A GENOMICS STRATEGY FOR BRITISH COLUMBIA’S MINING SECTOR
GENOME BRITISH COLUMBIA

Vision

*Genomics will revolutionize many aspects of our lives and provide solutions to humankind’s challenges.*

Mission

Genome British Columbia leads academia, government and industry in the growth of a world-class genomics R&D cluster to deliver sustainable social and economic benefits to British Columbia, Canada and beyond, through:

- Excellent projects and technology platforms,
- Innovative applications for the life sciences cluster,
- Strategic regional, national & international collaborations, and
- Proactive leadership in exploring societal impacts of genomics.
Genomics is the science that aims to decipher and understand the entire genetic information of an organism (i.e. microorganisms, plants, animals and humans) encoded in DNA and corresponding complements such as RNA, proteins and metabolites.

The knowledge and innovations emerging from this field are finding solutions to complex biological challenges, while at the same time raising questions of societal and economic importance.

Genomics has already brought huge economic and societal gains to Canadians through better healthcare, improving food quality, safety and production and protecting our environment and natural resources.

Looking ahead, genomics will be the foundation of Canada’s growing bio-economy (all economic activity derived from life science-based research), which is estimated to be responsible for some 2.25 per cent of GDP, or about $38 billion, by 2017.
# Table of Contents

**EXECUTIVE SUMMARY** .................................................................................................................. 2

1 **INTRODUCTION** .......................................................................................................................... 3

2 **THE IMPORTANCE OF THE MINING SECTOR TO BRITISH COLUMBIA** ................................. 3

3 **CHALLENGES AND OPPORTUNITIES IN MINING** ................................................................. 4

4 **THE ROLE OF GENOMICS IN ADDRESSING CHALLENGES AND REALIZING OPPORTUNITIES** ................................................................................................................................. 6

   4.1 **Background** ............................................................................................................................ 6

   4.2 **Opportunities for Genomics in Mining** .................................................................................. 7

5 **TOWARDS A GENOMICS STRATEGY** ...................................................................................... 14

   5.1 **Priority Areas** ......................................................................................................................... 15

   5.2 **Implementing a Genomics Strategy** ....................................................................................... 16
EXECUTIVE SUMMARY

BC’s abundant mineral resources have enabled development of an innovative, growing mineral exploration and mining industry. In 2012, the production value of B.C.’s mining operations was $8.3 billion and mining made up nearly 30 per cent of all provincial exports. More than 30,000 people were employed last year in mining, mostly in rural B.C. locations\(^1\). This makes it highly important to understand how (after seeing its impact on the health and other sectors) genomics can be applied in the BC mining context to deliver social and economic benefits.

The mining subsector faced significant economic uncertainty in 2013. The primary driver of the global mining industry’s growth is commodity prices, which are set in response to global supply and demand. This and other challenges provide a unique opportunity for building strong relationships with the industry when executives have more time to learn about innovations that they can implement later when more funds are available.

BC has been a centre of activity, and once a world leader, in the R&D of biological processes applied to mining for over 50 years. This often groundbreaking work was well supported by the mining industry and led to several developments that are utilized in some areas of the global industry today. Today, several Canadian mining companies, some based in BC, utilize biotechnological approaches in their offshore commercial operations in metals extraction (copper, nickel, gold) and in environmental mitigation applications.

Genome BC believes that new tools that genomics can offer at an ever-improving price point, will provide significant opportunities for making even greater impacts on the sector with benefits for all stakeholders. The main areas of opportunity for genomics in mining are:

- Water, Effluent
- Processing, Refining, Extracting
- Remediation, Tailings
- Environmental and Risk Assessment

\(^1\) http://www.empr.gov.bc.ca/Mining/Strategy2012/Pages/default.aspx
1 INTRODUCTION

Energy and Mining refers to extracted, naturally occurring resources, such as metals, coal, oil and gas, as well as environmental implications of activities related to exploration, production, transportation and closure related to these goods. In BC these are subsectors are key facets of the economy. Because of differences in governance, opportunities and challenges in the two subsectors of Energy and Mining in the Province of BC, this strategy document is focusing on the Mining subsector and a separate one was prepared for the Energy subsector.

Building on momentum gained in its initial sector strategy in 2007² Genome BC, along with Genome Canada and the other regional genome centres, embarked on a new sector specific initiative in 2013. Genome BC’s sector strategy and groupings of Energy and Mining, Fisheries and Aquaculture, Forestry and Agri-Food align with sectors of interest in the National strategy. The National initiative resulted in a document entitled: “Advancing Operations in the Canadian Energy and Mining Sector through State-of-the-Art Genomics Applications”³ which was taken in reference when preparing this BC specific documents.

The aim of this document is to guide strategic investment and setting of research priorities to support sustainable development of BC’s mining sector in alignment with other regional and national priorities.

