March 28, 2012

Dear Community Partner,

On behalf of the UBC Department of Chemical and Biological Engineering, we would like to thank you for participating in this Community Service Learning (CSL) partnership. We are very excited about the CSL project(s) happening with your organization.

As explained in our earlier conversations, the UBC students will provide services at no charge to and for the benefit of your organization to solve engineering-related problems related to their course CHBE 480 Hazardous Waste Processing Technology and faced by their community group. These projects challenge them to apply their knowledge and skills to real world problems and to gain new skill sets in the process.

The students have a wide range of backgrounds and bring a great deal of enthusiasm to their CSL activities. However, as they are still learning fundamental engineering concepts, they typically have limited practical experience. Consequently, they are not yet qualified to provide guidance or advice on any decisions that would otherwise require approval by a professional engineer, nor can they be expected to be held responsible for their work. Where applicable, you must seek a competent individual to carry out a review of the work performed. Furthermore, by taking them on, we require that you assume full responsibility for all liabilities arising from the activities performed by the students on your behalf.

Should you have any questions or concerns about risk management for the projects, please contact Alaya Boisvert, CSL Coordinator in the Faculty of Applied Science at alaya.boisvert@ubc.ca or 604-822-0493.

Thank you for sharing in the important job of educating the students. We are grateful for your ongoing support and look forward to building upon a lasting partnership!

Sincerely,

Peter Englezos, Professor and Head
Department of Chemical and Biological Engineering UBC
University of British Columbia
To: The Comox Valley Community
Mr. John Synder
Mrs. Lynne Wheeler
Mr. Jim Burgess
Instructors: Dr. R.J. Petrell,

This document was produced by: Mr. A. Alabbas | 19195072 | anwaralabbas@gmail.com
Mr. A. Lee | 91380071 | lee.andrewd@gmail.com
Ms. A. Arunan | 64957111 | busted_rulz@hotmail.com
Ms. G. Feyz | 70871116 | ghazal.feyz@hotmail.com
Mr. B. Leung | 68757087 | b.hw.leung@gmail.com

VANCOUVER HAWKS

CSL ANALYSIS PROJECT

“Analysis of the Raven Coal Mine”
Executive Summary

This report provides an analysis of key environmental, economic and public health effects of the proposed Raven Underground Coal Mine development near the Cowie Creek water shed in Fanny Bay, British Columbia. It discusses possible mitigation, treatment and remediation options in relation to the leachate that may be generated from the vast quantities of reject piles that will be stored on surface, during and after the mining operation. The Raven Underground Coal Mine project is proposed by Compliance Coal Corporation/ Comox Joint Venture (CJV) and is expected to produce approximately 30 Mt of run-of-mine (ROM) coal (an estimated 13 Mt is clean coal) over its 16 year life (AMEC, 2010). Mining operations are expected to generate 1.08 million tonnes of waste coal or reject material annually. The proposed mine site lies on the Cowie Creek water shed and is only 5km away from Baynes Sound, a water channel actively harvested by the local shellfish farmers.

In order to systemically assess the potential impacts of the Raven Coal Mine, several key stakeholders had been identified. These stakeholders include, the residents living near the proposed mine site and/or rely on the Cowie Creek water shed as a source for drinking water, potential Raven coal mine employees, the shellfish farmers harvesting bivalves from Baynes Sound and the Fanny Bay Water Works (FBWW). Once the stakeholders had been identified, hypotheses on the potential impacts on these stakeholders were made. Subsequently data from a wide-ranging number of sources [e.g. research papers on Acid Mine Drainage (AMD)] generated from wastes from other coal mines, laboratory analysis of shellfish tissue samples from waste piles in Union Bay suspected to be generating AMD and historical data and correspondences between the FBWW and other parties in relation industrial activities in the Cowie Creek water shed and their effect on quality and safety of the drinking water. The Quinsam mine hires 140 people directly according to a BC government news release. From this case study and other relevant sources on employment, a critical analysis of Raven Coal’s employment projections is conducted.

The review of past studies on composition of coal waste piles indicated that most coal reject piles had acid-bearing material in the form of pyrite (FeS₂), which is able to react with air and rain water when exposed to them on the surface. The liquid runoff from the waste piles are acidic due to the generation of sulphuric acid and this in turn promotes leaching of toxic heavy metals such as arsenic, cadmium, chromium, copper, lead, mercury, selenium and zinc from the waste piles. These dissolved contaminants are transported away and discharged elsewhere. Laboratory analysis of shellfish (clams and oysters) tissue found near the site of an historic waste coal pile occupying approximately 13 hectares of leased Crown Land in Union Bay, B.C. found elevated levels of Iron, Cadmium, Arsenic and Copper suggesting the possibility of transportation of heavy metal contaminants from waste coal piles to nearby locations. The employment claims made by Compliance Coal could not be confirmed but are suspected to be inflated due to comparable coal mining operations on Vancouver Island (specifically, the Quinsam mine). The evidence of inflation stems from misdirection. The concept of employment is skewed in order to provide the perception of job gain in the community, and the jobs include construction and infrastructure development that will not last the entire duration of the mine life.
The findings of the report and the evidences presented largely suggest that the mining operation has a strong potential to have adverse effects on the environment (e.g. alterations to surface waters, its associated ecosystems and ground water), the local Shellfish industry and public health if care is not taken to manage the mining processes in a manner that mitigates these adverse impacts. While a substantial amount of information is already available regarding the proposed mine and its potential impacts, the number of papers with all the research information consolidated in an easy-to-read manner remains few. The prospect of employment is skewed and not completely transparent. Given that it is being used as leverage for the project approval, these claims ought to be exposed or elaborated. Thus, it is hoped that the report would provide the resources needed for the public to deepen their understanding and awareness of the proposed Raven Coal Mine development and its implications.

To provide the community with recommendations from our perspective, the Prosperity Mine was selected as a case study. This rejected mine proposal provided a key insight into which processes lead to a rejection. The recommendations are i) to continue to pursue a joint federal-provincial review panel, ii) to involve academia to support claims of environmental risk, iii) to gain the trust of more community members and iv) to cultivate support from environmental interest groups.

If the mine proposal is accepted, recommendations have been developed on how to mitigate the environmental impacts. The recommendations include i) air quality mitigation measures, ii) water resources mitigation measures and iii) socioeconomic mitigation measures.

This conclusions and recommendations proposed in this report have been made after considerable thought and analysis of the information that had been available at the time of writing. While the authors of this report stand by the conclusions and recommendations made in this report, certain limitations of the report have to be also acknowledged. At the time of writing, information with regards to the coal composition and its acid-bearing potential has not been released by Compliance Coal as the assessment is still ongoing. Thus, it is difficult to predict the possibility and the extent of acid mine drainage with accuracy.
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1. Introduction

The authors decided to do a community service learning project on the proposed Raven coal mine by Compliance Coal. Initial and continued interest was sparked because the project was very close to the approval or rejection phase based on the environmental assessment.

By learning about the characterization of hazards, environmental assessments, hazardous waste treatment methods, and remediation throughout the industrial waste course, CHBE 480, the team was equipped with the necessary knowledge to address a real world case study. Initial research about the mine proposal produced many reports and comments from the mining company and its associated consulting firms. It was apparent that the project scope needed to be specified along with the interest stakeholders.

By visiting selected community members of the Comox Valley of Vancouver Island, the opposing side of the positive economic benefits boasted by Compliance Coal came into question. Certainly, the key stakeholders identified were the Comox Valley Community, Compliance Joint Venture, neighboring First Nations, and governmental structures. The problem statement and goals needed yet to be clearly decided upon.

2. Problem Formulation

The issues chosen were based on the social, economic, and environmental impacts of the proposed mine. Public health, employment, and habitat conservation were specifically chosen as major themes. The approval, or rejection, of the proposed mine was studied to see if significant concerns were found on the major themes.

2.1. Background

The proposed Raven coal mine will produce steel-making quality coal for Asian markets and will be based near the Buckley Bay terminal. The Compliance Joint Venture formed by the Raven Underground Coal project and Compliance Coal Corporation is the production company. They have indicated that 200 construction jobs and 350 full time mine, port, and transportation jobs will be created in the local area. The exact job title and responsibilities were not found after intensive research.

Local residents are somewhat divided about the proposed mine. Some support the plan and hope it will bring better jobs and ultimately a better standard of living. Conversely, some residents do not support the proposal because details about the environmental, social, and economic benefits are not specifically explained by the company.

It should be noted that the key selling point of project proposal is that it will create local jobs. With a life span of only 16 years, the mine will not even last long enough to stability support a standard mortgage loan. The number of out of town workers was also not indicated and is in question by the community. Issues were also raised about the impact of metal contamination in the Vancouver Island estuary that is used for shellfish farming.
2.2. Stakeholders

To provide an assessment that carries significance, it is important to first identify the affected parties. The term “stakeholder” refers to any such party, consisting of an individual or group of individuals, who would be affected by the assessed event. There are no requirements with regards to stakeholders, as long as the party is affected in some fashion the party is automatically a stakeholder. Consequently situations can form where stakeholders may not voice their opinion on an event, or may not be aware that they are being affected.

The nature and scope of this study yields a large number of stakeholders. Some stakeholders are split into groups to accurately address the impact upon each group. There are four principal stakeholder groups, including the Comox Valley Community, the Compliance Joint Venture, the First Nations within the region, and the Government. Amongst these, the Comox Valley Community and the Government are split into three sub categories each.

2.2.1. Comox Valley Community

The Comox Valley Community is extremely large in scope and to accurately address each stakeholder group’s concerns they have been organized into three separate groups. The residents of the Comox Valley region form one group. The British Columbia Shellfish Growers Association operating within the area form another group. Finally, the local contractors and potential employees at the Raven Coal Mine form another group.

2.2.1.1. Comox Valley Residents

The implementation of the Raven Coal Mine presents multiple issues to the residents of the Comox Valley Community. In the report published by AMEC for the Compliance Joint Venture, there are numerous concerns regarding the presence of impact on the aquatic environment, the terrestrial environment as well as the social aspects affected. The report recognizes that within the tributary system leading into Cowie Creek as well as the Baynes Sound area, there would be a potential issue of water quality degradation, aquatic species health effects, and subsequently a health effect on all species dependent on the aquatic life-forms present. These are all factors of concern for the residents of Comox Valley.

