing a new pond, the proposed location must be reviewed to make sure the environment, the conservation of natural resource and economic interests of the area are taken into account. A proposal for a new pond must be approved by the province's regulators and the site must allow for the construction of a mechanism to divert any groundwater that could affect the pond (Alberta Government, 2011). Since Alberta does address design and construction characteristic of pond locations, I will not look at this feature any further.

Regarding safety and stability of locations and pond construction, Alberta has experienced a few major pond failures. One in 1974 and one in 1979 were both as a result of unstable slopes. Another in 1978 also included a foundation problem (Grant et al., 2010). Though a major pond failure has not occurred in the oil sands industry since the 1970s, there are actions to further decrease the probability of a failure and decrease the severity of the consequences should a failure occur. Alberta could put more emphasis on the safety and stability of pond locations and construction. This sub-category will therefore be a focus of the policy options.

Management and usage

Regarding regulation, Alberta has a heavily regulated natural resource industry similarly to the three cases. The primary regulator is the Alberta Energy Regulator at the provincial level and the Federal Government of Canada plays a secondary role in managing the oil sands industry. Given that Alberta is already successfully addressing regulation, I will not look at this feature any further.

Following a thorough review of publicly available information at the time of this research, it appears as though Alberta does not currently require a systematic risk assessment or hazard identification to be completed before construction or throughout a ponds lifespan. Alberta regularly monitors oil sands' ponds and requires annual inspection by third party authorities. A quantification of the level of risk of each pond is however not currently a part of the inspection process (Alberta Government, 2011). Nowhere in the Oil Sands Conservations Rules, the Directive 074, or in the new Tailings Management Framework for the Mineable Athabasca Oil Sands is there any mention of a formal hazard identification to the tailings management process. In the Tailings Management Framework for the Mineable Athabasca Oil Sands the aim of managing and decreasing risk is discussed; however, only in the context of a proposal to implement progressive treatments and reclamation of tailings, and to ensure financial guarantees for these changes. With this new aim, the Government of Alberta and the AER could go one step further and include a risk assessment and hazard rating as a means of increasing the level of confidence present in successfully managing ponds and mitigating the risk of a failure. Calculating the probability of different types of risk is a tool that can be used to increase the safety measures in place and create appropriate emergency response plans. While doing this does not give certainty to the likelihood of future risks it is a common practice in natural resource industries. Since Alberta is not currently engaging in the practice of risk assessment and hazard identification, this will be a focus in the policy options.

Regarding emergency response plans, according to The Oil Sands Conservation Rules, the Alberta regulator may request that an oil sands site operator prepare and submit emergency response plan. These plans would be for various emergency situations, one being the uncontrolled release of pollutants and toxic materials into the air, water, or surrounding land. It is not however stated that such plans are automatically required by all companies but rather situation specific. Furthermore, the Rules do not explicitly outline an emergency response plan specific to a pond failure (Alberta Government, 2013a). No publicly available information is found stating whether or not Alberta requires emergency response plans to be drawn up by mine operators in preparation for the case of a pond failure. Information, however, is found supporting the idea that a lack of transparency exists with Alberta's tailings pond failure mitigation strategies. In 2010, the Pembina Institute, an environmental research think tank, stated that emergency preparedness plans from the Alberta oil sands are lacking and not made readily available to the public (Grant et al., 2010). More recently, the Government of Alberta has announced a desire to increase transparency between the government, industry, and the public. It says this will be done through improved monitoring, evaluations, reporting and publicly available information (Alberta Government, 2015b). There is no direct mention however of increasing transparency with respect to emergency planning. As such, emergency response planning will be a focus in the policy options.

Regarding a closure strategy, the Environmental Protection and Enhancement Act states that all areas used for oil sands development, which includes the tailings ponds, must be reclaimed following the completion of a project. The location must be restored to a pre-exploration state in terms of the land's capabilities and is then returned to the Crown (Alberta Government, 2015b). Given that closure strategies are addressed by Alberta, I will not look at this feature any further.

In summary, three out of the six sub-categories that emerged as primary features from the case studies analysis are not currently being addressed in Alberta. These key features are important and will be the focus of the policy options in the next chapter. The sub-categories are: the stability and security of a pond's location and pond construction, risk assessment and hazard identifications, and publicly available emergency response plans.

