Strategic Overview of Possible Mineral Development Scenarios – Phase 1
Peel River Watershed Planning Region

Prepared for
Economic Development
Government of Yukon

Submitted by
Gartner Lee Limited

September 2006

Gartner Lee

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September 7, 2006

Dennis Berry
Department of Economic Development,
Government of Yukon
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Whitehorse, Yukon Y1A 2C6

Dear Mr. Berry:

Re: 60285 – Strategic Overview of Possible Mineral Development Scenarios, Phase 1 Peel River Watershed Planning Region

Gartner Lee Limited is pleased to provide our revised final report on the above noted project. This has been a most interesting project and we look forward to assisting the Government of Yukon on any future phases of this work. In the meantime, if you have any questions, please do not hesitate to contact the undersigned at 633-6474.

Yours very truly,
GARTNER LEE LIMITED

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(60285_FNLRPT_Sept2006.doc)

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1. Introduction

The Peel River Watershed planning region hosts some of the most important mineral resources of the Yukon and Canada. However, due the remote nature of this area, it is largely under-explored and is not as well understood geologically as other parts of the Yukon. There are already a large number of high quality mineral occurrences and deposits in the area. This area has some of the best potential for new deposit discoveries in the Yukon.

1.1 Scope of Work

The objective of this work is to generate probable mineral development scenarios for the Peel River, given the known opportunities and constraints, to assist the Peel River Watershed Planning Commission with assessing future land use scenarios for the region. The first phase of this work includes:

1. A brief overview of existing legislation and regulation that are relevant to mineral development;
2. A discussion of current and possible future market conditions that include potential for mineral development;
3. A summary of mineral potential and known mineral resources in the study area, including identification of highest potential for know resources and areas of potential future discovery; and
4. Example of possible development scenarios for key types of mineral deposits known or possible in the study area. This will include key infrastructure needs (in the study area) for these deposits, and possible scenarios for providing those infrastructure

1.2 Statement of Limitations

The evaluation of mineral resources and mineral resource potential is by virtue of its nature, a very difficult task. Specifically:

1. Mineral resources are buried below the ground and not readily visible, measurable or even known. In other words, minerals are buried in the earth, therefore we cannot see them and cannot easily find them.
2. Mineral deposits (e.g. areas where minerals and elements are concentrated sufficiently in the earth such that they can be feasibly extracted) are rare and are relatively small in area; even the largest mineral deposits are only one or two kilometers in size, most are only several hundred meters in size. Finding a mineral deposit is very much equivalent to finding a needle in a haystack.

3. The search for buried mineral deposits essentially involves looking for some indication on the surface that there might be minerals buried below.

These factors significantly differentiate the quantification of mineral resources from other natural resources such as forestry or an oil & gas resource. Other natural resources are much more amenable to measurement, quantification, and prediction; however the same level of quantification, prediction and certainly simply cannot be expected from mineral resources.

The second confounding set of issues associated with mineral resources is the ever-evolving world of geosciences and the mineral industry:

1. The state of understanding of the earth and geosciences really is in its infancy. New discoveries continue to be made regularly with respect to how the earth, rocks and landscape were formed. This is especially true in the Yukon, and the Peel region specifically, given the remote nature of the area, which has seen very limited research and science.
2. New ideas and new theories allow for the discovery of new types of mineral deposits. This sometimes includes areas that were previously thought of as low mineral potential. An example of this is the Finlayson district, which in 1980's had no known mineral deposits, but now we know it hosts a number of high grade metal deposits, one of which (the Wolverine Deposit) may be in production in the near future.
3. Demand for mineral resources, and the prices paid for those resources, is highly dynamic and price trends are notoriously difficult to predict. A mineral deposit that is not economic today may become economic tomorrow based on a change in metal prices worldwide.
4. New technologies are constantly emerging. These technologies allow for mining of mineral resources that may not have been feasible using traditional technologies. Many of the emerging mineral resource technologies allow for extraction of minerals with reduced environmental impact (cost), thereby increasing the overall deposit's potential feasibility.