Table 1: Population Projection of Comox Valley

<table>
<thead>
<tr>
<th>Year</th>
<th>0-4</th>
<th>17-May</th>
<th>18-24</th>
<th>25-44</th>
<th>45-64</th>
<th>65+</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986</td>
<td>2,834</td>
<td>7,309</td>
<td>3,747</td>
<td>12,210</td>
<td>8,248</td>
<td>4,456</td>
<td>38,804</td>
</tr>
<tr>
<td>1991</td>
<td>3,143</td>
<td>8,591</td>
<td>3,228</td>
<td>14,502</td>
<td>10,095</td>
<td>6,090</td>
<td>45,649</td>
</tr>
<tr>
<td>1996</td>
<td>3,519</td>
<td>10,952</td>
<td>4,042</td>
<td>17,551</td>
<td>13,415</td>
<td>7,434</td>
<td>56,913</td>
</tr>
<tr>
<td>2001</td>
<td>2,732</td>
<td>10,616</td>
<td>5,075</td>
<td>15,064</td>
<td>15,241</td>
<td>8,999</td>
<td>57,727</td>
</tr>
<tr>
<td>2006</td>
<td>2,598</td>
<td>9,892</td>
<td>6,476</td>
<td>15,084</td>
<td>18,346</td>
<td>10,365</td>
<td>62,761</td>
</tr>
<tr>
<td>2011</td>
<td>3,184</td>
<td>9,164</td>
<td>6,217</td>
<td>16,909</td>
<td>21,154</td>
<td>11,754</td>
<td>68,382</td>
</tr>
<tr>
<td>2016</td>
<td>3,715</td>
<td>9,434</td>
<td>5,618</td>
<td>19,476</td>
<td>21,789</td>
<td>13,832</td>
<td>73,864</td>
</tr>
<tr>
<td>2021</td>
<td>3,980</td>
<td>10,600</td>
<td>5,137</td>
<td>21,603</td>
<td>21,820</td>
<td>16,318</td>
<td>79,458</td>
</tr>
<tr>
<td>2026</td>
<td>3,997</td>
<td>11,793</td>
<td>5,283</td>
<td>21,870</td>
<td>22,537</td>
<td>19,074</td>
<td>84,554</td>
</tr>
<tr>
<td>2031</td>
<td>3,944</td>
<td>12,341</td>
<td>6,077</td>
<td>20,863</td>
<td>24,357</td>
<td>21,523</td>
<td>89,105</td>
</tr>
</tbody>
</table>
Table 2: Population Distribution of Courtenay

<table>
<thead>
<tr>
<th>Population and dwelling counts</th>
<th>Courtenay, CY</th>
<th>British Columbia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population in 2011 1</td>
<td>24,099</td>
<td>4,400,037</td>
</tr>
<tr>
<td>Population in 2006 1</td>
<td>22,021 1</td>
<td>4,113,487 1</td>
</tr>
<tr>
<td>2006 to 2011 population change (%)</td>
<td>9.4</td>
<td>7.0</td>
</tr>
<tr>
<td>Total private dwellings 2</td>
<td>11,377</td>
<td>1,945,365</td>
</tr>
<tr>
<td>Private dwellings occupied by usual residents 2</td>
<td>10,089</td>
<td>1,764,637</td>
</tr>
<tr>
<td>Population density per square kilometre</td>
<td>820.2</td>
<td>4.8</td>
</tr>
<tr>
<td>Land area (square km)</td>
<td>29.38</td>
<td>922,509.26</td>
</tr>
</tbody>
</table>

According to the AMEC report compilation, the Comox Valley regional district supported a population of approximately 59000 individuals (Tapics ,2011). The latest census results conclude that the population in Comox Valley in 2011 had increased to 63538 individuals, signifying a 6.8% increase in population growth. Both the towns of Comox and Courtney experienced larger rates of population growth at 10% and 9.4% respectively. (Statistics Canada, 2011) With the population increasing over time, any significant change in the lifestyle or health will consequently possess a much more significant effect.

Figure 1: Population Change Projections (45 year basis)

The results from a demographics article put forth by the regional government indicate that a significant proportion of the population is composed of retirees and seniors. The amount of residents above the age of 45 is expected to increase dramatically over the next 20 years (BC Stats P.E.O.P.L.E. Run 31, 2006). Of the expected 45000~ residents who would be in the age bracket of 45+ by that time, nearly 50% (21523 citizens) will be in the age group of 65+. The expected total population at that time would be 89105 residents. Therefore, the amount of seniors would amount to nearly a quarter of the total population. For members of this age group, the environment is a major factor of concern as is personal health.
2.2.1.2. British Columbia Shellfish Growers Association

Another major stakeholder is the presence of the British Columbia Shellfish Growers Association, which uses Baynes Sound to operate oyster farms. The oyster industry employs an extensive amount of individuals from the Comox Valley region, providing the region with one of its main resources and industry. The industry is dependent upon the presence of oysters, which are extremely sensitive to changes in the water quality.

Consequently if the water in the Baynes Sound was contaminated by any foreign source, the oyster industry would be negatively impacted. As oysters filter feed to sustain themselves, the presence of any foreign contaminants will accumulate within the oyster itself. Over time, the amount of contaminants within the oyster will accumulate until it becomes a hazard. The British Columbia Shellfish Growers Association is especially concerned with the cadmium content in oysters. The presence of cadmium makes the ingestion of oysters a hazardous activity, as bioaccumulation in the human body leads to symptoms developing in the bone and kidney.
2.2.1.3. Local Contractors and Potential Employees

The third party at stake from the community contains the residents who are interested in the possibility of employment at the Raven Coal Mine. The Compliance Joint Venture has stated that it will make jobs present to the community. Employment at the Raven Coal Mine could potentially provide more industrial opportunities, providing the industrial stimulation to the community.

2.2.2. Compliance Joint Venture

The Compliance Joint Venture represents the individuals behind the Compliance Coal Corporation and interested foreign parties. Each individual possesses an ownership percentage in the Raven property, with Compliance Coal Corporation owning a majority of 60%, I-Comox Coal Incorporated owning 20% and LG International Investment Limited owning 20%. (Tapics, 2011) These three companies together form the Compliance Joint Venture which was instrumental in both proposing and supporting the Raven Coal Mine Venture. The objective behind the Raven Coal Mine Venture is to exploit the underground coal reserves which Compliance Joint
Venture identified. In establishing the Raven Coal Mine, Compliance Joint Venture seeks to generate revenue with coal exports while stimulating the local economy by providing economic opportunities.

At the time of writing, the Raven Coal Mine implementation has already complied with the BC Environmental Assessment Act in holding a public forum to debate the concerns regarding the mine, as well as publishing a project description report via AMEC Earth and Environmental. In compliance with the Environmental Assessment Act, the Raven Coal Mine project is now at a phase where it is awaiting review by the federal board.

If the venture was found to be questionable with regards to its environmental impact, the Compliance Joint Venture would be forced to revise its proposed operations to account for these additional impacts and the project would be postponed. At this point, the judgment falls upon the federal officials.

If the venture is found to be environmentally safe, then the implementation would go on as planned. Naturally, if the project is found to be hazardous at any point on social or environmental aspects, the resulting re-assessment would equate to large economic and social losses on the Compliance Joint Venture’s behalf.

2.2.3. First Nations

The AMEC report indicates that at least fourteen First Nations could be potentially affected by the implementation of the Raven Coal Mine. Though each of these First Nations parties is an individual stakeholder, only the K’omoks First Nation has openly voiced opposition to the mine implementation. This opposition was voiced in July of 2011 on the grounds that the rights of the First Nation relative to the mine implementation were not considered, and that there was a reason to suspect that the mine implementation would openly affect both the environment and the right to land usage of the K’omoks people (Gaiga, 2011).

2.2.4. Government

There are three government levels involved with the implementation of the Raven Coal Mine. The project must seek the approval from both the federal and provincial levels of government before the implementation is allowed to proceed. In addition, the land usage rights are under the provincial jurisdiction. The provincial jurisdiction extends to the environmental laws which are in effect, limiting the operations of the Raven Coal Mine to a certain extent.

The municipal government is involved with the management of the waterworks system present in the cities in the Comox Valley. If any groundwater contamination were to occur which would affect the water aquifers feeding the water supply, then the municipal government would be responsible for organizing the remediation. There has been a past history regarding the damage of the waterworks system due to the implementation and use of
the highway and even older industrial activity. This impacts both the municipal government as well as the provincial government.

Via consultation with a trustee of the Fanny Bay Water Works (FBWW), it was established that there is a direct causal relationship between implementing industrial activities and negative impacts upon the water works network. In addition to this, the trustee indicated that past inquiries and claims were also largely ineffective in addressing the real issue at hand.

3. Specifications, Development & Scope

3.1. Spatial Boundaries

The entire property utilized by the Compliance Joint Venture for use in the Raven Coal Mine is approximately 3200 hectares in area. While the Raven Coal Mine project itself is planned to be located far away from any residential zones, the project area is close to communities in both Fanny Bay and Buckley Bay. The underground mining sites, as shown in Figure 4, extend beneath the Cowie Creek, Tsable River, and numerous other water routes connecting to Baynes Sound. In comparison to the Raven Coal Mine site, the city of Courtney is slightly smaller land wise at 29.38 km\(^2\) versus the 32 km\(^2\) of the mine site.

![Figure 4: Underground Mine Site Schematic](image-url)
The majority of the region which spans the Raven Coal Mine area is described to be hilly with swamps. Several major rivers run through the area, forming a region with a large abundance of wildlife. Multiple groundwater well sites exist along the Tsable River and Wilfred Creek. The AMEC report indicates that the majority of the groundwater wells are used domestically, indicating that any contamination will immediately affect residents in the local area.

![Figure 5: Groundwater Well Locations](image)

As the majority of the mine is underground, the area above ground will be utilized primarily for office space and the processing site facility. Transport will occur in and out of the facility, which will require the establishment of a transport system into the facility. Additionally, storage facilities are required for the materials necessary in the processing. Surface facilities supporting the underground mine shaft includes the waste water systems, water supply systems, ventilation outlets, and drainage control.
In the environmental considerations, the environmental assessment strategy which AMEC adopted for the report indicates the presence of a LSA (Local Study Area) and RSA (Regional Study Area). Both the aquatic and terrestrial LSA cover the Tsable River region; whereas the RSA for both the aquatic and terrestrial study include the Fanny Bay region (Tapics, 2011). Both of these water bodies are major concerns for environmental assessment.