8.6. Secondary Methodology - Academic Literature Review

In this chapter, I undergo a scan of the academic literature to verify the results from the primary method of analysis. Key categories of successful tailings ponds management found in the cases and that are supported by the academic literature are determined to be essential to a successful pond strategy.

The notion that all three cases engage in broadly similar practices of tailings management yet implement them in vastly divergent manners is a concept supported within the literature. For example, while the cases may all be heavily regulated, they all do so at different levels of government or, though all three cases put importance on stability, only one uses risk assessments and hazard identifications to ensure the stability of ponds. In appearance, the cases appear to be engaging in many of the same practices and support the same broad categories of pond management. Yet, there are numerous differences within the sub-categories once I assess the practices and ground level implementation strategies. Natural Resources Canada confirms this lack of a single cohesive tailings management strategy and explains that: "no one solution exists for the secure management of all forms of tailings given that tailings facilities must be designed for site-specific environmental conditions, ore type, geochemistry, topography and other constraints" (Government of Canada, 2014). While this may be the case and one clear solution does not exist, it does not mean that measures cannot be taken to improve tailings management. Strategies must take into account the variances inherent to each pond but they all need to aim to decrease the interaction between tailings waste and the surrounding environments (Government of Canada, 2014).

Safety and Stability

The Economic Commission for Europe as part of the United Nations Economic and Social Council discusses the need for pond safety and stability. In order to have a safe pond, the stability of the foundation needs to be assured. If a pond is built on a slope it must be stable and secure. The possibility of a slope shifting needs to be accounted for. The foundation, including construction materials, needs to have a certain level of strength and stability. The tailings waste also need to be tested for stability; whether it is liquid or thickened tailings, reducing movement in the waste and mitigating negative effects from a change in consistency (induced liquefaction) is needed to maintain pond stability. The design and construction of a pond needs to account for erosion and include preparation for if it happens (Joint Expert Group on Water and Industrial Accidents, 2008).

Sustainable Development Principles for the Disposal of Mining and Mineral Processing Wastes by Franks et al. outlines seven principles to guide the responsible and sustainable development of mining waste disposal practices. Of the seven principles, the first listed is that of stability. The paper states that if tailings waste cannot be inert then it needs to at least be kept stable and well contained. Maintaining the chemical, physical, and geographical stability of the tailings is crucial. Ponds need to be able to endure natural events such as earthquakes, bad storms, and erosion over the course of time (2010).

Risk Assessment and Hazard Identification

The Economic Commission for Europe as part of the United Nations Economic and Social Council also discusses the importance of including a complete risk assessment and hazard identification to any proposed pond; it states that this should be done before any licensing is offered. The general process for undergoing a risk assessment is thoroughly discussed throughout relevant literature and most include five overarching steps. In this document a sixth step is included that goes beyond merely identifying the risks associated with a proposed pond to determine whether the risks can be deemed acceptable (Joint Expert Group on Water and Industrial Accidents, 2008).

Emergency Response Plans

The Economic Commission for Europe as part of the United Nations Economic and Social Council has developed Safety Guidelines and Good Practices for Tailings Management Facilities. One of the practices is an emergency plan. The document states that there should be emergency plans for each stage of a pond's lifespan including construction, operation, and reclamation. The emergency plans should be created prior to permits being issued for each stage. This ensures that a plan is ready to be executed at any point in time and not after a failure has already occurred. The plans should be designed, reviewed, and amended when needed by both the mine operator and a third party authority. Internal mine site plans need to be consistent with any external authority's plans in the case of a large or trans-boundary failure. Furthermore, the Safety Guidelines state that the emergency plans need to include a strategy for handling the most likely type of pond failure that could happen and a strategy for the worst case scenario (Joint Expert Group on Water and Industrial Accidents, 2008).

The United Nations Environment Programme and the Division of Technology, Industry, and Economics have prepared a document on the subject of emergency responsiveness entitled: APELL for Mining, Guidance for the Mining Industry in Raising Awareness and Preparedness for Emergencies at Local Level. The document emphasises the significance of having an emergency response plan in place and provides a detailed framework to establish one. Several cases of pond failures portray the severity of the consequences and the importance of having a plan to avoid a failure or at least mitigate the negative outcomes. It is important to have community consultation with respect to emergency preparedness. Open communication for the development of a shared strategy with any outside authorities or emergency response teams that may need to be involved in the plan is also important. Internal emergency plans must be posted at the site so that employees know how to respond if the need should arise. The document makes reference to Australia and its Minerals Industry Code for Environmental Management is an example of an industry leader in emergency response planning giving support to the case study results (United Nations Environment Programme, 2001).