Due to these issues, many geoscience experts are very reluctant to estimate mineral potential given the extremely high level of uncertainty and ever evolving state of knowledge. Given these limitations, the current work represents a reasonable approach and basis from which to begin to understand the potential mineral resources in the Peel River basin.

It is important to understand that this work is based on the geosciences community's best information and assessment to date. In the future new information, new discoveries, research and world market trends may radically alter the results of these assessments. New mineral deposits will be found within the Yukon, but when and where these finds will be made is largely unknown. Therefore, the management of our environment and natural resources in the context of land use planning should consider how best to anticipate and change our understanding of the earth and mineral resources it provides to us in the future.

2. Mineral Development Legislation and Regulation Overview

2.1 Environmental and Socio-economic Assessment

Generally this is a process to predict the environmental and socio-economic effects of proposed projects before they are carried out. This is done before any decisions are taken on whether, or how, a mining project may proceed. The process involves:

- Identification of possible effects;
- Proposing measures to mitigate adverse effects;
- Predicting whether, after implementing mitigation, there would be significant adverse effects; and
- Effects if a proposed project were to proceed.

The specific focus and requirements may change depending on the location of the project and the specific requirements of the legislation that applies in that location as outlined below.

2.2 Yukon Environmental and Socio-economic Assessment Act

Most environmental assessments in the Yukon are conducted according to the *Yukon Environmental and Socio-economic Assessment Act* (YESAA). This is federal legislation that sets out a process to assess the environmental and socio-economic effects of projects and certain activities in the Yukon. YESAA is legislation that flows from the requirements established in Chapter 12 - Development Assessment Process - of the *Umbrella Final Agreement* and of Yukon First Nations' Final Agreements.

The act establishes the Yukon Environmental and Socio-economic Assessment Board (YESAB). YESAB is an independent arms-length entity, made up of seven Board members, which is responsible for the implementation of the Act. Assessments under the Act are carried out by the Designated Offices, the Executive Committee and Panels of the Board according to specific regulations and rules established by the board. Assessments look at the environmental and socio-economic effects (positive and negative) of activities and are intended to integrate scientific information, traditional knowledge and other local knowledge and provide recommendations to governments that have management responsibility for the mining project. The assessment process incorporates principles that include recognizing and enhancing traditional First Nation economies and providing participation opportunities for interested persons.

The role the Yukon Government or federal government in the YESAA process may be as a "Decision Body." This is an agency responsible for issuing authorizations or permits. For a mining project, this can be Yukon Government, with respect to a Quartz Mine License, or the federal government if federal authorizations are required from Fisheries and Oceans if there is an impact to fisheries habitat.

First Nations would be Decision Bodies under YESAA for any projects that are proposed for assessment on settlement lands. For projects on crown lands, First Nations are expected to be active participants in all stages of the assessment process.

The legislation includes a requirement for consultation with affected First Nations prior to submission of a project for review.

2.3 Projects Affecting the Mackenzie Valley

The project area's eastern boundary is the Mackenzie Valley, a region covering a majority of the Northwest Territories. Where projects (either proposed in the Yukon or the Mackenzie Valley) have trans-boundary effects that are potentially significant on the other's jurisdiction or where a project physically crosses the boundary, assessment responsibilities are shared between the jurisdictions. Such projects may be subject to environmental assessment under the *Mackenzie Valley Resource Management Act* (MVRMA).

Major Mining Projects proposed in the Yukon that are likely to have impacts in the Mackenzie will involve the Mackenzie Valley Environmental Impact Review Board (MVEIRB). A joint assessment process may occur between the Yukon Socio-economic Assessment Board YESAB) and the MVEIRB. If there is a federal decision required, the Canadian Environmental Assessment Agency could be involved in a coordinating role, to facilitate the multi-jurisdictional assessment process.

2.4 Projects Affecting the Gwich'in Settlement Region

The Yukon portion of the Gwitchin Settlement Region consists of a Primary Use Area that includes a large portion of the Peel River Watershed and a Secondary Use Area in the Richardson Mountains. Projects in these areas would be subject to review by the *Yukon Environmental and Socio-Economic Assessment Act* (YESAA) as well as other Yukon and federal statutes that apply to mining activity. The most important of these are briefly described in the following sections.