3.2. Temporal Boundaries

Analyzing temporal boundaries considers the effect of implementing the mine over time. The AMEC report indicates that environmental changes are expected over time. To transport the coal out of the mine extra trucks will be necessary for transport and the additional trucks will contribute to changes in air quality. More prominently
however, the presence of methane in the mine will mean drastic changes in air quality. In order to facilitate shipping, the harbor of Port Alberni will require dredging to create a port deep enough to handle the coal freighters.

The water quality is also expected to change, which will affect the fauna and flora in the local region. Though the AMEC report indicates that the mine water will be treated “to the extent practical” and a water management plan will be developed, the specific details of the plan and the quality limits are not specified (Tapics, 2011). In order to reduce the impact on the water system, AMEC proposes to “mass mine infrastructure into the Cowie watershed”. Cowie Creek empties into Fanny Bay, located directly adjacent to intertidal shellfish farms. If contamination occurs in Cowie Creek, there will be a significant effect on these shellfish farms.

<table>
<thead>
<tr>
<th>Table 3: Wildlife Species at Risk in Comox Valley</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Species</th>
<th>SARA</th>
<th>Red-listed</th>
<th>Blue-listed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roosevelt Elk</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Shrew (Brookl. spp)</td>
<td>X</td>
<td>not observed</td>
<td></td>
</tr>
<tr>
<td>Purple Martin</td>
<td></td>
<td>observed flying over LSA; not nesting</td>
<td></td>
</tr>
<tr>
<td>Band-tailed Pigeon</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red-legged Frog</td>
<td>Special Concern Schedule 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Western Tattie</td>
<td>Special Concern Schedule 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pacific Sideband Snail</td>
<td></td>
<td>observed in LSA</td>
<td></td>
</tr>
<tr>
<td>Coastal Cutthroat Trout</td>
<td></td>
<td>observed in LSA</td>
<td></td>
</tr>
</tbody>
</table>

Note: LSA: Local Study Area; RSA: Regional Study Area; SARA: Species at Risk Act

At the end of the mine’s expected lifetime, AMEC proposes reclamation of the land by planting a new tree cover which would be compatible with timber harvest standards currently in place on Vancouver island. There will be coal reject piles, which AMEC proposes to leave on site and stabilize where necessary. For the period of time it is required to treat the coal reject piles through settling ponds, the area will remain unusable. Due to the nature of the settling ponds, the ponds will contain the majority of the toxins and be a hazard to local wildlife.

3.3. Intended Use and Goals

This report is intended to act as a tool for the general public to understand the details in regards to the Raven Coal Mine implementation project. Despite the substantial amount of information present in media sources, the amount of consolidated information remains sparse. This report aims to consolidate the information distributed in a fashion which can increase both awareness and understanding in the general public.

This report will qualitatively describe the effects of the mine implementation. As information with regards to the coal quality and composition has not been released it is difficult to predict the full extent of effects. The temporal effects after the mine lifespan can be approximated based upon the proposed mitigation plans in treating the air, water and soil. This report will also address the major concerns of the stakeholders with regards to the effect of the mine implementation on safety, the shellfish market, and the health of the residents.
The report will also quantitatively assess the likelihood of propagating this information throughout the community. Ultimately, the residents and other stakeholders are not expected to be the individuals who will actively change the mine implementation. After the mine lifespan, the Compliance Coal Corporation will be expected to perform the remediation process. It is important for the residents to understand the full effect of remediation as well as the overall effects of the mine during implementation and operation. Consequently, this report will include a portion to explain the process of distributing this information. This aligns with the intended use of this report to raise awareness.

4. Conceptual Design - Society, Economy, and Environment

When determining the important consideration themes assessing the proposed effect of the mine, the societal, economic, and environmental themes were chosen because they encapsulated the necessary impacting factors.

![Conceptual Design Diagram](image)

**Figure 8**: Conceptual Development Diagram
4.1. Public Health

Public health is a scientific discipline focused on the prevention of disease threats and health promotion of human populations. In the context of the Raven site, public health is a very important issue to the residents of CVRD.

4.1.1. Drinking Water

Drinking water is a source of water that is healthy and pure enough for consumption by human populations with low risks of short or long term harm. A water supply system, according to the Drinking Water Protection Act is defined as two or more ‘hook-ups’ to a water source. If these systems supply water to the public, “they must adhere to the standards outlined in the Drinking Water Protection Act” (Jenssen, 2007). In the Comox Valley, drinking water is sourced mostly from surface water reservoirs. These reservoirs include six lakes (Comox, Allen, Henderson, Langley, Graham and Chickadee), the Oyster River, Cowie Creek and Wilfred Creek. In addition to surface water sources, there is some reliance on groundwater via private domestic wells for drinking water (Jenssen, 2007).

The Raven Coal Mine will be discharging mostly into the Cowie Cowie Creek watershed, and partly into the Tsable River watershed. Two source wells exist in Cowie Creek that supplies Fanny Bay Waterworks with over 73 hook-ups to residents and businesses. The area provided includes the Tsable River south to Ship’s Point Improvement District (SPID) (Jenssen, 2007). The SPID sources water from three groundwater wells provided by the areas including and surrounding Wilfred Creek. The trustees of the SPID are very concerned about mine development and its affect on the quality and quantity of the water supply. They outlined nine major concerns that I have summarized below (SPID, 2011):

1. There must be a requirement for comprehensive aquifer mapping to investigate the interaction between surface and groundwater.
2. There must be unbiased source of expertise from a join federal/provincial independent expert review panel.
3. There must be baseline information on quality of both surface and groundwater including all possible contaminants.
4. There must be confirmation that surface water discharge from the Raven site will meet Canadian Drinking Water standards.
5. There must be a thorough understanding of the liability process to seek remedy in the event of a deleterious effect on the water supply.
6. There must be a comprehensive description of the water processing design of the Raven facilities.
7. There must be an explicit definition of the external monitoring regime.
8. There must be a highly secured performance bond.
9. There must be a true evaluation of the economic value of the mine in the context of the risks.
These demands, while in the context of drinking water, are quite poignant and address not only the affect on drinking water but questions the economic efficacy of the mine itself. The SPID has been operating for over forty years, and has earned the trust of the community to protect the drinking water supply. However, currently the SPID only treats the drinking water with chlorine. Even then, the chlorine treatment is less than standards due to the pristine nature of the water supply. If the water quality or quantity was compromised, treatment systems would need to be designed or water would have to be sourced from over 25 kilometres north (SPID, 2011). Furthermore, the SPID is only one of the potential areas of concern. Since the SPID is drawing water from sources nearby the Fanny Bay Waterworks wells (Jenssen, 2007), these major concerns must be shared among the water distribution systems in the Comox Valley Regional District (CVRD).

4.1.1.1. Aquifers

An aquifer is a geologic formation, group of formations or part of a formation containing enough saturated permeable material to produce significant amounts of water to wells and springs (Humphrey, 2000). The BC Aquifer classification system was established to help advise local communities in decisionmaking that involves groundwater resources (Humphrey, 2000). As well as identification, the classification system aims to determine the vulnerability of each aquifer in the region. After careful examination of the qualitative delineations provided by the classification system, two aquifers were identified as the most likely to be affected by groundwater contamination. Aquifer 414, “Rosewall Creek”, is located just south of Fanny Bay and has a large yield. Based on surficial geology and sediment observations, Aquifer 414 is deemed as vulnerable to contamination. The second Aquifer pertaining to the Raven site is Aquifer 419, “Wilfred Creek”. It is enclosed by the Wilfred Creek valley and flows into Baynes Sound just south of Ships Peninsula. Aquifer 419 yields large volumes of water with four large capacity wells in the vicinity. Given the sediment content in the geology reports, this aquifer is classified as moderately vulnerable to contamination. Additional aquifer locations are explored, including one possible location at Ships Point and if its existence were confirmed, it would likely be somewhat vulnerable to contamination (Humphrey, 2000).

Vulnerability is classified using the D.R.A.S.T.I.C. model developed by the US EPA. It takes into account seven parameters: Depth to Water (D), Recharge (R), Aquifer Medium (A), Soil Medium (S), Topography (T), Impact of the Vadose Zone (I), and Hydraulic Conductivity (C). Figure 9 is the Comox Valley aquifer vulnerability. Although the aquifers aren’t delineated on this map, it’s clear that the areas around Fanny Bay and Ships Point are classified as the highest level of vulnerability.
Several industries draw water from Aquifer 414 and 419, including aquaculture, agriculture, water bottling and other industries. It is unknown whether these two aquifers would be contaminated from the Raven site. With surface water discharge and water use from the Raven site in the context of the vulnerability of these aquifers, it is imperative that the threat to aquifers be explored further.