Stability, safety and security of pond locations and construction; risk assessments and hazard identifications; as well as emergency response plans are all supported by the case studies analysis and the academic literature as key features of a successful tailings management strategy. Therefore, these features are used in establishing potential policy options in the next section.

9.

Policy Objectives, Criteria, and Measures

In this chapter I discuss the objective of a new policy, the criteria to evaluate the policy options, and the specific measures to assess and compare each alternative. Three policy options are presented and evaluated each according to the criteria and measures. For the Alberta oil sands industry to decrease the risk of a tailings pond failure, both the short and long term objectives need to be considered.

9.1. Policy Objectives

One main long term objective exists – for Alberta to achieve a stronger system of tailings management. This long term objective is to mitigate the risk of pond failures. Achieving this is twofold: first there is the need to decrease the likelihood of a failure occurring and second there is a need to reduce the severity of the consequences in the case that a failure does occur unexpectedly.

To achieve the long term goal, an important short term objective is to increase transparency and the public disclosure of information. Given the public pressure on the oil sands industry and the government to ensure the upmost protection of the environment and communities, there is a pressing need to address the short term goals as promptly as possible. The short term objective is essential in progressing with the long term goal and thus should be accomplished within the next two to five years. The long term objective cannot be realized until the province has met the short term objectives.

9.2. Criteria, and Measures

To evaluate the policy options five criteria are established: effectiveness, security and protection, sustainability, cost, and stakeholder acceptability. Each criterion has a specific measure and a reference value to allow for ranking the options. The ranking takes the form of high, medium, and low with a corresponding 3, 2, 1 scoring. For the criteria that have more than one measure, the scores from each measure are added up and divided by the number of measures; this ensures all criteria have the same weight. Any form of weighting is left up to the discretion of the reader if there is a desire to prioritize certain criteria. Each policy option receives a score for each criterion. The option with the highest overall score is considered to be the preferred policy option. Table 4 provides a summary of the criteria, measures, and reference values. Following the table is a brief description of each criterion and how they are measured.

Table 4. Criteria and Measures for Policy Evaluation

Criteria	Definition	Measure	Benchmark	Score
Effectiveness				
Mitigation of pond failures	Is the policy option achieving the primary objective of mitigating pond failures?	Likelihood of failure (LF) and severity of consequences (SC)	LF+SC < status quo LF or SC < status quo LF + SC = status quo	High = 3 Medium = 2 Low = 1
Security/ Protection				
Preventing harm to communities and people	Does the policy reduce the negative impacts on public safety, human health, and infrastructure?	Severity (S) of consequences to public safety, human health, infrastructure	S much less than status quo S slightly less than status quo S not changed from status quo	High = 3 Medium = 2 Low = 1
Sustainability				
Promoting sustainability of the environment	Does the policy reduce the interactions between tailings waste and the surrounding environment?	1) Level of potential interaction (I) between tailings waste and environments	I much less than status quo I slightly less than status quo I not changed from status quo	High = 3 Medium = 2 Low = 1
		2) Ability to restore environment to pre-failure conditions (PFC)	Fully restore to PFC Partially restore to PFC	High = 3 Medium = 2

Criteria	Definition	Measure	Benchmark	Score
			No restoration to PFC	Low = 1
Cost				
Operational costs	Will the option require hiring personnel or outside agencies, new infrastructure or equipment?	Cost of physical (PC) and human (HC) capital	Lowest cost ≠ PC or HC Moderate costs = PC or HC Highest cost = PC+HC	High = 3 Medium = 2 Low = 1
Stakeholder Acceptability				
Resistance from Oil sands companies	Amount of resistance an option will encounter based on level of effort and time required	The number of hours of work (Hrs) required to implement the policy	Hrs = 20% more than status quo Hrs = 30% more than status quo Hrs = 40% more than status quo	High = 3 Medium = 2 Low = 1
Level of awareness with local residents of nearby communities	Residents' perception of level of public transparency and awareness	Level of transparency and awareness (TA)	TA much larger than status quo TA slightly larger than status quo TA not changed from status quo	High = 3 Medium = 2 Low = 1

Note: High=3=best, Medium=2=good, Low=1=less good.