2.5 Quartz Mining Act

This Yukon legislation governs hard rock mining activities in Yukon. This act is in two parts; Part 1 deals with the disposition of mineral rights on crown lands. It establishes a process for acquiring mineral rights by staking claims and a process to manage these rights by establishing specific requirements to record and maintain mineral claims. Part 2 establishes specific reclamation requirements for exploration activities. These are defined in the Mining Land Use Regulations under this legislation. The legislation also establishes the requirement for an operator to obtain a "Quartz Mine License." Generally these licenses establish terms and conditions for land-based impacts for mining projects.

2.6 Placer Mining Act

This legislation is very similar to the Quartz Mining Act, except that it is specifically designed to manage mining of surface gravels.

2.7 Waters Act

This legislation establishes requirements for licensing the use of water and the deposit of waste in Yukon. Virtually all mining projects require the use of water and a license issued under the authority of this legislation.

The *Waters Act* establishes the Yukon Water Board. The mandate of the Yukon Water Board is described in Section 12 of the act:

> *"The objectives of the Board are to provide for the conservation, development and utilization of waters in a manner that will provide the optimum benefit therefrom for all Canadians and for the residents of the Yukon Territory in particular."*

The Board also has statutory obligations under Chapter 14 of the Umbrella Final Agreement (*"UFA"*), principally that the Board shall not authorize any substantial alteration of the quantity, quality or rate of flow of water on or adjacent to settlement land, unless it is satisfied that there is no alternative which could reasonably satisfy the requirements of the applicant and there are no reasonable measures by which the applicant could avoid causing the alteration. There are also similar obligations upon the Board where a traditional use of water by a First Nation person in their traditional territory may be adversely affected by a licensed use.

Mining projects must also meet the requirements of the *Metal Mining Effluent Regulations ("MMER")* for the discharge of waste.

The Board may issue two types of licenses. Type "A" licenses generally are for larger projects, and often involve a public hearing. These licenses require the signature of the Yukon Government Minister responsible for the Water Board. This is the Minister of Executive Council Office. Type "B" licenses are generally for smaller projects and are issued directly by the Board. The criteria for each type is defined in regulation. Licenses for major projects normally include requirements for financial security.

The Board operates according to the rules of *Natural Justice and Procedural Fairness*.

2.8 Territorial Lands (Yukon) Act

This Yukon legislation governs the use of vacant crown lands in Yukon. Mining projects require authorizations under the Lands Act for certain kinds of activity as follows:

- Surface lease of mining rights;
- Land Use Regulation (for activities that do not occur on mining claims and are not regulated under the Quartz Mining Act or Placer Mining Act such as access roads that are not on mining claims;
- Quarry Regulation (commonly for gravel pits used on road construction);and
- Coal Regulation (for coal mining projects)

2.9 Other legislation

Numerous laws of general application apply to mining activity. Examples of particular significance include:

Yukon Statutes

- *Yukon Environment Act*
- *Occupational Health and Safety Act*

Federal Statutes

- *Fisheries Act*
- *Canadian Environmental Protection Act*

2.10 Yukon Mine Site Reclamation and Closure Policy

This policy establishes requirements for mining companies to address the costs of reclamation of land used for mining purposes. It is designed to encourage early reclamation and closure planning, to recognize progressive reclamation, and to ensure that public risk for closure liability is minimized.

Key components of the policy include:

- Mine operators are responsible for reclamation, care, maintenance and abandonment of the site;
- Every mine is required to have an approved reclamation and closure plan that has been approved by the Yukon government before development proceeds;
- The reclamation and closure plan will be adjusted at regular intervals as new information is collected; and
- A Certificate of Closure will be issued when mine development or production and reclamation is terminated and the Yukon government is satisfied that the mine operator has complied with all license conditions.

The Yukon government will determine the form and amount of security, to be provided by the mine operator, to cover the full amount of outstanding mine reclamation and closure liability. The amount will be periodically adjusted in accordance with decreased or increased site liability.