2 THE IMPORTANCE OF THE MINING SECTOR TO BRITISH COLUMBIA

BC is Canada’s largest exporter of coal, and is particularly well known for high-quality metallurgical coal used for steelmaking. BC is the largest producer in Canada of copper, and the only province producing molybdenum. Nineteen mines are currently in operation (9 metal, 10 coal), and by 2015 eight new mines are planned and nine others to be expanded under the BC Jobs plan. Of the 30,000 people employed in the mineral exploration, mining, and related sectors in 2012 in BC, 12,500 were directly involved in mine operations⁴. The planned expansion is expected to provide a total of 15,000 projected new jobs⁵.

Metallurgical coal is BC’s most valuable mineral commodity and is expected to remain in high demand in Asia. Most of BC’s coal is exported to Japan and South Korea for

---

² http://www.genomebc.ca/portfolio/research-overview/
³ http://www.genomecanada.ca/en/sectorstrategies/
⁵ BC Mining Strategy 2012.
steel production to support large-scale urbanization. It is projected that China will be the biggest coal importer by the early 2020s and is becoming a particularly strong investor in BC’s coal mine developments.

BC’s mineral exports to Asia exceeded those to the US for the first time in 2011. Copper is BC’s highest value metal output and expected to remain in strong demand for use in computer and cell phone technology, some green technologies, and to manufacture anti-microbial surfaces.  

Molybdenum is used for making steel alloys (e.g. stainless steel), tools, and machine parts and is also expected to stay in high demand. Zinc, gold and silver exploration continues to receive attention from investors since supply is limited especially in politically stable regions of the world. BC’s rich mineral potential and stable policy environment is expected to encourage further mineral investment in the province.

3 CHALLENGES AND OPPORTUNITIES IN MINING

The mining subsector faced significant economic uncertainty in 2013. The primary driver of the global mining industry’s growth is commodity prices, which are set in response to global supply and demand. To reduce the risk arising from fluctuations in commodity prices, most firms focus on minimizing capital and operating costs and maximizing extraction efficiencies. Only the most efficient mines can afford to continue operating when prices are low. Financing difficulties and commodity price fluctuations resulted in risk aversion towards investment in non-core activities. Because of the cyclic nature of these industries, it is believed that sooner or later a boom period will follow the current downturn. These challenges provide a unique opportunity for building strong relationships with the industry when executives have more time to learn about innovations that they can implement later when more funds are available.

Mining activities, with their large-scale infrastructure and waste management requirements pose significant risks to surrounding environments including endangered species, remote communities and unique cultures. Mitigation of these risks is an important social, political and increasingly economic factor to consider when reviewing the sector. The critical challenge facing BC’s Mining sector is how to grow the sector efficiently while ensuring its safety, sustainability, and ability to deliver benefits to British Columbians now and in the future. Opportunities lie not only in reducing costs and increasing productivity but also in the development of risk mitigation, monitoring tools and better understanding of the social and

---

6 BC’s Mining Strategy 2012.  
environmental effects of industry activities through high quality sample and data collection.

The mining industry is increasingly conscious about reducing operating costs and increasing productivity. Application of bio-heapeleaching and bioreactors, while successfully employed abroad, has not been widely used in Canada due to a number of technical and economic challenges. There is an opportunity in a careful review of these processes for optimization for Canadian climate and operations.

Genomics research is relatively new to the Mining sector, and regulators, industry, and other sector stakeholders poorly understand its utility. There remains reluctance to embrace technologies that involve bacterial cultures for fear of lack of robustness, sensitivity to changes in process parameters, low process availability and changes in the environment. There is an opportunity to demonstrate the applicability of genomics as a tool to the sector through experience and stories not only from within the industry but also from other sectors where it has already made an impact such as Health or Forestry.

Independent of the economic, infrastructure and innovation context, the sector shares challenges in the following areas, each with special opportunities for genomics that will be covered in detail in the next section:

- Identifying new resource reserves or expanding current ones
- Navigating the regulatory landscape
- Managing public perception, obtaining environmental and social license to operate
- Lack of industry-wide, high quality environmental baseline data and exposure monitoring
- Energy and water sustainability
- Reducing costs associated with environmental remediation and restoration
- Optimizing operational and extraction efficiency
- Increasing industry interest and overcoming distrust of biological processes
THE ROLE OF GENOMICS IN ADDRESSING CHALLENGES AND REALIZING OPPORTUNITIES

4.1 Background

Genome BC was established with the vision that the genomic sciences hold significant potential for providing solutions to the challenges facing societies, economies, and communities in BC. While direct investment in the Mining sector is small (< $2M) compared to its full portfolio of close to $600M, Genome BC has invested approximately $18M in eleven British Columbia-based genomic projects, spanning discovery, applied and translational, that can be applied directly or indirectly to the sector. Table 1 lists the eleven projects covering mining, energy and environment related investments, of which the first two were directly serving the mining industry.