Effectiveness – This criterion looks at if the policy option achieves the primary objective (i.e., of mitigating the risk of pond failure). To determine whether or not a policy option is effective in mitigating the risk, both the likelihood of failure occurring and the severity of the consequences are addressed. For the measure of the likelihood of failure, the status quo is the benchmark. If a policy option decreases both the likelihood of a failure and the severity of the consequences it ranks high (3). If an option decreases only one of the two aspects associated with risk then it ranks medium (2). If an option has no impact on the risk of a pond failure then it ranks low and is given a score of 1.

Security/Protection – This criterion measures the aim of preventing harm to the surrounding communities resulting from a pond failure. Security and protection are measured in terms of public safety, human health, and protection of infrastructure. The measure is of the severity of the consequences to public safety, human health, and infrastructure. An option ranks high (3) if it decreases the severity of the consequences, ranks medium (2) if the severity of the consequences is somewhat affected, and ranks low (1) if the severity of the consequences remains the same as the status quo.

Sustainability – This criterion looks at whether a policy can reduce the disturbances to natural habitats by maintaining or at least by restoring the ecosystems once a project is complete and the site is closed. Sustainability has two measures: first, the level of potential interaction between tailings waste and the surrounding environments. If the policy decreases the potential for interaction between the tailings and the environment it ranks high (3), if the policy somewhat decreases the potential for interaction it ranks medium (2), and if the policy does not affect the level of interaction it ranks low (1). Second, is the ability to restore the environment to pre-failure conditions. If the option allows for the negatively impacted ecosystems to be fully restored to pre-failure conditions it ranks high (3), if it allows for the area to be somewhat restored to pre-failure conditions it ranks medium (2), and if it does not allow for any restoration of the ecosystems it ranks low (1).

Cost – This criterion looks at the operational costs of implementing a new policy. In this case, most costs are presumed to be borne by the industry (i.e., oil sands companies). The cost of a policy option is compared against the baseline of the status quo. The costs of the selected policy option will be in addition to current costs and are measured in terms of annual expenses. This criterion looks if the policy option requires the hiring of new personnel or outside agencies (human capital), and if it requires capital costs to build new infrastructure or purchase new equipment (physical capital). The less additional physical and human capital required by the project the higher it ranks. The option that requires neither physical nor human capital costs ranks high (3), the option that requires only physical or human capital but not both ranks medium (2), and the option that requires both physical and human capital costs ranks low (1).

Stakeholder acceptability – For the purpose of this analysis two primary stakeholders are considered: private firms (i.e., the oil sands companies) and nearby communities .The government of Alberta is not taken into account because it is assumed that the government is responsible for creating and upholding the new policy, therefore is viewed as a neutral party. The government will not be the one implementing the policy and will not be affected in the way that the companies will in their daily operations. Similarly, the nearby communities will have a strong stake in the matter as it is their safety that is most immediately at risk. Due to time constraints, it is thus the perspectives of the two most directly impacted stakeholders that are taken into account for this analysis.

For oil sands companies, this criterion looks at the amount of resistance an option will encounter by the companies. Stakeholder acceptability is measured by the cumulative number of hours of work required by all employees at a given company to implement the option and produce the expected change from the status quo. The number of hours of work does not include the hours worked once a policy is operational. The more hours of work required by a company to implement a policy, the more resistance it will encounter and the lower it will rank. This measure captures the time loss and it is not a measure of monetary cost. An option that requires only a 20% increase in hours worked ranks high (3), an option that requires a 30% increase in hours worked ranks medium (2), and an option that requires 40% more hours worked than the current number of hours with the status quo ranks low (1).

For residents of nearby communities, stakeholder acceptability looks at the level of public awareness that exists for each given policy option. It is the perspective of the local residents' that is assessed in determining the level of transparency. Transparency is measured against the current level of publicly available information as the benchmark. A policy option that increases the level of transparency within the nearby communities and leads to an increase in the available information is ranked as high and given a score of 3. An option that only somewhat increases the level of transparency ranks as medium (2) and an option that maintains the current level of transparency and third party involvement ranks low (1).