3. Discussion of the Mineral Commodity Market Trends and Mineral Development

3.1 The Immediate (Short Term) Outlook

It is important to distinguish between short-term market cycles and long-term trends based on market fundamentals. Metal prices have increased, on average, 70% over the last three years. A market analysis and projection published in 1999 by the World Bank Commodities Team [1] did not foresee this short-term event and, at that time, forecast a gradual improvement in prices for the long-term, based on market fundamentals. These longer-term trends are similar to those predicted today by the World Bank, six years later, and at a time of significantly improved market conditions. While the short term changes are noted, the important consideration for the longer term are the fundamentals, as noted above.

Short-term cyclical changes are a function of a complex interplay between supply and demand driven by global economic circumstances, smelter capacity, stockpiles, cost of fuel, and the timing of supply due to mine closures and new discoveries. Most market analysis focus on these short-term factors to try and predict price movements in the near future, generally for the purpose of informing investment decisions. Historically, metal prices show a cyclical pattern in response to the variety of economic circumstances.

The World Bank offers the following concise analysis of the current situation and immediate outlook:[2]

> “Although metals and mineral prices rose during the first months of the year, they have since stabilized, and in October 2005 they were at the same level as in March of that year. Conditions in some metals and minerals markets remain tight, due to low inventories and various supply disruptions. In the case of aluminum, copper and zinc, prices remain elevated (partly reflecting higher energy content in the production of these goods). Demand has weakened markedly for tin and nickel.
>
> Analysis of past non-oil commodity cycles suggests that this one may have run its course. Already, it distinguishes itself from previous episodes by having lasted longer. In part, because energy prices have also been high, which was not always the case during previous episodes.
>
> In so far as high fuel prices increase production costs in both agriculture and metals and minerals, they may have reduced the supply response, keeping prices higher longer.
>
> In line with the projected slowdown in global growth and increased supply, prices of agricultural products and metals and minerals are projected to decline somewhat in 2006.
>
> After several years of rising commodity prices, there are indications of a stabilization and even reversal of gains in the markets for…metals and minerals.”

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[1] Global Commodities Markets: a Comprehensive review and price forecast, World Bank publication Volume 7, 1234, #19880

[2] World Bank Prospects for a Global Economy, 2006, Online Companion, November 16th, 2005.

3.2 The Long-term Outlook

Most of the forecasts for mineral commodities rely on the assumption that the market fundamentals as they relate to mineral development in the past will be a useful guide to the future.

Essentially, commodity prices are a function of supply and demand driven by the factors noted above. Mineral commodities are unique in that this supply of wealth is buried, and requires sophisticated methods of exploration and development to find, extract and market. The quantity, quality and location of mineral commodities is not definitively known.

John Tilden, a leading academic in the field of mineral commodities[3] makes the following observations in the context of considering the worldwide supply of minerals in the future:

> “While global demand is expected to continue to grow, the reserves for almost all mineral commodities are sufficient to last for at least several decades even at growth rates above those currently prevailing. We also know that reserves are not fixed, but are more appropriately thought of as working inventories. By exploration and other means, companies can and do add to reserves over time, and additions to global reserves have in the recent past occurred on a regular basis. This coupled with the stable or falling production costs and prices for many mineral commodities over the past several decades has produced a widespread consensus among the experts that the threat of mineral depletion is not an immediate concern.”

Tildon goes on to say:

> “…the availability of mineral commodities over the long run largely depends on a race between the cost reducing effects of new technology and the cost-increasing effects of resource depletion. While new technology has successfully offset the adverse effects of depletion over the past century, the course of new technology in the future is impossible to predict. This means no one knows for certain the future trends in resource availability.”

China is a major player in most commodities. In terms of scale and magnitude, China’s mining industry ranks third in the world, although production statistics are sketchy. Most of China’s mineral production is consumed locally by state owned enterprises or banks. The country has about 80,000 state-owned mining enterprises and 200 000 collectively owned mines.