Building on this portfolio, Genome BC is working to maintain engagement in the sector. Consultations with members of the industry, academia, government, associations and supporting organizations suggest that genomics has a potential for making a significant and potentially disruptive contribution to the sector by introducing new processes and tools that can change the status quo. The challenge is to build enough interest that triggers resource investment into exploring genomics solutions through a few demonstration projects such as the two listed in Table 1.

Table 1: Genome BC Funded Projects Applicable to Mining, Energy and Related Environment

<table>
<thead>
<tr>
<th>Project</th>
<th>University</th>
<th>Budget</th>
<th>Partners</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive Mitigation of Mine Drainage</td>
<td>UBC</td>
<td>$1.55M</td>
<td>Teck and Imperial Metals</td>
</tr>
<tr>
<td>Mount Polley Heap Leach Metagenomics Project</td>
<td>none</td>
<td>$28K</td>
<td>Imperial Metals</td>
</tr>
<tr>
<td>Explosives Biodegradation</td>
<td>UBC</td>
<td>$3.45M</td>
<td>US Department of Defence – SERDP, Canadian Dept. of National Defence</td>
</tr>
<tr>
<td>Greener Hydrocarbon: Hydrocarbon Metagenomics</td>
<td>U.Calgary, UBC</td>
<td>$1.93M</td>
<td>Conoco, Encana, Shell, Suncor, Syncrude</td>
</tr>
<tr>
<td>Frog Sentinel species: FrogScope</td>
<td>UVic</td>
<td>$402K</td>
<td>Environment Canada, UBC</td>
</tr>
<tr>
<td>Health Assessment Tool for Marine Mussels: Myt-OME</td>
<td>VIU</td>
<td>$407K</td>
<td></td>
</tr>
<tr>
<td>Microbial Envirogenomics</td>
<td>UBC</td>
<td>$4.6M</td>
<td></td>
</tr>
<tr>
<td>Microbial Community Monitoring as a Forest Management Tool</td>
<td>UBC</td>
<td>$1.3M</td>
<td></td>
</tr>
<tr>
<td>Applied Metagenomics of the Watershed Microbiome</td>
<td>UBC</td>
<td>$3.2M</td>
<td>BCCDC</td>
</tr>
<tr>
<td>Environmental Genomics of RNA Viruses</td>
<td>UBC</td>
<td>$104K</td>
<td></td>
</tr>
<tr>
<td>Community Genomics of Subarctic Oxygen Minimum Zones</td>
<td>UBC</td>
<td>$432K</td>
<td></td>
</tr>
</tbody>
</table>

BC has been a centre of activity, and once a world leader, in the R&D of biological processes applied to mining for over 50 years. This often groundbreaking work was

---

8 Genome sciences encompass genomics and related disciplines including transcriptomics, proteomics, metabolomics, metagenomics, systems biology and bioinformatics that together contribute new insights into the underlying biology of living things.
well supported by the mining industry and led to several developments that are utilized in some areas of the global industry today. Historically, bacterially assisted leaching has been practiced in Canada, notably for uranium extraction in Ontario. Today, several Canadian mining companies, some based in BC, utilize biotechnological approaches in their offshore commercial operations in metals extraction (copper, nickel, gold) and in environmental mitigation applications. However, the promise of a much greater role of bio-technologies in the sector has not been realized. Many companies do not consider such processes as an option and others that do carry out initial evaluations usually end up selecting conventional processing and mitigation routes. Nonetheless, successful advances in commercial applications have taken place outside of Canada both in the extractive and environmental remediation areas of the industry. More recently, new Canadian projects have been announced, including uranium bio-heapleaching and the remediation of arsenic-bearing gold tailings for gold recovery using stirred-tank bioreactors.

Genome BC believes that new tools that genomics can offer at an ever-improving price point, will provide significant opportunities for making even greater impacts on the sector with benefits for all stakeholders.

4.2 Opportunities for Genomics in Mining

Genomics has a potential role in all aspect of the mining lifecycle from prospecting through processing to remediation and closure. It is easy to see a role for genomics in mitigation of environmental disturbances, especially the effects on biodiversity and wildlife. While rocks and minerals have no genomes, the environment around them has special organisms that evolved to serve unique purposes associated with minerals and extreme environments. Most of these unique functions, while embodying true innovation potential, are unexplored to date.

Genomics is the powerful tool to uncover applications exploiting the unique functions of organisms living on or near mining activities. Just as the sequencing of the human genome led to a myriad of applications in cancer diagnosis, tracking of communicable diseases, developing biomarkers to predict drug response, etc.; understanding the microbial world of mining activities has a potential to create new monitoring and process control tools that will inform decision making and optimize processes. Below are examples of specific areas where genomics is expected to make an impact. The areas correlate with the list above, under Challenges and Opportunities in Mining.

---

10 http://www.dnimetals.com
• **Identifying new resource reserves or expanding current ones**

Bacteria play a significant role in moving metal to the surface resulting in anomalies that can be used as indicator for mineralization below. Accordingly, bacterial fingerprinting on the surface may be developed as a new bio-prospecting tool. For example, there are examples of bacterial populations around kimberlites (associated with diamonds) that may provide a link to a geochemical process deep below the surface. Bacterial fingerprinting can be added as supplementary data to geophysical databases for informing exploration.