4.1.1.2. Watersheds

A watershed is “a drainage basin containing the land that drains into the entire watershed where streams and tributaries contribute to a larger network of the river’s watershed. Each watershed in a region is biologically isolated from the others, and the plants and animals have mutually adapted to living in a self-contained community. Water systems in a watershed include: interception (forest canopy), surface run-off (top soil), interflow (soil), and groundwater (aquifer)” (Jenssen, 2007). There are three watersheds of concern that may be affected by the Raven Coal Mine above-ground facilities: the Tsable River, Cowie Creek and Wilfred Creek watersheds. If any of these watersheds are used for human drinking water consumption (which they are) then it is classified as a community watershed. The drainage area above the downstream point of diversion on a stream for water use that is for human consumption and that is licensed under the Water Act for waterworks purpose or a domestic purpose if the licence is held by or is subject to the control of a water users’ community incorporated under the Water Act. (Jenssen, 2007)

This is an important piece of legislation for the residents of the CVRD. It emphasizes the community’s control over a community watershed.
Figure 10: Compliance Coal Raven Coal Mine Site Watershed Distribution

4.1.2. Transportation

Though the extraction of coal occurs on site, the Raven Coal Mine Venture intends to export the coal to the likely markets in the Asiatic, Central, and Southern America regions. The processed coal will be transported from the site to local port facilities for final shipping. Included in the AMEC report is the intended port for coal export, located in Port Alberni. The physical requirements for the port site demanded a facility capable of facilitating Panamax vessels, as well as easy access to the Pacific Ocean. The alternative choice considered by AMEC was at Duke Point, but this option was rejected on the basis of uncertainty over the existing facilities and potential for development at Duke Point.
4.1.2.1. **Roadways**

The intended method of transportation for coal between the mine site and the port is via the Inland Island Highway and Alberni Highway, otherwise known as Highways 19 and 4 respectively. Highway trucks would be used on a daily basis to facilitate the transport of coal. Figure 12 shows the “B Train” truck proposed for usage in the AMEC report.
As these trucks are assumed to operate on a 24 hour per day, 7 day per week basis, the traffic volume on both highways will definitely increase during all times of the day. The AMEC report indicates that the pollution emitted by these highway trucks in regards to dust release will be minimal with the usage of tarps. AMEC indicates that the Alberni Highway is used extensively by other industrial companies for transport purposes. *(Tapics, 2011)*

The use of highway trucks will increase traffic volume on both Highways 19 and 4. A comparison in highway volume can be drawn from the current highway usage, based upon data documented by the Ministry of Transportation and Infrastructure. Taking annual volume statistics for the year of 2011 between Highway 19 and Highway 1, there is a significant difference in the traffic volume of both highways. The average daily traffic over the span of a week was 109467 vehicles for Highway 1, compared to a value of 2655 for Highway 19 *(BC Ministry of Transportation and Infrastructure, 2011)*. For Highway 19 with a substantially lower volume, the effect of these “B Train” trucks is much more significant. In addition to this, the substantial rainfall which the region receives makes the highway a significant hazard, a hazard which the presence of the “B Train” trucks adds on to.

### 4.1.2.2. Railways

The alternative considered by AMEC is the rehabilitation of a 120 year old train line connecting the Comox Valley region to Port Alberni. This existing train line is owned by the Island Corridor Foundation and would require overhauls in order to handle the transport of coal. There are two major concerns regarding the implementation of the train line. Firstly, there would be an additional capital cost required for the operation of the train line and overhauling the facilities. In addition to this, there are concerns regarding the flexibility of the train line. Once
implemented, the export of coal would be entirely dependent on Port Alberni. The use of highway trucks provides flexibility in terms of transporting coal to alternative ports along the Victoria Island coastline.

4.1.3. Air Emissions

The air emissions from coal mining are directly related to two separate variables. Firstly, the process used for coal treatment is significant in determining both the composition and amount of emissions. The second and more significant factor is the composition of the coal. The composition of the coal influences the chemicals which are released when the coal is treated or used as a fuel. For coal batches of low purity with many trapped chemicals, the process of combustion will release a significant amount of pollution into the air. The AMEC report indicates that the majority of the coal veins found in the Raven Coal Mine are high quality with few impurities. However the report does not indicate the composition of these veins.

Methane naturally forms along with coal and is present amongst the veins. When the coal is mined, the methane is released and consequently becomes a hazard regardless of whether it escapes the mine or not. Methane, as a colorless and odorless gas, is one of the greenhouse gases (GHG) and readily burns once it hits a certain concentration at room temperature. High concentrations of methane pose a suffocation hazard as well as a combustion hazard. The amount of methane present in a coal mine is directly related to the size of the veins and the larger the mine, the more methane which is potentially stored inside. The AMEC report indicates that 127500 m³ of methane is expected to be produced on a daily basis (Tapics, 2011). The mitigation method proposed by AMEC is ventilation dilution.

The AMEC report acknowledges that there are potential effects on the air quality. The report accounts for GHG emissions and dust emissions from the mine site and transport. The immediate affected locales include the region around Fanny Bay, Buckley Bay, Tsable River, and Wilfred Creek. The proposed mitigation strategies are largely dependent on removing exposure routes. However there is a strong emphasis on application only when economically feasible. This implies that if the process was not economically feasible, the mitigation strategies would not be implemented.

4.1.4. Occupational Safety

With the implementation of an underground mine, there are many factors which create hazards for the workers employed within the mine. Though modern technology has reduced the likelihood and severity for many of these hazards, NMA reports indicate that the number of annual fatalities attributed to mining did not fall significantly between the years 2007 and 2010. A large proportion of these deaths were attributed to mine collapses and explosions. This is a fact which has not changed significantly from the period of 2003/2007 to 2007/2010 (Mine Safety & Health Administration, 2011). Clearly, the presence of these hazards has not been reduced significantly.
4.1.4.1. Hazards

The NMA report includes a large list of hazards which contribute to worker fatalities in underground mines. Of the NMA hazard list, the most prevalent hazards include mine collapses and explosion related hazards. Mine collapses refer to situations when the ceiling or the walls of the mine cave in. Workers may be killed or trapped in a mine passage as a consequence of a mine collapse. A mine collapse can occur due to a number of reasons, including but not limited to seismic activity, human error, mechanical error, and material degradation. The wide range of causes creates a difficulty in development a safety plan which can address every contingency.

Another major factor in mine fatalities is the presence of methane gas. Methane gas is combustible at concentrations above 5% (Air Products & Chemicals, Inc., 1999). Commonly released when the coal vein is extracted, methane gas will react to any ignition source and the resulting flame spreads quickly through methane presence in the air. In a mineshaft with limited oxygen sources, this can quickly become extremely dangerous and thus proper ventilation to keep the methane concentration at a minimum is an absolute necessity.

Some of the other hazards involving underground mines include the flooding of a mineshaft by groundwater, accidents of human error likes slips and falls, disasters such as earthquakes, explosive detonations and problems involving electrical shorts. All of these hazards can escalate quickly into major problems for the miners.

4.1.4.2. Risks

The risk is the likelihood of the hazard occurring and leading to a fatality. Without the proper safety measures it is highly likely that fatalities will occur over the lifetime of the mine. To mitigate the risk presented to the workers, AMEC has stressed the necessity of implementing a proper ventilation system. In addition to this, the report indicates that a maximum extraction height is present in the mines to reduce the likelihood of stress induced mine collapses. Other than this however, the AMEC report makes no statement on the actual safety of the mine once in place.

4.2. Economic Analysis

The Fanny Bay economy and the larger Vancouver Island economy are predominantly resource-based. Major industrial sectors include aquaculture, forestry and mining.

The Fanny Bay shellfish industry, and in particular, Baynes Sound has been identified as a promising growth sector in the Western Economic Diversification Canada’s plan. Efforts undertaken by the Federal government include upgrading the commercial wharf at Fanny Bay to reduce transportation delays and increase the amount of commercial traffic in the area. The new wharf facility is expected to allow for the continued expansion of the Baynes Sound shellfish industry, benefitting local businesses such as the Baynes Sound shellfish producers and Pentlatch Seafoods Limited, owned by the K’omoks First Nations.
4.2.1. Raven Coal Mine

The proposed Raven Project proposes to remove metallurgical or steel making coal for export to Japan and South Korea. Port Alberni is identified to be the preferred port for overseas transportation. For this project, which will last for 16-17 years, job positions are available in different parts.

“Roughly 6,000 workers will be needed in the mining industry by 2016, according to a recent Report on Female Participation within BC’s Mineral Exploration and Mining Industry.” It has been stated in the employment opportunities of the project proposal that more than 200 construction jobs and 350 well-paying, full-time mine, port and transportation jobs will be created in Comox Valley and Port Alberni. Annual operating costs will be approximately $ 70 million, of which $ 30 million will be direct salaries, wages and benefits.

4.2.2. Market

It is questionable whether this number of workers is needed by this mine or not. Besides the discussion of salary levels, there should also be a component of discussion on who benefits from this wealth creation. The most direct comparison of salary level available is Quinsam Mines in Campbell River (underground mine) and Teck Coal (open pit). Underground and coal plant hourly workers at Quinsam are paid between $45,000 and $ 70,000/year (2010). Treck Coal’s open pit coal miners are paid between $53,000 and $78,000/year (2011). Mine manager and staffs will likely be paid between ($ 80,000 and $120,000/year). All in all, only few of the proposed 350 permanent workers are likely receive salary and benefits packages of $100,000/year.

Due to the coal mining short term life time (estimated 16-17 years), the job positions would not be permanent. Moreover, it also should be considered that whether the locals, who are mostly employed at their own jobs right now and are not experienced in coal mining, will get the job or not.

A recent news release by the British Columbia Government Ministry of Energy and Mines on Jan. 25th 2012 mentioned that the “Quinsam Mine provides wages and benefits for about 140 employees living on Vancouver Island totaling more than $14 million per year. Quinsam is traditionally a large supplier to the cement industry in the Lower Mainland, and also exports coal to customers offshore.” Proof of the claim provided was not referenced.

4.2.3. Loss Potential

The BC shellfish industry is an innovative, competitive economic sector that is a world leader in sustainable shellfish culture. Priorities of the association include:

- Support of water quality activities, programs and advocacy

- Support of the implementation of industry based Environment Management System Code of Practice

- Development of a generic marketing program for BC shellfish
• Consistent regulations at both the federal and provincial level
• Development of on farm food safety programs for quality assurance
• Support of the Centre for Shellfish Research

As discussed in previous sections toxic heavy metals from acid mine drainage in mining industry may put shellfish health in danger.

4.2.4. Seafood Industry

BC shellfish growers, Environment Canada, Health Canada and the CFIA are steadfast in their monitoring of water quality on a daily basis and harvest prohibitions are put in place whenever toxin levels increase above the safety standard. As one of the heaviest regulated food industries in Canada, the shellfish grown in BC is vigorously tested before going to market.

![Figure 13: Economic Return on Shellfish Industry](image)

More than 600 people are already employed in shellfish industry in Comox Valley including farm owners, Collectors, seller in local markets and exporters. In 2009 shellfish production was 34,000 tonnes (64M$ value) in Canada. Figure 14 illustrates the total economic activity and production over the years of 2001 to 2009.