It appears that much of the current upward pressure on mineral commodities relates to the continued demand within China for mineral products. China is now becoming a net importer, rather than exporter of

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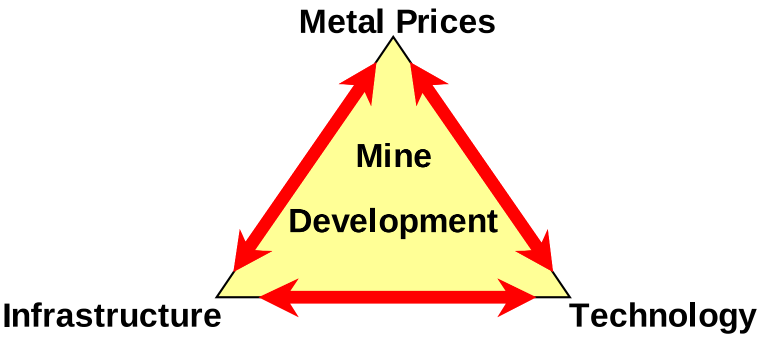
[3] Depletion and Long Term Availability of Mineral Commodities, John E. Tilden, Colorado School of Mines, 2001

metals. It is reasonable to believe, as the Chinese and other Asian economies continue to develop rapidly, that commodity prices will continue to show strength in the coming years.

3.2.1 Conditions for Mineral Development

The conditions required to make development of any given mineral deposit viable are varied and complex. Obviously, a pre-requisite for development of a mine is that the mineral resource must be present: mineral deposits do not simply exist everywhere, but represent a very unique location where the mineral resource of interest is concentrated by some geological phenomenon. The discovery of the location is the focus of much of the economic activity around the world. In other words, mines can only exist where the minerals are found; mines cannot be relocated or substituted, as each deposit is unique.

Once the mineral resource is established, the successful development of mine relies primarily on the conjunction of three factors as illustrated below:



- Metal Prices, the focus of the discussion above, are a function of the global market. World metal prices must be sufficient such that the value of the ore mined covers the cost of the mine development, operation, closure and a reasonable expectation of profit.
- Technology: mining technology improves over time, driving the cost of mine development ever lower (including costs associated with increasing environmental responsibility). This allows for the development of deposits what were historically sub-economic.
- Infrastructure: the last apex is the means for transporting resources to the mine site and the transportation of the mine's commodity to market. The infrastructure required for this transportation must exist or be developed such that the transportation is cost effective in the context of the mine development.

Regulatory environment and resource/tenure certainty are often citied as requisites for mine development. However, without the conjunction of the elements of metal price, infrastructure and technology, the mine development will not occur, regardless of the social environment. The inverse is also true: should the mine development conditions be met, and the project look highly viable, the issues of regulatory environment and resource/tenure certainly can be addressed.

4. Mineral Potential and Mineral Resources of the Peel Planning Region

The Peel planning region hosts some of the Yukon’s and Canada’s most significant mineral deposits:

1. The Crest iron deposit found in the study area, is the largest iron ore deposit in North American, and therefore is truly a resource of national and global importance;
2. The Bonnet Plume coal deposits contain 85% of the Yukon’s known coal resource, and as such represent an important potential long-term energy resource for the Yukon.
3. The Wernecke Mountains contain unique rocks referred to as “Wernecke Breccias”. The same rocks are found in Australia, where there they host very successful copper-gold-uranium mines. These are significant deposits and they are likely to be found in the Wernecke Mountains as well. Already, to date, multiple mineral occurrences of this type have been found with potential for finding viable deposits of this type.
4. There are at least two known lead-zinc deposits of modest size with many additional lead-zinc occurrences, suggesting excellent potential for more lead-zinc deposit discoveries.

4.1.1 Mineral Deposit Types

When evaluating mineral resources and mineral potential, it is best to assess these based on mineral deposit types. The rationale is that mineral deposits can be grouped into types defined by a “deposit model”, and by using the deposit model, the expected size, grades, metals contained and other issues can be estimated. The concept of mineral deposit models is important because the type and size of a mine development can be best predicted/estimated by its deposit type.