Optimizing recovery of residual metals from waste (effluents, tailings) via bacterial processes (eg. the Bactech process described below) could yield significant cost savings by improving process efficiency and performance. Higher efficiency extraction and better reliability of the extraction process could increase resource estimates and overall metal production.

• **Navigating the regulatory landscape**

Genomics can map the presence of all active as well as dormant life forms or it can be used to track a selection of DNA fingerprints to gain information about species of interest and their changes over time. The opportunity for genomics is described with examples under the “baseline data” heading below. From a regulatory and permitting point of view this provides an opportunity for supplementing environmental data (based on observation and counting) with DNA fingerprints to better assess the presence or absence of species of interest which will provide fact based information to assess risks described later in this document.

Genomics tools can potentially reduce the cost of environmental assessment and time for permitting if data and tools are shared and standardized across the sector reducing duplication of efforts and increasing transparency. Properties often change hands through mergers and acquisitions and new owners have to redo the work that was already done. Quite often they cannot rely on historical data because it was collected under different or unknown procedures. Industry-wide sample and data collection standards and data depositories could make a significant impact on utilizing environmental data. The sector is already familiar with government sponsored, geoscience databases. Similarly, an environmental database could benefit all users without losing competitive advantage. Genomic data would add an important new layer of information to such databases.

The fairly new field of toxicogenomics can be applied to assess complex and cumulative toxicity profiles once it is not cost prohibitive and its specificity, selectivity and reliability are demonstrated to regulators. Toxicogenomics will help determine which species are vulnerable, and in what ways, to toxic substances based on their
unique genetic make-up. Identifying this susceptibility will allow regulators such as Environment Canada to prioritize species for conservation planning, and develop appropriate conservation activities. As well, regulators will use this information to identify the effects of priority contaminants of concern\textsuperscript{12}. While industry may be concerned about consequences of tighter regulations, in many cases current exposure limits impose very strict windows that are not supported by data, rather were set on the side of caution (e.g. selenium). Genomics could result in relaxing some regulations by providing data where numbers were set arbitrarily\textsuperscript{13}.

Metabolomic, proteomic and/or genomic fingerprinting of contaminant profiles and organisms in water can be used to trace pollution to its source. The Watershed Metagenomics project listed in Table 1 aims to create such tools to manage watersheds through the BC Centre for Disease Control (BCCDC). Source tracking has application not only at potential runoffs into lakes and rivers, but also in testing ballast water on ships for invasive species during transportation of the goods.

- Managing public perception, obtaining environmental and social license to operate

Public opposition to mine development in BC stems, in part, from the perceived risks to its environment including communities and cultures. Genomics can be used to better characterize environmental and health effects and potentially minimize the associated risks.

Environmental impact assessment studies currently rely on models built on physical, chemical and environmental data. Genomics can contribute new information about microorganisms and their interactions that may yield more precise estimation of impacts and risks if added to environmental models. The US Environmental Protection Agency (EPA) states that it is likely that genomics approaches will greatly assist in advancing risk assessment and regulatory policy and decision-making processes\textsuperscript{14}. The EPA has created a genomics task force to examine the broader implications genomics is likely to have on programs and policies in 2004, and the Government of Canada has a similar program under the Genomics Research and Development Initiative (GRDI)\textsuperscript{15}. Better impact assessment tools will be essential for data driven, objective evaluations required to gain public acceptance.

\textsuperscript{12} https://www.ec.gc.ca/faunescience-wildlifescience/default.asp?lang=En\&n=3F9A1AD5-1&xsl=privateArticles2.viewfull&po=13EA4383
\textsuperscript{13} Environmental Health Perspectives, 118/1 January 2010
\textsuperscript{14} http://www.epa.gov/osa/pdfs/EPA-Genomics-White-Paper.pdf
\textsuperscript{15} http://grdi-irdg.collaboration.gc.ca/eng/about/success_stories/toxicogenomics.html
Public perceptions of health effects of mining related activities on human health as well as wildlife are negative, but not supported by rigorous scientific data. There is an opportunity to apply genomics to assess effects of combinations of pollutants, levels and lengths of exposure using toxicogenomics as described above and provide better understanding of causes and effects.

Genomics can also assist in understanding the spread of communicable diseases such as TB in mining communities that will in turn protect workers from future outbreaks as it was demonstrated in a Genome BC /BCCDC collaborative proof of concept study\(^\text{16}\).