The total economic activity generated from aquaculture in Canada in 2007 was $2.1 billion dollars. Aquaculture creates thousands of jobs and millions of dollars in income, providing substantial socio-economic contribution to many coastal and rural communities where aquaculture takes place. Table 4 indicates the totals of GDP, employment and income generated per province over Canada.
Table 4: Economic Analysis on Provincial Basis

<table>
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<tr>
<th>Economic Indicator</th>
<th>NL</th>
<th>NS</th>
<th>PEI</th>
<th>NB</th>
<th>QC</th>
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<td></td>
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<tr>
<td>Direct</td>
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<td>42,800</td>
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<tr>
<td>Direct</td>
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<td></td>
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<tr>
<td>Direct</td>
<td>6,200</td>
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<td>2,720</td>
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<td>5,030</td>
<td>6,290</td>
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4.3. Habitat Conservation

The proposed Ravel Coal Mine can potentially cause certain habitat disturbances due to its close proximity to water bodies such as the Tsable River, Cowie Creek and Baynes Sound. Disturbances to the salmon and bivalve populations are of particular concern in this report. There is a potential for acid mine drainage from exposed and waste rock during the mining process and toxic effluent leached from rocks can include arsenic, cadmium, chromium, copper, lead, mercury, selenium and zinc.

Elevated concentrations of these heavy metals are highly toxic to the salmon population. An important past case study is the Mount Washington Mine, an open pit copper mine which operated only from 1964-1966 but has been a major source of acid rock drainage entering the Tsolum River near Courtenay (White et al., n.d.). The elevated concentrations of copper in the Tsolum River had caused the depopulation of the river’s salmon species like the coho, pink and chum salmon and the rainbow, steelhead and cutthroat trout because high copper concentrations can kill young salmon and deter adult salmon from returning to the river to spawn (BC Wild, & Environmental Mining Council, n.d.).

With regards to the bivalve population of Baynes Sounds, Cadmium is an important heavy metal pollutant of concern. Cadmium does not pose an acute toxicity to bivalves as most heavy metals do to salmons. Instead, cadmium is bioaccumulated in bivalves. In fact, Pacific oysters (Crassostrea gigas) collected on the coast of British Columbia have occasionally shown cadmium (Cd) concentrations at or above 2µg g⁻¹ (wet weight) (Lekhi et al., 2008). However, if concentrations of Cadmium become extremely high, these bivalves may become toxic to animals and humans that consume them. Thus, animals in the Baynes Sound habitat such as migratory birds may be indirectly and adversely affected as a result of the elevated Cadmium concentrations in the bivalves. The subsequent sub-sections take a closer look at the species found in each of the water bodies of concern.
4.3.1. Tsable River

The Tsable River has an estimated drainage area of 105.1 km$^2$ and it supports anadromous fish such as the Coho, Pink and Chum salmon and some Steelhead and Cutthroat trout. Pink and Chum salmon spawning grounds are located near the mouth of the river with lakes in the Tsable River watershed supporting wild and/or stocked Rainbow and Cutthroat trout populations.

4.3.2. Cowie Creek

Cowie Creek has an estimated drainage area of 21.4 km$^2$. The lower portion of the creek is home to anadromous fish such as Coho, Pink, and Chum salmon, Steelhead, and Cutthroat.

4.3.3. Baynes Sound

Baynes Sound consists of over 9000 ha of shallow coastal channel fringed by protected bays, open foreshore, tidal estuaries, inshore marshes and adjacent forests and falls under within the Regional District of Comox Strathcona and includes the foreshore of the City of Courtenay and the Town of Comox.

According to the Sensitive Ecosystems Inventory (SEI) project, three out of the seven identified sensitive ecosystem types lay along the coast of Baynes Sound. These include wetlands, riparian and coastal bluff. As a result, Baynes Sound is internationally recognized as important habitat for migratory birds and is ranked as the most important wetland complex on Vancouver Island by the Pacific Estuary Conservation Program (PECP) and the Pacific Coast Joint Venture.

![Figure 14: Sensitive Ecosystem Locales](image)

In terms of intertidal vegetation, mixtures of red, brown and green algae, with eelgrass beds in the mid-lower zones and marsh vegetation in higher areas can be found on Baynes Sound.
In addition, a minimum of 23 creeks and rivers (including the aforementioned Tsable River and Cowie Creek) drain into Baynes Sound, providing spawning and rearing habitat for Coho, Chum, Chinook, Pink, Sockeye, coastal Cutthroat and Steelhead. The intertidal zone of Baynes Sound is used as a juvenile rearing area at various times of the year (Healey, 1980).

Of particular note to this report are the wild bivalves of Baynes Sound. Intertidal bivalves of Baynes Sound form a rich mixture of native and exotic species, with relative distributions and abundance on each beach determined primarily by the area available at each tidal elevation and the substrate type.

### 4.3.3.1. Bivalves

The bivalve community is dominated by two major species, mussels (family Mytilidae) and oysters (family Tellinidae).

#### 4.3.3.1.1. *Crassostrea gigas*-Pacific Oyster

The most common oyster species in Baynes Sound is the “introduced” Pacific oyster, *Crassostrea gigas*. Oysters are found attached to rocks and pilings in the intertidal, as well as loose on the substrate, either singly or in clusters. Much of the intertidal Baynes Sound area is under tenure for aquaculture.

#### 4.3.3.1.2. *Venerupis philippinarum*-Manila Clam

The exotic Manila Clam, *Venerupis philippinarum* dominates the next intertidal zone. They were accidentally introduced to BC with Japanese oyster seed in 1930 and have spread quite rapidly since then. They achieved commercial significance in the late 1980s, and currently are the most important wild-harvest clam species in BC.

### 4.4. Release Mechanisms

There are several environmental issues to consider in relation to coal mining processes. These include land use, waste management, atmospheric pollution and water pollution. This report would look at coal waste management and water pollution in greater detail.

The issue of waste management and water pollution are inter-related and the phenomenon of *Acid Mine Drainage* provides insights as to how contaminants found in coal wastes are released and subsequently transported to nearby surface water bodies. Coal mining processes generate massive amounts of unusable waste coal (composed of mixed coal, soil and rock). The proposed Raven Coal Mine is expected to generate 1.08 million tonnes of waste coal or reject annually and these waste piles are a rich source of minerals. The release mechanism of the heavy metal pollutant from the waste piles and into the water bodies are described in the following processes.
4.4.1. Pyrite Oxidation

Minerals are usually in their reduced, elemental state in the deep geological environment. Mining, however, allows the introduction of oxygen into the geological environment and oxidizes these minerals. The same occurs when reduced minerals are brought to the surface and deposited in waste piles (Wiggering 1993a, b). The most common family of such minerals are the sulphides and the oxidation of some sulphides (of the type \( \text{MS}_2 \)) leads to the production of protons (i.e. acid). Pyrite, or iron disulphide, is ubiquitous in most coal deposits and may exist in potential association with other chalcophile elements such as As, Bi, Cd, Co, Cu, Ga, In, Hg, Mo, Pb, Re, Sb, Se, Sn, Te and Zn (Spears et al., 1994). When pyrite containing waste piles left exposed to air come into contact with water, pyrite undergoes a series of complex, oxidation reactions. The following simplified equations describe the net processes:

\[
2\text{FeS}_2 + 2\text{H}_2\text{O} + 7\text{O}_2 = 2\text{Fe}^{2+} + 4\text{SO}_4^{2-} + 4\text{H}^+ (\text{aq})
\]

Pyrite + water + oxygen = ferrous iron + sulphate acid

Further partial oxidation of ferrous (\( \text{Fe}^{2+} \)) to ferric (\( \text{Fe}^{3+} \)) iron consumes some protons but Ferric iron may act as an electron acceptor for further pyrite oxidation or hydrolysis could occur. Both of these processes release further protons and the overall sequence of reactions will be acid producing. This lowers the pH and maintains the solubility of the ferric ion in the runoff. The resulting runoff from the coal waste pile is known as mine drainage.

\[
4\text{FeS}_2 + 14\text{H}_2\text{O} + 15\text{O}_2 = 4\text{Fe(OH)}_3 + 8\text{SO}_4^{2-} + 16\text{H}^+ (\text{aq})
\]

In summary, mine drainage is formed when pyrite is exposed to and reacts with air and water to form sulphuric acid and dissolved iron. The low pH of the runoff is able to increase the solubility of other heavy metals such as arsenic, cadmium, chromium, copper and lead found in the waste piles and causes these heavy metals to leach out and dissolve into the runoff. This runoff containing heavy metals is carried off the mine site by rainwater or surface drainage and deposited into nearby streams, rivers, lakes and groundwater. Elevated concentrations of dissolved heavy metals in water bodies can be highly toxic as they can be readily absorbed by plants, animals and fish and can also be bioaccumulated and biomagnified in the food chain. There is also the possibility that when the pH of the mine drainage becomes greater than 3, either through contact with fresh water or neutralizing minerals, the previously soluble ferric ions will precipitate out as Iron(III) hydroxide, a yellowish-orange solid. Iron oxides and oxyhydroxides are other types of iron precipitates that are possible. Not only do these precipitates reduce the aesthetic value of the water bodies, they also disrupt aquatic ecosystems.

4.4.2. Oxidation of Other Metal Sulphides

Other sulphide minerals present in the waste pile would oxidize similarly to pyrite. Some examples of these sulphide minerals include sulphides of zinc, copper or nickel. However, it must be noted that oxidation of sulphides
of the form MS does not in itself release acid. For instance, sphalerite (ZnSO\textsubscript{2}) oxidises in the following manner without yielding protons.

\[ \text{ZnS}_2 + 2O_2 = \text{Zn}^{2+} + \text{SO}_4^{2-} \]

Subsequent hydrolysis of metal ions may release protons but studies indicate that pH is unlikely to be depressed below 5.5 the zinc ions only undergo partial hydrolysis.

### 4.4.3. Role of Bacteria in Acid Mine Drainage

The oxidation of pyrite in mine drainage water is catalysed by the acidophilic sulphide-oxidising bacteria, \textit{Thiobacillus ferrooxidans}, which thrives at a pH range of 1.5–3.0. By catalysing the oxidation of ferrous sulphide to ferric sulphate, this bacterium greatly accelerates the otherwise slow chemical oxidation of iron sulphide. Thus, the rate and degree by which acid-mine drainage proceeds is greatly determined by bacterial action. While \textit{Thiobacillus ferrooxidans} is probably the most well-known and predominant bacterium associated with acid mine drainage, a range of other iron/sulphur-oxidising bacteria exist and have been isolated from coal spoil heaps and drainage waters (McGinness and Johnson 1993). These include \textit{Leptospirillum ferrooxidans}, \textit{Thiobacillus thiooxidans} and \textit{Sulfobacillus thermosulfidooxidans}. The exact species present and their relative activities depend on site-specific conditions like temperature and pH (Norris, 1990).