By using deposit types, trends can assist in predicting these types of deposits are found and where new, similar discoveries could potentially be made. Mineral occurrences are inventoried in a database maintained by the Yukon Geological Survey. This database contains summaries of all the known information about the known mineral occurrences. Within the Peel River watershed planning region, there are 219 known mineral occurrences (Deklerk and Traynor 2005). With respect to deposit types found in the planning region, they are classified as follows:

Table 1 . Summary of Mineral Deposit Types in Peel Planning Region

Deposit Model	Number of Occurrences	No. of Known Deposits	Comment
Carbonate hosted Lead-Zinc deposits (Mississippi Valley Type (MVT) and "Blende" type)	71	1	Similar to Prairie Creek NWT, Pine Point, NWT or Polaris Mine, NU
Iron Oxide Copper Gold (IOCG) Copper, Gold, Uranium, Cobalt	56	1 (iron reserve only)	Similar to Cloncurry District, Australia
Iron Formation	1	1	Crest Iron Deposit
Coal	16	7	Most detailed studies been done on Illtyd Creek deposit.
Volcanogenic Massive Sulphide (VMS), Copper-lead-zinc-silver-gold	3	1	Similar to deposits of Finlayson District
Sedimentary Exhalative (Sedex) Lead-Zinc-Silver	4	0	Similar to Faro Mine
Polymetallic veins	18	0	Most likely related to IOCG occurrences
Copper-silver veins	16	0	Most likely related to IOCG occurrences
Bedded gypsum	2	0	Industrial mineral typically used for manufacture of drywall (wallboard)
Sediment hosted Barite	3	0	
Barite veins	2	0	
Other	4	0	Misc. other deposit types
Unknown	20	0	
Total	219	13	

Of the deposit types listed in Table 1, the first six are likely the most important to the Peel Region. Given the constraints of the current scope of work and extent of geological knowledge, only the first five are discussed in further detail in the following sections with regards to known resources and mineral potential. In the opinion of the project team, the general order of importance of these deposit types is as follows:

1. Crest Iron
2. Wernecke Breccias (IOCG)
3. Carbonate hosted Pb-Zn deposits
4. Coal
5. Sedex Lead-Zinc deposits

4.2 Crest Iron

The Crest Iron deposit is a flat lying, sedimentary iron deposit located at the headwaters of Iron Creek, a tributary of the Snake River, near the NWT-Yukon border. The deposit is a world-class size deposit, and is the largest of its type in North America. The US Geological Survey estimates that the current US-Canada known iron reserve base is 7,100 million tones of iron (Jorgenson 2006). The Crest deposit contains some 2,600 million tonnes of iron: therefore the Yukon's Crest deposit alone constitutes almost 40% of Canada and the United States iron reserves. Given the importance of this resource, it is not a question of *if* the Crest deposit will be developed, but rather a question of *when* the deposit will be developed. If the Crest iron deposit is not developed in a near future metal cycle, then it will be a resource that will be utilized by our children or our grandchildren. The development of this deposit to date has largely been limited by its remote location and lack of infrastructure required for the transport of iron ore.

The iron ore at the Crest consists of relatively flat lying strata of iron oxide (hematite) ore. Much of this ore is exposed at surface or requires minimal stripping. The Yukon Minfile states the current reserve estimate at the Crest is 3.2 billion tonnes of iron ore accessible at a 1:1 or less stripping ratio (ratio of ore to waste rock), and at a grade of approximately 44% iron. The 1963 assessment report filed by Crest Exploration Company was reviewed for the current project and in that report it states the ore reserve is 6 billion tonnes, with potential for over 20 billion tonnes of iron ore. The ore is relatively fine grained and contains phosphate (an undesirable mineral in iron ore), and therefore the ore would have to be milled and processed before it could be usable in steel making.

The location of the Crest deposit is shown on Figure 1. The extent of the known deposit reserve actually covers a large area (relatively speaking for mines), an area approximately 9 km x 8 km. The iron bearing rock formation is referred to as the "Rapitan Group". The extent of this formation is shown as Figure 1, and it represents the most likely area where, within the Peel River Watershed area, potential exists for finding similar deposits.

Note that the iron-oxide copper-gold mineral occurrences of the Wernecke Breccias (discussed below), are sometimes considered for iron ore potential. However, relative to the Crest, these deposits (e.g. the Pagisteel deposit) are relatively low grade and small size for iron deposits. Therefore, it is assumed that the Wernecke Breccia deposits would not be mined for their iron content.