- **Lack of industry-wide, high quality baseline data and exposure monitoring**

There is a significant need for new environmental tools to assess impact and bioavailability of potential pollutants, track their sources, and to monitor biodiversity. Genomics has the potential to enable these tools, and thereby provide faster and more conclusive data than current methods based on models or sentinel species. In collaboration between the University of Victoria, Environment Canada and the BC Ministry of Environment, the feasibility of a non-lethal sampling of fish fin was described for the determination of potentially harmful effects of a wide range of environmental contaminants using ‘omics technologies\(^\text{17}\). New methods that provide more certainty will be welcome by public, regulators, as well as industry.

The Barcode of Life project at the University of Guelph uses DNA barcoding to identify species\(^\text{18}\). The project received very strong interest from the mining community when presented at the Biodiversity Workshop at the 2013 TRCR conference in Vancouver. Genomics tools could also enable protection of biodiversity around disturbances using barcoding and fingerprinting to monitor changes in populations, or collection of data on threatened single species, such as the boreal caribou.

Genomic technologies could increase understanding of dietary and other behaviours of critical species and enable identification of habitat requirements, and conservation strategies. Functional genomics could lead to the development of biomarkers for predicting physiological state, fitness or stress, and behaviour, which in turn could inform decision making for habitat restoration.


\(^\text{17}\) Aquatic toxicology (Amsterdam, Netherlands) 09/2013; 142-143C: 239-247

\(^\text{18}\) [http://www.barcodeoflife.org/content/about/what-dna-barcoding](http://www.barcodeoflife.org/content/about/what-dna-barcoding)
• **Energy and water sustainability**

While genomics cannot directly impact energy sustainability of mining operations (however, it can have a significant role in advancing bioenergy not described here), water purification for recycling and reuse is a significant opportunity for applying genomics. Industrial processes use large amounts of freshwater for extraction and processing, creating very large volumes of industrial contaminated water, which if efficiently and effectively recycled, could reduce water consumption, save costs for the industry and protect an important resource.

To meet optimal water quality levels, mining companies treat their water with chemicals to remove dissolved metal. These treatments, while effective, are also expensive and produce their own by products which then must be carefully contained or treated further to ensure safety. Bioremediation of contaminated waters is not new to the industry but it is still not clear what microbial communities live on mine waste, what makes them function and flourish, and how can their function be maximized. The Passive Mitigation project listed in Table 1 is an example for research aimed at uncovering the best mitigation potential, but more research is needed to fully understand the method before monitoring and troubleshooting tools can be designed based on genetic information especially for full scale operations.

There is an increasing number of companies providing waste water purification technologies to the mining industry and many of them apply biological filters in combination with physical separation and chemical treatment (GE Water, Veolia, Inotec, Newterra, Waterloo Biofilter). Company representatives from several of these companies expressed their interest in knowing more about what genomics could do to improve their processes during interviews at trade shows.

• **Reducing costs associated with environmental remediation and restoration**

Planning for closure is an essential part of new mine developments. Planning and data driven demonstrations that convinces regulators of an effective closure plan helps speeding up recovery of funds set aside for closure and often speeds up the permitting stage. For example, better understanding of interactions of bacteria with metals and minerals may uncover new ways of mitigating or even stopping acid rock drainage (ARD) making the currently applied perpetual treatment unnecessary, resulting in significant cost savings. Boojum Research for example, is developing biofilms to stop acid rock drainage and genetic information is used to better understand the underlying biology. BC based BioteQ Environmental Technologies

---

19 [http://www.boojumresearch.com](http://www.boojumresearch.com)
have commercialized ARD remediation processes that provide return on capital investment through the recovery and sale of residual metals in waste rock.

Similarly, remediation of tailings and wastes using optimized microbial inoculums, conditions and feeds could significantly improve the speed and efficiency of remediation compared to current trial and error based methods as it was discussed under water sustainability above. Remediation using passive or active biological treatment is used worldwide but criteria for success are still not clear. While some companies are highly successful applying it on large scale, others struggle to find the right conditions. Genomic evaluation of causes and effects as piloted in the Passive Remediation project in Table 1 could lead to successful industry-wide applications. A white paper prepared by CH2M Hill in 2013 concluded that no treatment technology is “one size fits all” for selenium remediation and active and passive biological processes add a cost effective function to the mix.

Genomics may also assist restoration of specific habitats for threatened wildlife by helping predict the feasibility and outcomes of restoration activities. Genomics can help guide selection of trees and other vegetation for use in forest restoration treatments, while studies of bacterial and archaeal community structure can help guide restoration of peatland habitats.

Restoration of healthy and productive soil after disturbances, especially at colder climates, is a big challenge for the sector. Genomics could enhance the propagation and breeding of native plants that can then be used to restore areas disturbed by industry activities. Scientists at the University of Saskatchewan are actively engaged in restoration efforts in cold climates and are using genomics to better inform their findings.