10.

Policy Options

In this chapter, I present three policy options as possibilities to mitigating the risk of a pond failure in Alberta's oil sands industry. While the options are analyzed individually, for the purpose of determining the most favorable option, they can be implemented separately or as a multi-policy solution that implements more than one option. None are mutually exclusive and if implemented together could increase the likelihood of successfully mitigating the risk of pond failures given the complex nature of the issue. The status quo is not presented as an option as it is assumed that all policy options will be on top of the current practices.

10.1. Policy Option 1: Tailings Dewatering

This option would require the mandatory dewatering of tailings to specified levels, as determined by experts. Presently, not all oil sands companies have shifted to reducing the total amount of water in the tailings (e.g., thickened/paste tailings, dry stack or methods of centrifuging). This option would therefore require an industry shift to decreasing the amount of water permitted in the tailings[11]. The method selected to decrease the percentage of water would be up to the discretion of individual companies so long as predetermined allowable limit is met. The dewatering of tailings would be implemented in a phased-in approach over the next three to five years. The aim of this option is threefold: first, to produce a solid and secure substance with a surface that is capable of bearing heavy weights such as by machinery and other vehicles; second, to dry out the tailing in a reasonable amount of time to allow for reclamation of the land;

[11] All information on tailings dewatering, including the three aims, are from (BGC Engineering Inc., 2010)

and third, to decrease the amount of movement present in the tailings, eventually to the point of the substance no longer requiring the containment of pond walls.

10.2. Policy Option 2: Risk Assessment and Hazard Identification System

This option would require mandatory risk assessments by the mine operators with an evaluation from a competent third party as part of the pond design and construction stage. This is to determine the construction materials needed, level of inspection, and monitoring of the pond once it is operational. The identification of hazards throughout the life of the pond would also occur to make any necessary adjustments to maintaining the integrity of the pond. This option would require the implementation of six steps by the oil sands companies[12]: first, perform a hazard identification of all potential hazards including the possibility of flooding from the liquid tailings. The number of hazards found will direct the level of scrutiny in the rest of the assessment; second, descriptions of the possible types of failures that could occur need to be made with the potential causes for the failures; third, a list of who and what could be affected by the failures need to be outlined. The list would include surrounding communities, the environment, and nearby infrastructure; fourth, a description of the actions being taken to avoid the possible failures needs to be established with the actions that would be taken to reduce the negative impacts if a failure occurs. This step includes creating an emergency response plan that is made available to the regulator and surrounding communities; fifth, an evaluation needs to be done on the negative impacts on the communities, environment, and infrastructure if a failure occurred followed by how the actions in step 4 could mitigate these impacts; and sixth, the probability of the different types of failures need to be calculated. Lastly, the mine operator needs to decide if the level of risk is acceptable to proceed with the project.

[12] All information on the steps of a risk assessment and hazard identification are from the (Joint Expert Group on Water and Industrial Accidents, 2008).

10.3. Policy Option 3: Publicly Available Emergency Response Plans

This option would require the implementation of mandatory emergency response plans specific to tailings pond failures, by all oil sands companies. The plans need to be known by all employees at the pond site and displayed on location. The details of the plan also need to be known by the regulator, the nearby communities, and be publicly available on industry and government websites. The plans would be designed prior to construction, approved by the regulator, and updated throughout the life of the pond[13]. Each stage of operation needs to have an updated emergency response plan including one for the closure of the pond. The potential risks associated with floods or pond failures need to be accounted for. The emergency response plans must include seven components: first, the reach and the purpose of the plan need to be clear; second, all parties involved in the emergency plan must be aware of the possible types of failures, the risks of a failure, and know who/what could be affected; third, all employees at a mine site need to know their responsibilities in the case of a failure; fourth, clear procedures need to exist for who to contact for assistance with the plan if a failure occurs and all those to notify of the emergency, such as nearby communities; fifth, an outline of all required equipment and where to access it in the case of a failure; sixth, separate plans for each possible type of failure need to be established and accessible; seventh, the emergency response plan need to have a list of actions for restoring the surrounding areas.