**Pollution prevention:**

Pollution prevention is a part of pollution management. It actually is about anticipating and preventing pollution instead of reacting to it. Minimizing or avoiding the creation of pollutants and wastes is definitely more effective than treating them. And even sometimes it is more cost effective.

Pollution prevention is needed to secure a safe and healthy environment and prosperous economy.

The federal government believes that pollution prevention is the most effective means of protecting the environment.

**Pollution prevention basics:**

Traditionally waste has been managed through treatment, recycling, control equipment, and landfilling. These are often referred to as “end-of-pipe” processes. These solutions cost money, and are sometimes not environmentally sound.

Effective pollution prevention requires a different approach to the design and operation of mines, farms, and any other facility that can potentially create waste and pollution. Some techniques of the implementing of pollution prevention are named below:

- substances of concern;
- efficient use and conservation of natural resources;
- material and feedstock substitution;
- product design/product reformulation;
- process changes;
- reuse and recycling on-site;
- training;
- purchasing techniques;
- equipment modifications;
- operating efficiencies/clean production

**Mining pollution prevention, Control and Cleaner Production:**

Mining processes have the potential to cause environmental damage on many fronts. Beginning with the exploration of prospective sites, through to the refining and purification of minerals, a large number of contaminating wastes are generated both directly and indirectly. In underground mines, the surface disturbance is less obvious, but the extent of subsidence can be very large. Methane generation and release can also be a problem under certain geological conditions.

If groundwater systems are disturbed, the possibility of serious pollution from highly saline or highly acidic water exists. Impacts may continue long after mining ceases.

Table 5 presents the levels of liquid effluents, solid waste, and dust generated by the major mining techniques:

**Table 5: Loads Per Unit of Coal Production, by Mining Technique (tons per 1000 tons coal produced)**

<table>
<thead>
<tr>
<th>Waste characteristics</th>
<th>Surface mining</th>
<th></th>
<th>Underground mining</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Contour</td>
<td>Area</td>
<td>Conventional</td>
<td>Longwall</td>
</tr>
<tr>
<td>Liquid effluents</td>
<td>0.24</td>
<td>12</td>
<td>1</td>
<td>1.6</td>
</tr>
<tr>
<td>Solid waste</td>
<td>10</td>
<td>10</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Dust</td>
<td>0.1</td>
<td>0.06</td>
<td>0.006</td>
<td>0.01</td>
</tr>
</tbody>
</table>
Early planning and careful design of operations is the key to minimizing pollution associated with mining activities. Before mining begins a mining plan and a mine closure and restoration plan must be prepared and approved.

**Development plan**

Defines the sequence and nature of extraction operation. At a minimum, the plan must address the following:

- Removal and proper storage of topsoil
- Early restoration of worked-out areas to minimize the extent of open areas
- Diversion and management of surface and groundwater to minimize water pollution. Simple treatment to reduce the discharge of suspended solids may be necessary
- Identification and management of areas with high potential for AMD generation
- Minimization of AMD generation by reducing distributed areas
- Preparation of a water management plan for the operation and post closure that includes minimization of liquid wastes
- Reduction of dust by early re-vegetation and by good maintenance of roads and work areas
- Control of the release of chemicals (including floatation chemicals) used in beneficiation processes.
- Minimization of the effects of subsidence by careful extraction methods in relation to surface uses
- Controlling Methane, a greenhouse gas, to less than 1% by volume, to minimize the risk of explosion in closed mines
- Development of restoration and re-vegetation methods appropriate to the specific site condition
- Proper storage and handling of fuel and chemicals used on site, to avoid spills

**Mine Closure and Restoration Plan**

The plan should include reclamation of open pits, waste piles, beneficiation tailings, sedimentation basins, and abandoned mine, mill, and camp sites. Mine reclamation plan should include:

- Return of the land to conditions capable of supporting prior land use
- Contouring of slopes to minimize erosion and runoff
- Planting of native vegetation to prevent erosion
- Management of post closure AMD and beneficiation tailings

**Target pollution loads**

Implementation of cleaner production processes and pollution prevention measures can provide both economic and environmental benefits. The loads represented in the Table-1 would be a useful source for pollution prevention purposes.

**Emissions Guidelines**

Emission levels for the design and operation of each project should be established through the Environmental Assessment process. The guidelines below present emissions levels normally acceptable to the World Group.

**Air Emissions**

Controls may be required on individual sources, such as ventilation exhausts, if they have a significant effect on ambient particulate levels. In case of using coal crushers or dryers, fabric filters or other systems should be used to recover coal and reduce particulate emissions to the level below 50 milligrams per normal cubic meter (mg/Nm³).

**Liquid effluents**

Using ponds to catch storm water and to reduce suspended solids should be provided for all effluents before discharge from the site. Table 6 illustrates the Acid Mine Drainage and Liquid Effluents from Coal mining in units of milligrams per liter, except for PH.

**Table 6: Acid Mine Drainage and Liquid Effluents from Coal mining. Milligrams per liter, except for PH**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Maximum Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PH</td>
<td>6-9</td>
</tr>
<tr>
<td>TSS</td>
<td>50</td>
</tr>
<tr>
<td>Oil and Grease</td>
<td>10</td>
</tr>
<tr>
<td>Iron</td>
<td>3.5</td>
</tr>
<tr>
<td>Total metals</td>
<td>10</td>
</tr>
</tbody>
</table>
Monitoring and Reporting

Frequent sampling may be required during start up and upset conditions. Waste water from the discharge should be monitored weekly for PH, TSS and Oil and Grease.

Cleaner technologies and strategies in the mining industry:

Conventional end-of-pipe technologies were used against this contamination. However, the advent of strict environmental legislation and ineffectiveness of several of these end-of-pipe systems, made it necessary to implement more effective cleaner technologies. The importance of minimizing and managing pollutants in the industry has led to the emergence of a number of cleaner technologies.

- Each system takes thermodynamics seriously.
- The use of each system results wastes reduction, minimization, reuse, recovery and disposal.
- Each system, from the long term perspective, is cheaper than end-of-pipe clean up technology

High-tech flue gas desulphurization (acid gas scrubbers)

Most metals occur as sulphides, and when smelted, emit significant amount of sulphur dioxide, which is the principal component of acid rain, into the atmosphere. The burdens and costs of soil, water, and ecosystem remediation, have been important reasons why mining companies have adopted technical flue gas desulphurization (wet scrubber) systems at their sites.

In a typical scrubbing process, high temperature combustion gases rise upwards through a smelting tower, and enter the scrubber, which quenches the flue with streams of lime-rich solution. The gas then proceeds upwards through a series of spray healers that introduce a uniform liquid flux of droplets. These alkaline slurries, in effect, chemically neutralize the acid gas before it is released into the atmosphere.

Waste water treatment technologies

Cleaner Production (CP) is the most effective approach to achieving improved water quality. The most prevalent water pollution issue in the mining industry is Acid Mine Drainage (AMD). Since Coal and most metals occur as sulphides, separating their deposits from uneconomic gangue creates vast quantities of waste rock and tailings, which, if flushed with rainwater, creates AMD. An almost equally serious water pollution problem confronting mining operations is contamination from heavy metals, particularly copper, lead cadmium and arsenic.

The previous approaches that have been used to solve these problems have been unable to effectively prevent environmental damages, and consequently, resulted huge cleanup costs for firms.
A number of advanced wastewater treatment technologies, however, have emerged in recent years that more effectively mitigate these water pollution problems. These include:

- Electrochemical methods
- Plasmotechnologies
- Membrane filtration
- Evaporation/Crystallization
- Biodegradation processes
- Chemical precipitators

Adopting preventative water pollution strategies, such as those listed above, minimizes toxic effluents, and helps put a firm in a better position to avoid the costs of ecological “shock” created by mining wastes dispensed into water bodies.

5.1. Mine Proposal Rejection

5.1.1. Environmental Review Process

The B.C. Environmental Assessment (EA) process provides a framework for reviewing major projects like the Raven Coal Mine to assess their potential impacts. The process is imperative to ensure that major projects meet the goals of environmental, economic and social sustainability. In addition, the process also provides a platform in which the issues and concerns of the public, First Nations, interested stakeholders and government agencies can be looked into.

The environmental assessment process has three stages. They are the Pre-application, application review and the Decision stage.
Figure 15: Environmental Assessment Process Flow Diagram

The proposed Raven Project is currently in the pre-application stage of the environmental assessment process. The pre-application stage is required to ensure that when an application for an environmental assessment certificate is reviewed it contains the necessary information to allow the Environmental Assessment Office (EAO) to undertake its assessment and make recommendations to the Ministers making the decision. Two of the key steps in this stage include preparation of draft terms of reference that specify the matters that must be studied and information that must be included in the EA application and review and comment on the draft terms of reference by the working group, First Nations and the public. For the Raven Coal Mine project, the public comment period for the Public Comment Tracking Table was held from November 15, 2011 to November 29, 2011. The next public comment period will be on the Application for an Environmental Assessment Certificate and Federal Environmental Approval.

5.1.2. North American versus European Environmental Impact

The methodology of the North American Environmental Assessment process involves assuming that the proponent proves sufficient measures for mitigating environmental risks and hazards that are considered as a standard and from public comments. In the European system, the burden of proof is on the proponent in ensuring that all the possible risks and hazards are considered and quantified to be accepted for approval. Indeed the North American process is reactive to environmental disasters whereas the European process is proactive. It should be noted that the European process is focused more on risk management.

5.1.3. Possible Shortcomings in the B.C. Environmental Review Process

In 2010, the Federal government rejected an $800-million project, the Prosperity Gold and Copper Mine, which was to be built near Williams Lake in British Columbia. Environmental considerations and protection of First Nations interests formed the basis for the rejection of the Prosperity Mine proposal by Taseko Mines Ltd. The mine proposal involved the destruction of Fish Lake. The lake is a fish-bearing lake with an estimated 85,000 rainbow trout of which around 4,500-5,000 are caught annually (Environmental Assessment Prosperity Project - Fish Lake, 2010). The lake was to be drained to be used as a pit for waste tailings from the mine. The proposal had managed to obtain the B.C. government’s approval on the count that the economic benefit outweighed the environmental destruction. However, the proposal was rejected by the Environment Minister, Jim Prentice because of the pronounced environmental effects rising from the loss of the entire ecosystem associated with the lake. This includes loss of all associated wetlands, a number of streams and not to mention, the cumulative and irreversible impact on the blue-listed (endangered) grizzly bears. The potential loss of the lake, as a sacred place for cultural and spiritual practices for the Tsilhqot’in and Xeni Gwet’in First Nation, had also prompted strong objections from the First Nations of concern and this would probably have been another contributing factor for the rejection of the proposed mine.
One of the most concerning aspects of the mine proposal is that it had obtained the approval for the proposal despite the planned draining of Fish Lake, a highly detrimental environmental impact by most measures. Environmental issues do not seem to be given equal weight as economic considerations in the B.C. Environmental Assessment process. If the track record of the B.C. Environmental Assessment Office (which has never recommended a project to be rejected) is an indicator to go by, it is unlikely that the Raven Coal Mine proposal is going to be rejected by the provincial government. A study by The Environmental Law Centre on improving the effectiveness and the credibility of Environmental Assessment Act lends insights to some of the shortcomings of the environmental assessment process in B.C.