- **Optimizing operational and extraction efficiency**

The size, scale and location of mining operations are enormous challenges for biological applications. However, countries like Chile produce increasing amount of copper by bio-heap leaching and several companies such as the Canadian firm Biotech have constructed and operate large bioreactors up to 1,500m³ capacity. Challenges with commercial processes are around engineering and process control of very tight parameters to keep microbes happy (temperature, pH, concentrations, oxygen level, etc). Bioreactors are expected to be reliable with minimal downtime, which is currently a major challenge for the industry. Potential opportunities for

---

21 https://www.engr.usask.ca/iFaculty.php?wonjae.chang
genomics and other ‘omics for addressing some of the challenges are in developing monitoring tools especially online or fast turnaround tests to uncover what is happening inside of the reactor or heap at any given time. The company Paques\textsuperscript{22} headquartered in the Netherlands already applies quantitative PCR to follow changes in microbial communities in their bioreactors. Other genomics applications include enrichment of bacteria with optimal metabolic properties for given application.

Current metal extraction technologies such as gravity and flotation processing have efficiencies between 75-90\%. Companies around the world would welcome opportunities to recover the 10-25\% metal left in the rock. Optimizing biological extraction through innovation could provide new ways to recover residuals or extract metals that are difficult to process by current methods.

- **Increasing industry interest and overcoming distrust of biological processes**

  Interest by industry has diminished in recent years resulting in a weakening of the relationship between industry and research of biological systems due to lack of advancement in biological technologies. Industry has been content to maintain the biotechnologies that have been put into practice but without supporting R\&D for new or improved technologies. The advent of new genomic tools has the potential to improve existing technologies already in use and to promote the development of new technologies. In addition, many ideas that have been discarded in the past on technical and/or economic grounds could be revisited.

- **Other opportunities**

  In addition to the mining specific opportunities listed above, there is a potential for identifying alternative revenue sources from exploiting special properties of biomass or microbes thriving in extreme environments for non-mining applications (pharma, nutrition, cosmetics, or material science). For example, new research is aimed at naturally evolved enzymes involved in hydrocarbon conversion that can provide ways to produce synthetically difficult intermediates for the pharmaceutical, food, and cosmetic industries as a result of finding from the Hydrocarbon project in Table 1 and led to a new startup called Metamixis\textsuperscript{23}.

Understanding the soil microbiome and its reaction to environmental or industrial change is a growing field in genomics but very few industrial applications have been implemented to date. KB-1, developed at the University of Toronto and now sold by

\textsuperscript{22} [http://en.paques.nl/pageid=40/Applications.html](http://en.paques.nl/pageid=40/Applications.html) and personal communications

\textsuperscript{23} [http://www.metamixis.com/](http://www.metamixis.com/)
Siremlabs is one example where a specific microbial community was commercialized for the natural removal of chlorinated solvents from contaminated soil\(^24\).

### 5 TOWARDS A GENOMICS STRATEGY

The landscape for genomic research in mining in BC is still in its infancy but leading edge scientists and innovative industry thinkers believe it has great potential for the future.

The capacity and tools for genomic research in BC has increased exponentially and many important partnerships and collaborations have been formed. The pipeline of discovery and applied research, seeded by Genome BC and others, is yielding deliverables being applied by government and industry end users, and is poised to further improve sector sustainability and productivity. While much remains to be done, this strong track record, enabling infrastructure, along with projected growth in demand for BC mining products makes a compelling case for strategic investment in new applications of genomics to BC’s Mining sector\(^25\).

Through extensive consultation culminating in a March 2013 workshop and follow-up survey, the Genome Canada Energy and Mining sector strategy process provided stakeholders with a greater appreciation of commercial and environmental needs for applied genomics. Additionally, Genome Canada has announced a new partnership program called Genomic Applications Partnership Program (GAPP), which aims to: promote the application of genomics to sector challenges; promote commercialization of genomics technologies by enabling the transfer of genomics-derived solutions from academia to users; increase the socio-economic impact of genomics research by accelerating its translation to application or market; and create and foster a more productive interface between academia and users.

Genome BC also launched a new User Partnership Program (UPP) in 2013. UPP is designed to directly address the challenges defined by users in BC’s key sectors, including mining. By engaging industry, government regulators, health authorities, not-for-profit organizations and other sector users early in the implementation process, Genome BC aims to improve the translation of research innovations to products, services, policy, and practices.

Genome BC has been consulting with stakeholders in Canada’s and BC’s Mining sector to understand how genomics might be applied to maximize economic and social benefits arising from various sector activities. Based on this intelligence, and

\(^{24}\) [http://www.siremlab.com/products/kb-1]

\(^{25}\) Genome BC Energy & Mining Sector Asset Map 2013

Genome BC Sector Strategy for Mining

As at May 2014
supported by its experience in applying genomic tools to other natural resources sectors as well as health, a priority list of targeted applications of genomics to BC’s Mining sector is being developed for discussion and consultation.