The next chapter analyzes the three policy options with respect to the criteria and measures defined in chapter 9.

[13] All information on the emergency response plans, including the seven components, are from (Joint Expert Group on Water and Industrial Accidents, 2008).

11.

Evaluation of Policy Options

In this chapter, each policy option is evaluated, given a ranking and score for each criterion. The evaluation of the options in this research is done relative to the status quo. This establishes an understanding of the impacts of different policy options on tailings management and sets up a basic framework for future work on the subject. Before any of the options could be implemented, numeric values would need to be determined by industry experts to properly quantify the ranking and scores of each option. Given time constraints this step is not within the scope of this paper. The final results are discussed following the evaluation of the third policy option.

11.1. Policy Option 1: Tailings Dewatering

Effectiveness – Reducing the quantity of water in tailings can decrease the industry liability (BGC Engineering, 2010). With a lower water content, there is less movement in the tailings which increases the stability of a pond. Regarding the risk of pond failures, this option both decreases the likelihood of a failure occurring and decreases the severity of any consequences in the case that a failure does occur. It therefore ranks high (3).

Security/protection –In the chance of a failure, this option decreases the severity of the consequences to public safety, human health, and infrastructure. Higher density tailings would travel at slower speeds and not go as far as tailings with a high water content, which is the case of the status quo. This option therefore ranks high (3) for this measure.

Sustainability – With the status quo, the potential for movement in the tailings is high. By limiting the movement of the tailings (both while contained and if spilled) this decreases the level of potential interaction between the tailings and the environment. For this reason, this option ranks high (3) for this measure.

For the second measure of sustainability, the option's ability to restore the environment to pre-failure conditions is good. Dewatered tailings can have major advantages in terms of land reclamation (BGC Engineering, 2010). Less area of the environment is likely to be touched by the dewatered tailings which suggests that more landscape could be readily restored. It is easier to clean up solid waste in comparison to liquid waste that seeps into the ground and absorbs more easily. This option therefore scores high (3).

Cost – This option requires significant amounts of financial commitment from individual oil sands companies. To dewater the tailings regardless of which method of is chosen, physical capital, such as new equipment and updated infrastructure for this advanced technology, is needed. Employing new personnel required to operate the new technologies is also needed. The commercial implementation of this option can cost hundreds of millions of dollars (BGC Engineering, 2010). Relative to the other options, dewatering the tailings is the most costly and as a result, it ranks low (1).

Stakeholder acceptability – This option requires substantial amounts of effort and time as it will take individual companies several years (at least a 40% increase in the company's cumulative hours worked) to fully implement. It requires notable shifts in current methods of operation so employees will need training on new techniques. Given these necessary conditions to adopt tailings dewatering across all oil sands companies, this option will be met with considerable resistance from the companies. Therefore, this option ranks as low (1).

With all oil sands companies required to reduce the water in tailings, this will become an industry standard. While this option does not require a direct increase of publicly available information, it does promote awareness across industry, government, and the public of the expected practices. Hence, local residents will expect these practices to be common and generate an increase in awareness. This option thus ranks medium (2) in terms of transparency.

11.2. Policy Option 2: Risk Assessment and Hazard Identification System

Effectiveness – By establishing a new framework to plan, evaluate, and assess the hazards of a given pond at every stage of operation this dramatically decreases the probability of a failure (Government of Western Australia, 2013). Given the requirement to establish the level of risk for each pond and a set of procedures for maintaining the safe operation, the likelihood of a failure decreased and the level of preparedness for dealing with the consequences increases. This option therefore ranks high (3).

Security/protection – This option will have some positive impact on decreasing the severity of the consequences on public safety, human health, and infrastructure. The main focus of this option is however directed at preventative measures (Joint Expert Group on Water and Industrial Accidents, 2008), and less so on emergency preparedness and therefore ranks medium (2).

Sustainability – By identifying possible waterways, lands, and ecosystems that could be affected by a pond failure, efforts to promote sustainability can be successful (Joint Expert Group on Water and Industrial Accidents, 2008). It is difficult however, to assess whether or not in practice this would be accomplished until after a failure has occurred. Due to the uncertainty in the actual outcome, this option ranks medium (2).

For the option's ability to restore the environment to pre-failure conditions, this would depend on the level to which an emergency preparedness component was included into the system. Given that the focus is primarily on prevention this option ranks medium (2).