4.3 Wernecke Breccias (IOCG)

Wernecke Breccias host potential iron-oxide copper gold deposits. To date, there have been no deposits of this type delineated in the Yukon, however there is excellent potential for their discovery. Currently, there are over 71 known occurrences of this type in the Peel River Watershed planning region. It is believed that the mineralization of the Wernecke Breccias are most similar to the Cloncurry district in Australia. (Hunt, pers. comm., 2006) This district in Australia hosts a number of large, successful copper gold mines, including the 167 million tonne Ernest Henry mine. These deposits are typically mined for copper, gold and occasionally cobalt and uranium. Of eight deposits in the Cloncurry district reported by Williams and Skirrow (2000), the median deposit size of this group is 3.6 million tonnes, with 10% of deposits being larger than 40 million tonnes. Median copper and gold grades of these deposits is 1.5% and 1.5 g/t respectively.

The location of the known IOCG occurrence in the Peel River Watershed planning region are illustrated on Figure 2. In the area of the known IOGC occurrence there are numerous others, often vein type occurrences. These are likely related to the IOCG mineralization. The Wernecke Breccias are confined to a group of old rocks known as the Wernecke Supergroup. The outline of the known extent of Wernecke Supergroup is shown on Figure 2.

The Yukon Geological Survey has recently completed a new mineral assessment for the Peel Region. These mineral assessments used by the Yukon Geological Survey are a state-of-the-art methodology that represent the best possible attempt at addressing the difficult problem of mineral potential. These assessments combine the best known geological information (from a variety of sources) for a given deposit type, along with interpretations from a panel of leading geological experts on the region and type of deposits. This data is then used to generate a probabilistic model of which belts are rocks are most likely to host a given deposit type.

A special set of scenarios have been run by the Yukon Geological Survey at the request of the project team for the purposes of this current project. Specifically, the Peel region and North Yukon Region mineral assessments have been combined and a set of deposit specific mineral potential assessments have been generated. The mineral potential for IOCG deposits is shown on Figure 2. This illustrates the areas where it would be most likely to find deposits of this type.

4.4 Carbonate Hosted Lead-Zinc Deposits

The carbonate rocks (limestone dolomite, etc.) found in the Peel River watershed host several lead-zinc deposits and very high number of lead-zinc occurrences. There are two variants on these deposits: one referred to as “Mississippi Valley Type”, or MVT deposits, and the second relatively newly discovered deposit type referred to as “Blende” type. MVT deposits are often high-grade, but smaller deposits that often occur in clusters. Examples include the deposits of Pine Point, NWT or the Polaris mine in Nunavut. The Blende type is named after the Blende deposit near Mayo. Another example of this is the Prairie Creek mine in NWT. The significant difference between the MVT and Blende type deposits is that the latter contains silver in addition to lead and zinc. Environmentally, these deposits, although small, are attractive in that they are hosted in limestone or similar rocks with little to no pyrite, and therefore do not have significant acid-rock drainage problems such as found at Faro or other Sedex style Pb-Zn deposits.

There are primarily two defined carbonate hosted deposits in, or immediately adjacent to, the Peel River Watershed planning region:

1. Goz: 2.5 million tonnes at 11% zinc
2. Blende: 19.6 million tonnes averaging 3.04% zinc and 2.8% lead.

Average deposit sizes for MVTs are 1 to 10 million tonnes with a typical median size around 3 million tonnes (Bradshaw 2006). Blende type deposits are not as well defined, but are assumed to have a median size of 1.3 million tonnes with the Blende deposit itself being the largest at almost 20 million tonnes.

The location of the known carbonate hosted Pb-Zn occurrence and deposits in the Peel River Watershed planning region are illustrated on Figure 3. The mineral potential for carbonate hosted Pb-Zn deposits is also shown in Figure 3. This illustrates the areas where it would be most likely to find deposits of this type.