5.1 Priority Areas

Given the particular challenges and opportunities facing BC’s sector (see section 3) and the strategic plans of key provincial and national stakeholders four key areas have been identified as those most likely to contribute to the sustainability or productivity of BC’s Mining sector. Details and examples of what genomics can contribute to these areas were described in Section 4.

i. Water, Effluent
Increasing demand and decreasing supply of fresh water makes it necessary to reduce, reuse and recycle water used at every stage of operations. Water is a common challenge for the industry but is not seen as part of proprietary know how that companies protect from each other in order to gain competitive advantage. It is more likely that mining operations will collaborate in research aimed at more efficient water utilization. Water purification suppliers such as GE Water, Inotek and Envirogen may also be interested in the collaborative effort.

ii. Processing, Refining, Extracting
A second priority is the application of genomics to processing. This is a more guarded area of operations and it is more likely that companies will only invest in research in a tightly guarded group because results will affect their cost curves and bottom line. Bioreactors, bioheapleaching and new methods for precious and base metals and rare earths to increase recovery are potential areas for development.

iii. Remediation, Tailings
Genomics offers significant potential to provide new tools for remediation of disturbed sites, removing traces of metals by microbial processes from waste, degrading hydrocarbon and other contaminants, and monitoring or preventing acid rock drainage. Similarly to water, remediation is also a precompetitive area where companies will likely collaborate to solve industry-wide challenges.

iv. Environmental and Risk Assessment
One of the most important applications of genomics and related sciences to BC’s Mining sector relates to enhancing the sector’s social license (i.e. perceptions of citizens that can influence the extent to which they support or reject various industrial activities). Genomics could help build the social license in a number of important ways as it was described in Section 4. Research aimed at environmental and risk assessment is expected to be collaborative and will involve regulators, environmental organizations, consultants and industry players.
5.2 Implementing a Genomics Strategy

The application of genomics within BC’s Mining sector has the potential to enable strong, competitive sector growth based on product quality and security, technological soundness, economic viability, environmental integrity and social license. However, real progress towards these goals will depend on a number of factors.

Alignment with Stakeholders and Their Strategic Priorities:
The vision outlined in the current document must be well aligned with the strategic priorities of other stakeholders in the sector. Building and maintaining this alignment will be critical for success; strategies that include and address the needs of all stakeholders will build goodwill and commitment, attract greater investment and collaboration, and yield greater, more broadly beneficial results.

- Environment Canada
- Canada’s Energy Strategy
- Ministry of Mining and Energy Strategic Plan
- Ministry of Environment
- Ministry of Forests, Lands and Natural Resources
- BC Ministry Service Plans
- Industry Priorities
- Public Priorities
- Genome BC 2015-2020 Strategic Plan

A Roadmap for Using Genomics to Position BC’s Mining Sector for Success:
The overarching goal of developing a genomics strategy for BC’s Mining sector is to distill knowledge of the challenges and opportunities facing the sector, the previous investments and strengths, and the priorities of all stakeholders relevant to the sector into an actionable set of next steps.

The Genome BC 2015-2020 Strategic Plan targets application for genomics in the following areas in the Mining subsector and related environmental challenges. Applications

---

28 http://www.empr.gov.bc.ca/Mining/Strategy2012/Pages/default.aspx
29 http://www.eao.gov.bc.ca/
30 http://www.for.gov.bc.ca/major_projects/mining/
31 http://bcbudget.gov.bc.ca/2014/serviceplans.htm
32 GenomeBC 2015-2020 Strategic Plan
are envisioned in partnership with industry, as well as federal and provincial partners such as BC Mining Association, BC Ministry of Energy and Mines, BC Ministry of Environment, Environment Canada, and the Canadian Mining Innovation Council:

- Characterize and manipulate microbial communities involved in remediation of tailings to improve water quality.
- Apply novel tools that are economical alternatives to current standards in order to improve water quality and water treatment affected by human activities.
- Decrease the environmental footprint of mining extraction via advances in bioremediation.
- New tools to mitigate acid rock drainage.
- Increase the rigor in assessing and monitoring environmental impacts, biodiversity, bioavailability, toxicity, and tracking sources of pollution.
- Identify microbial communities and the genes responsible for detoxifying common environmental contaminants from human activities, which will pave the way for creating new technologies/new organisms to enable remediation.
- Monitor ecosystem changes (at a molecular level) for early detection of harmful impacts to the environment or to human health, and develop metrics for environmental health.
- Record BC’s biodiversity (land and water) in a digital catalogue of life in order to improve ecosystem monitoring, control agricultural and forestry pests and invasive species, and uncover organisms that can benefit society.
- Improve resource recovery of extractive technologies

The strategic plan also targets opportunities for commercialization:

- Partner to advance 5 new products/tools such as predictive tools for acid rock drainage; bacterial fingerprinting for detecting deep mineralization; monitoring tool to assess operational efficiency in bioreactor or heap leach pile; database for environmental data; etc., for advancing the productivity/profitability of private sector.
- Partner to advance 5 new environmental products and services. Many of these will benefit other sectors and will cut across several sectors. Opportunities with government regulators also exist to adopt technologies where there is demonstrated benefit to preserving BC’s environmental ecosystem and monitoring impacts of human activities.