Cost – This option needs a team to develop the initial strategy and make any adjustments over time. It also requires the hiring of addition personnel and outside agencies to perform the increased level of inspection, monitoring, and reporting.

Physical capital costs could be needed overtime as a result of recommended changes or mandated repairs as per inspection specifications. It does not however require initial physical capital costs and therefore ranks as medium (2).

Stakeholder acceptability – By incorporating more rigid protocols there will be increased responsibilities among employees with a need for training in the new techniques. The hiring of new employees for the addition of new responsibilities will also be required. Working more frequently with outside agencies and the implementing the additional steps into daily operations will entail at least 30% more cumulative hours worked and thus ranks as medium (2).

Given that the option requires increased frequency of inspection and reporting along with greater levels of information available to employees, regulators and the public, transparency will increase. Local residents of nearby communities should experience a large increase in awareness surrounding the operations of tailings ponds therefore this option ranks high (3).

11.3. Policy Option 3: Publicly Available Emergency Response Plans

Effectiveness – There are two components to mitigating the risk of a failure: the first is decreasing the likelihood of a failure occurring and the second is decreasing the severity of the consequences. While this option is not aimed at preventative measures, it does address the consequences and therefore ranks medium (2).

Security/protection – The presence of emergency response plans are critical in preventing harm to communities and people (United Nations Environment Programme, 2001). With the aim of decreasing the severity of the impacts of a failure on public safety, human health and infrastructure this option does very well and therefore this option ranks high (3).

Sustainability – To protect the integrity of the environment and reduce the magnitude of the impacts of a failure (United Nations Environment Programme, 2001), this option aims to reduce the level of interaction between the tailings and environment. Similarly to option 2 however, it is difficult to say with certainty whether or not it will be successful. Presuming an emergency response plan does accomplish its goal, it would rank high (3).

The second measure can be analyzed more adequately in that an emergency response plan includes a major component focused on the restoration and rehabilitation of the surrounding environments in the case of a failure. As such, the option ranks high (3) for this measure.

Cost – This option requires the least amount for operational costs relative to the status quo. It requires the personnel to develop and implement an emergency response plan. Periodic testing of the plan will need to be done which also requires either additional personnel or increased hours of operation for existing employees. No physical capital costs are required and so this option ranks high (3).

Stakeholder acceptability – This option requires similar adjustments to option 2 such as the training of employees in new techniques and procedures but has far less change to daily operations, it does not require as high a level of collaboration with outside agencies, and few new employees will be needed which cuts down on the number of hours needed to be implemented. Given these differences this option will be met with minimal resistance by oil sands companies and ranks high (3).

The capacity to respond to an unanticipated failure is an asset to a tailings management strategy. With well informed citizens and communities prepared for a pond failure there is a better chance of adequately dealing with an emergency (Emery, 2005). The requirement of the emergency response plan to be transparent and publicly available will by definition increase the transparency surrounding tailings management. The nearby communities must be made aware of the emergency response plans in case there is a need to react. The option therefore ranks high (3).

11.4. Policy Option Evaluation Results

Table 5. Policy Option Evaluation Results

Criteria	Tailings Dewatering	Risk Assessment/ Hazard Identification	Emergency Response Plan
Effectiveness	**3**	**3**	**2**
Mitigation of pond failures	High (3)	High (3)	Medium (2)
Security/ Protection	**3**	**2**	**3**
Preventing harm to communities and people	High (3)	Medium (2)	High (3)
Sustainability	**3**	**2**	**3**
Promote sustainability of environments	High (3)	Medium (2)	High (3)
	High (3)	Medium (2)	High (3)
Cost	**1**	**2**	**3**
Operational costs	Low (1)	Medium (2)	High (3)
Stakeholder Acceptability	**1.5**	**2.5**	**3**
Level of resistance from oil sands companies	Low (1)	Medium (2)	High (3)
Level of awareness with local residents of nearby communities	Medium (2)	High (3)	High (3)
Total Score	**11.5**	**11.5**	**14**

Note: High=3=best, Medium=2=good, Low=1=less good

12.