One of the most pertinent inadequacies of the B.C. Environmental Assessment is its failure to require the evaluation for the ‘need and alternatives to projects’ (University of Victoria Environmental Law Center, 2010). A robust EA planning and decision-making process generally requires three types of alternatives to be examined by proponents: “alternatives to”, “alternative methods” and the “null” (or “no go”) alternative. “Alternatives to” are functionally different ways of dealing with a particular problem or opportunity (e.g. waste diversion is an “alternative to” waste disposal). “Alternative methods” refer to different operational options or ways of carrying out the same activity (i.e. establishing a new landfill or expanding an existing landfill, or utilizing engineered facilities or “natural attenuation” designs, are “alternative methods” of carrying out waste disposal). The “null” (or “no go”) alternative refers to the assessment of the environmental risks and benefits if the proponent simply does nothing to address the identified problem or opportunity. Requiring the evaluation of the need and alternatives to projects has the benefit of allowing the developers of the project to seriously explore more sustainable ways of implementing the project.

Another lacking aspect of the B.C. Environmental Assessment process is that the Environmental Assessment Office provides no policy or methodology outlining its process for cumulative effects assessment (although EAO states that cumulative effects are considered in its assessment). Cumulative effects assessment (CEA) is evaluating the impacts of a project in combination with other projects or activities that have been or will be carried out. The importance of considering cumulative effects of multiple projects and activities on ecosystems at multiple scales (local, regional, national, etc.) has been accepted for decades with a conference of Canadian and U.S. experts concluding in 1985 that the “failure to take cumulative effects into account ‘is resulting in damage to the environment’ on a range of scales from local through regional/national to global and that if environmental assessment cannot properly take them account ‘the usefulness and credibility of the whole process must be in doubt.’ (University of Victoria Environmental Law Center, 2010)

The study goes on to suggest several recommendations for improving British Columbia’s EA. Among them, the suggestion of enabling the public to participate in assessments in a meaningful, constructive, timely fashion is salient to this report. In order for the public to participate in a meaningful and constructive manner, they have to be aware of both the impacts of the project as well as the structure and the shortcomings of the EA process.
5.1.4. Activism and Awareness

Activism refers to the policy or action of using vigorous campaigning to bring about political or social change. In the case of the Raven Coal Mine, activism would be required to consolidate and present the potential deleterious environmental, economic and social consequences of the mine so as to build a strong case against the Raven Coal Mine. Those who are opposed or concerned about the proposed Raven coal mine project will continue to identify and research issues surrounding it, and raise the public’s awareness to those issues.

In a letter, John Tapics, CEO of the Raven Underground Coal project, stated that people deserve to receive accurate and precise information about the proposed project. He also mentioned that technical studies prove 100% of the coal at the Raven Project is metallurgical and 88% of the processed coal will be suitable to sell to steel companies for steel making.

It is obvious how the public reacts to this statement. It sounds like this project is so beneficial that the negative issues could be ignored.

Here is the confusing part. Once according to an announcement of Compliance Energy Corporation, press released the pre-feasibility study results for the Raven Project: out of the total raw coal mined, the average wash plant yield was estimated at 44%. This is the saleable product of coal after it has been processed and washed. Of that saleable product, an average 88% semi-soft metallurgical coal and 12% thermal middlings product will be produced over the mine life.

So the raw Raven Coal can be described as 38% low quality metallurgical coal, 6% thermal coal, and 56% non-saleable garbage that will be disposed of on the surface at the mine site.

Which of these claims is accurate?!

5.2. Mine Proposal Approval

Several factors are contributing to the project’s progression through the approval process. Political and economic pressure is being exerted on the various levels of government. Changes to the environmental assessment process would expedite the mine’s construction. Furthermore, the engineering consultants, AMEC, have been hired by Compliance Coal and produced a report in which the Raven project is put in a positive light.

5.2.1. Political Pressure

Several important events in the assessment process have hindered the community’s efforts to develop educated opinions on the Raven project. First, the Environmental Assessment Office refused to acknowledge the demand for a thorough aquifer study to address groundwater contamination concerns and the potential effects on Baynes Sound (Wheeler, 2011). The political position of the BC premier Christy Clark is also strongly and outspokenly in favour of the mine’s approval.
5.2.2. Economic Pressure

In addition and related to the political pressure, significant investments have been made in support of the Raven project being approved, despite the project being in the assessment stage. $323,028.00 have been invested into an underground mining program at North Island College in anticipation of the mine’s opening (Wheeler, 2011).

5.2.3. Legislation (Federal Budget 2012 Environmental Assessment Change)

The majority federal Conservative party of Canada presented the new 2012 Budget containing an interesting section regarding environmental assessment. All major projects of federal interest will have a maximum 2 year limit on the environmental assessment process retrospectively. This means that project like the Keystone pipeline will have their environmental assessment decisions made by the fall of 2012. Since the Raven coal project proposed mine will be in British Columbia and fall under provincial environmental assessments, the federal government will not do an assessment and the new budget rule does not apply.

6. Recommendations & Conclusions

6.1. Prosperity Mine Proposal Rejection

In British Columbia’s recent history, the rejection of the Prosperity Mine proposal is the most prominent step towards environmental justice in the mining industry. It deserves the publicity given that it is the only mine proposal to have ever been rejected in British Columbia. It serves as a flagship for current and future proposals, and how the community can achieve success through activism and awareness building. Environmental groups including the David Suzuki foundation, concerned citizens and First Nations groups all contributed to raising awareness through scientific research. The scale of the Prosperity Mine gained enough traction as a perceived environmental risk such that a special government panel was convened to reconsider the proposal. The provincial government did not participate in the panel, as it had already been approved on the provincial level. However, perhaps to the surprise of the provincial government, the proposal was rejected by the special panel.

What can we learn from the Prosperity Mine rejection? First, pushing the project to a joint provincial-federal special panel seems to be a last bastion for decision-makers to reject a proposal. Second, increasing the awareness of the environmental risks, or perceived environmental risks inspires more scientists and citizens to participate in the dialogue and in the process accrues more allies and advocates. Third, the involvement of environmental groups, especially those with public trust and popular spokespeople, is a significant source of scientific involvement. Finally, proposing environmentally friendlier alternatives and modifications to the project is a positive method to involve engineers and the mine company in the dialogue. Given that these alternatives will likely be too costly to implement into an economically feasible mine plan, this exposes the vulnerability of the original mine proposal to scrutiny and the unwillingness of mining companies to adjust the profit margin in the spirit of environmental stewardship.
Based on the Prosperity Mine proposal as a case study, some recommendations for the Raven Coal Mine proposal can be formulated:

1. **Continue to pursue a joint federal-provincial review panel.**

   How can we get the attention of the federal government? There are some obstacles to convincing the federal government that environmental stewardship is in their best interest under the economic, environmental and social umbrellas. First, following the rejection of the Prosperity Mine proposal, the provincial government has used this as leverage to pressure the acceptance of other projects. However, the federal government has already invested $765,000 in the development of the shellfish industry in Fanny Bay and will continue to supply up to $7 million “to support economic growth, job creation and the future sustainability of B.C. coastal communities affected by challenges within the salmon fishery.” Can the federal government be reminded of the security of this investment?

2. **Involve academia to support claims of environmental risk.**

   In order to garner trust from communities, academia is needed to provide unbiased information. When the government and the environmental review process fails to respond to public objections, it is the role of academia to step in and help the community. One way to achieve this goal is to involve students. Community Service Learning projects like this one can pave the way for more attention from students. Investing time into involving academia could provide useful input in the form of theses and reports.

3. **Gain the trust of more people in the community.**

   To gain the trust of the community, more public awareness activities are needed. Door-to-door campaigns may be effective in raising awareness. Press releases and publicity stunts could draw attention from outside the community, and in the scope of concerned citizens all over British Columbia. The perception of what affects “our back yard” needs to be changed so that all British Columbians recognize that our environment is our back yard. By conveying the sense of urgency and the impacts of this mine proposal, more community members can be motivated to participate in dialogue. We can do this by highlighting a few key risks through creating images and infographics that convey scientific information.

4. **Cultivate support from environmental interest groups.**

   Environmental interest groups have experience in this process. If the Raven Coal project can be adopted by these interest groups as an urgent and relevant pursuit, perhaps enough people can be engaged to start a
sizeable movement. We can do this by targeting local celebrities, spokespeople from popular environmental interest groups and also by talking to local politicians. If the Raven Coal project can be branded as a political benchmark, perhaps the opposition parties could use it as leverage for their agenda while increasing awareness for the environmental impacts.

6.2. Potential Impacts of Coal Mining

In this section, the potential impacts of coal mining projects are discussed in general terms. The impacts of a specific project can vary substantially and will be determined by specific factors.

- **Air Quality (including Global Climate Change and Carbon Footprint)**
  Emissions resulting from construction and mining activities include vehicle emissions; possible release of methane, hydrogen sulfide, and coal dust through the venting of shaft mines.

- **Water Resources (Surface Water and Groundwater)**
  Water quality could be affected by: AMD, Activities that cause soil erosion, weathering of newly exposed soils, discharge of waste or sanitary water and pesticide application.

- **Socioeconomics**
  There will be direct beneficial impacts including creation of new jobs for workers, and the associated income and taxes paid, as well as royalties. Indirect beneficial impacts would occur as a result of the new economic development.

Adverse impacts could occur as a large number of workforces will migrate in. Some economic losses could also happen. Mining activities could also potentially affect property values.