We view the following as the essential steps most likely to advance BC’s Mining sector over the short- and mid-term through genomics:
• Create a value proposition to industry evaluating the impact a potential new genomic tool could make on a current process. Leveraging relationship with industry, associations and consultants an economic assessment should be prepared that compares a current technology with a biological one in strategic areas. Based on industry feedback such document is the first step to gain interest in innovation.

• Build partnerships to support more evidence-based research. Partnerships with academic researchers in priority areas are of strategic importance since they most likely have close industry ties that can immediately be leveraged for new projects. Moving forward, Genome BC needs to catalyze more relationships like these while promoting application of research findings to areas of importance in mining. Close and enduring relationship with heads of research, engineering or sciences in BC academic institutions (through meetings, cosponsoring workshops, roundtable discussions, focus groups) will assure that Genome BC is involved in any project discussion that has a biological component and has an opportunity of adding value to project impacts.

• Parallel with this “bottom up” approach, it is important to build relationship with associations and regulators (through attending committee meetings, promoting genomics through presentations and stories, attending conferences and workshops, hosting short courses, focus groups, discussions, etc.) who then can drive direction of research and innovation towards relevance to industry. This “top down” approach requires a critical mass of scientists who can respond to the calls of the industry.

• The Entrepreneurship Education in Genomics (EEG) program by Genome Canada provides students with opportunities to see where their research findings might be applied in the industry, who will be the users and what commercialization paths exist for their innovations. Upon graduation, these students are expected to have a more industry relevant and market ready mentality about research. Similar initiatives through collaboration with business schools, innovation offices, technology transfer offices can ensure that future researchers are best positioned for answering to industry challenges. Sponsorship of industry chairs is another approach Genome BC can take to make sure research capacity for applying genomics to mining is sufficient in BC.

• In order to fully understand the sector, Genome BC has created an “asset map” for the mining industry in BC\(^3\). The asset map is a living document and lists mines, suppliers, consultants, industry experts, associations, academic experts, genomics experts, regulators, government bodies, infrastructure, markets,

\(^3\) Genome BC Energy & Mining Sector Asset Map 2013

Genome BC Sector Strategy for Mining

As at May 2014
transportations, etc. specific for the BC context. The asset map can be drawn upon when evaluating opportunities and challenges for genomics in the Mining sector.

- Upon implementation barriers must be understood and mitigated. Biological processes are rarely a core function in this industry, the end products of metal and coal have no genes, and processes are driven by engineers and chemists. Accordingly, it is essential to develop a targeted communications and education strategy to increase sector and public knowledge about genomics and its potential in mining. It is also essential that researchers and others within the genomics and the biological sciences in general, develop a clear understanding of the needs, challenges and priorities facing the industry in its operations and new mine developments. The communication strategy needs to cover industry publications that reach the right audience, as well as it needs to inform approaches described above for academic and industry outreach. Stories from proof of concept projects, outcomes of workshops and roundtables and other forums can be shared with a wide audience through industry associations. Applications of genomics can be demonstrated through presentations at conferences, and by visiting associations and governing bodies. Sponsorships and memberships in strategic areas will provide visibility for Genome BC and can build a reputation that could ease access to important stakeholders and decision makers.

- Creation of industry innovation consortia with focus on applying genomics to areas of economic, environmental and/or social importance can address common challenges for the industry (i.e. restoring disturbances such as open pits, removal of trace metals from waste, etc). Government support for mining is strong in BC, but in order to gain public acceptance, many conditions need to be met as it became evident in the recent downturn of Taseko Mine’s New Prosperity proposal. Because most of the conditions are environment related, Genome BC needs to be at the table where investment in research to address the conditions is discussed.

- The sector strategy must be supplemented with a comprehensive consultation process. Feedback from industry experts, national and international associations, consultants, government, regulators, and researchers from around the world needs to be solicited regularly in order to stay competitive and relevant. Establishment of and regular communication with sector steering committees is essential to ensure successful implementation of the strategy.

- Invest in high priority areas with near-term impact to demonstrate the value of genomics to industry participants and regulators. In order to gain acceptance by the sector, it is essential to develop a portfolio of proof of concept stories
that can demonstrate the applicability of genomics to opportunities described in Section 4.2.

- Develop longer-term priorities for genomics investments and developments through targeted programs, economic development incentives, building on research capacity, etc. Longer-term efforts should aim to create large-scale high impact projects to demonstrate full scale and industry wide applicability of genomics in mining. Collaboration with industry associations, regulators, economic development organizations and other funders is seen as key to success for a long-term strategy.

Taken together, these steps will give industrial, academic and government stakeholders the tools to propel BC's Mining sector to a sustainable international leadership position in the global market for mining products and services.
POWERING
BC’S MINING SECTOR

400 – 575 West 8th Ave
Vancouver, BC V5Z 0C4
T: 604 738 8072
F: 604 738 8597
E: info@genomebc.ca
www.genomebc.ca