Recommendations

The analysis of the policy options shows that the emergency response plan has the highest cumulative score and is thus the most favorable option. This option represents the policy that achieves the best balance between effectively mitigating the risk of a tailings pond failure and of having relatively low costs along with high stakeholder acceptability. If only one option can be implemented at this time, the recommendation is to adopt emergency response planning. This policy will make a positive difference in reducing the negative environmental impact of ponds and increase the likelihood of successful cleanup, restoration, and reclamation of surrounding areas. It requires the least costs, encounters the least amount of resistance from companies and promotes high levels of community awareness.

The analysis uncovers the challenge in trade-offs between a policy that may meet the criteria of effectiveness, security and protection and sustainability yet either be costly or not do well from the perspective of stakeholder acceptability. While tailings dewatering and a risk assessment and hazard identification system are more costly and require more time and effort to be implemented, they would both do very well in meeting the need of improving tailings management in Alberta and of mitigating the risk of pond failure in the oil sands.

As such, if it is feasible to implement more than one option, it is highly recommended that all three options be implemented as a multi-policy solution. In the short term, emergency response plans need to be implemented as soon as possible and be fully incorporated at all tailings pond sites. Establishing risk assessment and hazard identification systems at all existing ponds should be done in the medium term along with being incorporated into the design plans of any new ponds. The long term objective is to transition all oil sands companies over to methods of dewatered tailings and ensure that all future operations utilize dewatered tailings right from the start of a project. Together, the three policies can more effectively address the complex reality of tailings management than one policy can on its own.

13.

Concluding Remarks and Suggested Next Steps

With a thriving natural resource industry, Alberta, Canada must prioritize policies that enhance the safety and sustainability of industry practices. Having a prosperous and growing oil and gas sector, the industry is a major contributor to provincial economic growth, level of employment and the existence of a high standard of living amongst residents. Alberta is the third largest source of oil in the world and one of the few major deposits of oil sands found anywhere. The current predominant method of mining for extracting the oil leads to the necessity of disposing of and storing the tailings waste. The ponds filled with toxic, undesirable leftovers from the extraction process represent a serious threat to the environment, communities, and nearby infrastructure.

This essay therefore focuses on the negative impacts of tailings ponds, specifically those associated with a pond failure. A literature review, case studies analysis, and a survey of international documents on industry standards and best practices establish some of the causes of pond failures, the consequences of a failure, and the ways of mitigating the risk.

The three cases on Western Australia, Australia; the United Kingdom; and Arizona, USA contribute to identifying three key sub-categories of successfully managing tailings ponds: the stability and security of a pond's location and construction, utilizing risk assessment and hazard identifications, and having an emergency response plan. The secondary methodology confirms that these sub-categories are best practices encouraged internationally. Three policy options are generated from these results and evaluated based on how well they meet the objectives of five criteria.

Two recommendations are made. The first recommendation is for the policy of emergency response plans that scored the highest in the analysis. If only one policy can be feasibly implemented in Alberta at this time then an emergency response plan should be selected. This policy best achieves the balance between reducing the risk of pond failure and improving security and sustainability while also taking into account cost constraints and stakeholder acceptance. Both tailings dewatering and a risk assessment and hazard identification system meet the requirements of the first three criteria but fall short when looking at cost and stakeholder acceptability.

If more than one option can be feasibly adopted, the second recommendation is to implement all three options. The success of Alberta's tailings management will be most effectively enhanced by using a multi-policy solution given that the three options are not mutually exclusive but rather complementary to one another. Mitigating the risk of a pond failure in the future will have the greatest likelihood of success if all three policies are put into regulation. Mandatory dewatered tailings, risk assessment and hazard identification systems along with publicly available emergency response plans are recommended as key additions to the current tailings management strategies in Alberta.

Future considerations

This essay offers a framework from which to build off of in establishing future policies in Alberta. As stated in chapter 9, empirical values for all criteria were not included in this research as a result of time constraints and limited primary expert resources. Future work on the subject should therefore determine specific quantitative benchmarks for each measure. Other limitations in this research included challenges with the scope of the issue. Tailings pond failures present numerous other negative environmental impacts beyond those that were discussed here. Furthermore, there are other viable policy options that should be taken into consideration as well. Resolving the complex problems associated with tailings ponds goes beyond a one policy solution and future work requires expertise from not only policy analysts but also from engineers and professionals in science-based and technical fields.

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