6.3. Mitigation

Mitigation measures can be applied to avoid or minimize impacts from coal mining. In order to identify and use an appropriate mitigation measure, first the potential impacts of a project on a specific resource should be evaluated. Then, project and site specific factors should be identified to determine whether the impact can be avoided or mitigated, what actions should be taken, how effective the mitigation plan will be, and how much does the mitigation plan cost.

**Air Quality Mitigation Measures**

The following examples of mitigation measures that could be applied to reduce air quality impacts of a project depending upon site and project specific conditions. Impacts to air quality are related to project emissions.
Develop a final set of mitigation measures for any project in consultation with the appropriate federal resource management agencies and stakeholders. Conduct these consultations early in the project development process and preferably prior to final project siting and design.

**Siting and Design Mitigation Measures**

Siting and Design considerations that mitigate impacts include:

- Surface access roads and on-site roads with aggregate materials, wherever appropriate.
- Minimize disturbed areas.

**General Mitigation Measures**

There are some general mitigation principles that could be used for all phases of a coal mine project such as:

- Use dust abatement techniques on unpaved, unvegetated surfaces to minimize airborne dust and during earthmoving activities, prior to clearing, before excavating, backfilling, compacting, or grading, and during blasting.
- Post and enforce speed limits to reduce airborne fugitive dust from vehicular traffic.
- Revegetate disturbed areas as soon as possible after disturbance. (This should include interim revegetation along road beds once heavy construction is completed and heavy mining equipment has been moved in.)
- Keep soil and coal refuse moist while loading into dump trucks.
- Keep soil and coal refuse loads below the freeboard of the truck.
- Minimize drop heights when loaders dump soil and coal refuse into trucks.
- Tighten gate seals on dump trucks.
- Cover dump trucks before traveling on public roads.
- Cover construction materials, stockpiled soils, and stockpiled coal refuse if they are a source of fugitive dust.
- Employ water injection or rotoclones on all overburden drills.
- Use chutes, drapes, or other means to enclose conveyor transfer points, screens, and crushers; cover all conveyors.
- Install and use sprays of water for coal-handling and conveying equipment.
- Suppress and extinguish spoil and coal fires as soon as is reasonable and safely possible.
Water Resources Mitigation Measures

Impacts to water resources pertain to the project footprint (e.g., land disturbance, erosion, changes in runoff patterns, and hydrological alterations), Project emissions (e.g., sediment runoff, AMD, and water releases), and source use (e.g., water extraction).

Siting and Design Mitigation Measures

- Identify and avoid unstable slopes and local factors that can cause slope instability (groundwater conditions, precipitation, seismic activity, slope angles, and geologic structure).
- Identify local hydrogeology. Determine areas of groundwater discharge and recharge and their potential relationships with surface water bodies and groundwater quality. Avoid creating hydrologic conduits between two aquifers.
- Minimize the planned amount of land to be disturbed as much as possible.
- Use special construction techniques in areas of steep slopes, erodible soils, and stream crossings.
- Construct drainage ditches only where necessary. Use appropriate structures at culvert outlets to prevent erosion.
- Do not alter existing drainage systems, especially in sensitive areas such as erodible soils or steep slopes.
- Handle earth materials and runoff in a manner that minimizes the formation of acid mine drainage, prevents adding suspended solids to stream flow, and otherwise prevents water pollution. Construct sedimentation structures near the disturbed area to impound surface water runoff and sediment. Maintain as necessary, including discharge of water meeting applicable water quality standards, so as not to exceed designed storage capacity.

General Mitigation Measures

The following mitigation measures could be applied to any kind of mine project:

- Apply erosion controls
- Save topsoil removed during mining and use to reclaim disturbed areas
- Avoid creating excessive slopes during excavation and blasting operation
- Clean and maintain catch basins, drainage ditches, and culverts regularly
- Limits pesticide use to nonpersistent, immobile pesticides

Socioeconomic Mitigation Measures
The economic effects of coal mining can be positive effects of increases in employment and local revenue and royalties whereby few, if any, mitigation measures may be necessary. However, with large mining projects there are situations in which existing infrastructure and social services are inadequate to meet the needs of large workforces that are not local to the area. This is especially true on tribal lands where there can be both cultural differences and disparities among incomes, education, and access to basic needs, such as running water and electricity. The following mitigation measures may be applicable to avoid or reduce these impacts, depending upon site- and project-specific conditions.

- Coal mining companies could work with tribal, state, and local agencies/governments to develop community monitoring programs that will be sufficient to identify and evaluate socioeconomic impacts resulting from coal mining.
- Coal mining companies could work with tribal, state, and local agencies to develop community outreach programs that would help communities adjust to changes triggered by coal mining. Such programs could include any of the following activities:
  1. Establishing vocational training programs for the local workforce to promote development of skills required by the coal industry.
  2. Developing instructional materials for use in area schools to educate the local communities on the coal industry.
  3. Supporting community health screenings, especially those addressing potential health impacts related to the coal industry.
APPENDIX A: CALCULATIONS
The Mathematical Modeling of a Public Awareness Campaign

In order to model the awareness campaign based on reaction engineering principles, we first define the following variables. Let variable $A$ be the population of people not aware of the current Raven Coal mine project or similar issues, let variable $B$ be the population of people aware of the issue, and let variable $C$ be the population that either becomes indifferent about the issue or deceased or simply removed. A person cannot be a combination of $A$, $B$ or $C$ at a particular time, and therefore $N$ is the total population in the model area and Equation 1 holds true.

$$A + B + C = N \tag{1}$$

For an unaware individual to become aware about an issue, an aware person must make them aware about it. This modeled as an autocatalytic reaction mechanism shown in Equation 2

$$A + B \rightarrow^{\alpha \Delta t} B + B \tag{2}$$

where $\alpha$ is the second order reaction constant [persons$^{-1}$ time$^{-1}$]. It is assumed to be constant for all conditions. A person aware about the issue of interest may not be interested and may become indifferent. The removal rate is modeled as the reaction mechanism shown in Equation 3

$$B \rightarrow^{\beta} C \tag{3}$$

where $\beta$ is the first order reaction constant [time$^{-1}$]. It is assumed to be constant for all conditions. Combining Equations 2 and 3 into a single reaction mechanism results in Equation 4.

$$A \rightarrow^{\alpha \Delta t} B \rightarrow^{\beta} C \tag{4}$$

The rates of species $A$, $B$, and $C$ at the time infinitesimally larger, $\Delta t$, than the current time, $t$, is equivalent to the current value of the species and the consuming reaction mechanisms. The results are shown in Equation 5.

$$A(t + \Delta t) = A(t) - \alpha A(t)B(t)\Delta t \tag{5}$$
$$B(t + \Delta t) = B(t) + \alpha A(t)B(t)\Delta t - \beta B(t)\Delta t$$
$$C(t + \Delta t) = C(t) + \beta B(t)\Delta t$$

By taking the limit as $\Delta t$ approaches zero on the results of Equation 5, Equation 6 displays the differential equations.
\[ \frac{dA}{dt} = -\alpha AB \]  
\[ \frac{dB}{dt} = \alpha AB - \beta B \]  
\[ \frac{dC}{dt} = \beta B \]  

In order for the model to be more robust, it must have no dimensions. Equation 7 presents the non-dimensional variables

\[ A' = \frac{A}{N}, \quad B' = \frac{B}{N}, \quad C' = \frac{C}{N}, \quad \lambda = \frac{\alpha N}{\beta} \]  
\[ dA' = \frac{dA}{N}, \quad dB' = \frac{dB}{N}, \quad C' = \frac{dC}{N}, \quad dt' = \beta dt \]  

where \( A', B', C', t' \) and \( \lambda \) are the non-dimensional forms of their respective non-prime definitions. The result of such an effort is shown in Equation 8.

\[ \frac{dA'}{dt'} = -\lambda A'B' \]  
\[ \frac{dB'}{dt'} = \lambda A'B' - B' \]  
\[ \frac{dC'}{dt'} = B' \]  

Using MATLAB code to produce Figure 1, the result curve shapes can be observed when assuming that \( \lambda \) is equal to 10, \( A' \) is 99%, \( B' \) is 1%, and \( C' \) is 0% as initial conditions.
The goal is to reach the point where the percentage of the population was more aware compared to being unaware about the desired issue, the crossing point is theoretically important. By the chain rules of calculus, the relationship between A’ and B’ can be derived as shown in equation

\[
\frac{dB'}{dA'} = \frac{dB'/dt}{dA'/dt} = \frac{\lambda A' B' - B'}{\lambda A' B'} = \frac{1}{\lambda A'} - 1
\]  

(9)

Solving the equation analytically with the initial conditions A_0’ and B_0’ respectively, Equation 10 is produced.

\[
B' - B'_0 = \frac{1}{\lambda} \ln \frac{A'}{A'_0} - (A' - A'_0)
\]  

(10)

Knowing that the sum of the initial conditions results in a sum total of one, and that at the cross point the value of B’ is equal to A’, Equation 11 results.

\[
\ln \left( \frac{e^{\frac{A'}{B'_0}}} {e^{\frac{A'_0}{B}} \lambda} \right) = \frac{\lambda + \ln A'}{2}
\]  

(11)

The analysis has been conducted to show that there is in fact a reasonable model to try to spread awareness about a project. It was related to the chemical reaction engineering methods learned by the authors. Other simplistic models and assumptions can be found in literature that are used to actually model the spread of a rumor, disease, and populations.

```matlab
function CHBE480_Awareness_Solver
    clear all; clc; close all
    t=0:0.01:1;
    ini=[1-0.01 0.01 0;];
    solverplot(t,ini)
    disp('End Function')
end

function solverplot(t,ini)
    [t,D] = ode23(@odeequations, t, ini, odeset('RelTol', 1e-5));
    plot(t,D(:,1),'-k',t,D(:,2),'.k',t,D(:,3),':k')
    xlabel('t');
    ylabel('Percent of Total Population');
    legend('A' Unaware', 'B' Aware', 'C' Removed');
    axis([0 max(t) 0 max(max(D))])
end

function dDdt=odeequations(t,D)
    R=10;
    dDdt=zeros(3,1);
    dDdt(1)=-R*D(1).*D(2);
    dDdt(2)=R*D(1).*D(2)-D(2);
    dDdt(3)=D(2);
```

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References


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References