4.5 Coal

The Bonnet Plume Basin contains the majority of the Yukon's coal reserves. Within the study area, there are 16 known coal occurrences, 7 of which are defined as deposits. The currently known coal reserves in the Bonnet Plume are 670 million tonnes. The median deposit size is on the order of 100 million tonnes, with the largest deposit being the Illtyd Creek deposit at 190 million tonnes. The coal is thermal grade coal, suitable for power and heat production. This is in contrast with most of the coal mines in British Columbia which are metallurgical grade coal. Metallurgical grade coal commands a significantly higher price per tonne than thermal coals.

The location of the known coal occurrence and deposits in the Peel River Watershed planning region are illustrated on Figure 4. The coal deposits are typically found in the Tertiary age rocks of the Bonnet Plume Basin. However, there are a few anomalous coal showings outside of this area. The extent of the Bonnet Plume Basin which hosts potential for coal deposits is shown on Figure 4. Note that for the anomalous coal occurrences outside of the basin, an arbitrary 5 km potential buffer covering prospective rock units, has been drawn around said coal showings.

5. Example Mineral Development Scenarios

5.1 Crest Iron

The Crest iron deposit was explored extensively in the 1960's, but has received very little contemporary attention. A pre-feasibility study was done by Canadian Bechtel Corporation in the 1960's, but a copy of this report is currently not available to this project. However, given the dated nature of the pre-feasibility study, it is doubtful that it is relevant today.

5.1.1 Mining

Assumed open-pit bulk mining operation using very large earth moving equipment, with the following attributes:

Table 2 . Iron Ore Mine Scenario

Mine Type	Open Pit
Deposit Size	6,000,000,000 tonnes
Assumed production rate	15 million tonnes of iron /yr (assumed based on typical size of modern Canadian iron mine size)
Average ore grade	44% iron
Assumed recovery rate	60%
Assumed total ore mined per year	57,000,000 (162,000 tonne/day)
Average stripping ratio	0.2:1 waste:ore (32,400 tonnes/day waste rock moved) – note early mine life stipping ratio much lower, possibly no stripping required for initial mine life.
Mine life based on reported deposit size	110 years based on 6 billion tonne reserve.

Note that given the flat lying, laterally extensive nature of the deposit, mining with progressive reclamation similar to that using in open-cast coal mining may be possible with this deposits. The progressive reclamation would backfill the pit behind mining with waste rock, thereby restoring the landscape as the mine progresses through the deposit area.

5.1.2 Milling

There are a number of iron ore products that can be produced, but for the purposes of this assessment it is assumed, the final product would be iron ore concentrate with iron ore pellet production off-site (e.g. at the port site, etc.)

Table 3 . Iron Ore Milling Scenario

Assume Milling Method	Conventional flotation with gravity pre-concentration
Assumed recovery rate	60%
Assumed concentrate grade	65%
Total annual concentrate production	15 million tonnes / year
Assumed power consumption	56 MW (from Hartman 1992)
Annual water consumption	650 to 1000 L/s (10,000 to 15,000 gpm) – Assumed total process uses 330,000 gpm, but 95% of water is recirculated. 3-5% of this is needed as make-up water. 80% of make-up water returned to environment (US EPA 1994)
Total tailings production	34 million tonnes / yr

Note that the tailings produced from iron ore mining are substantially less environmentally detrimental relative to other metal mines (e.g. Faro). Although there are some elevated metal concentrations associated with the iron ore tailings, the primary issue will be physical disposal of large volumes of ground rock flower.

5.1.3 General and Administration

Generally it is assumed the days of the “mine town” are gone. Therefore, the mining operation would be supplied by a work camp only. Given the length of the mine life, the camp would likely be a more permanent, higher quality work camp than those typically found at many mines. The proposed Galore Creek mine in northern British Columbia proposes to mine at a similar rate to that assumed for the Crest deposit. From the Galore Creek example, we can assume a workforce of 400 to 500 people full time.

5.1.4 Infrastructure

Power

A source of power is an important infrastructure requirement. The mine would likely require on the order of 75 MW of power, which is a substantial amount. It is unlikely power would be supplied from a regional electrical grid or from on-site diesel generation, rather power could be generated from nearby or on-site sources such as:

1. On-site generation such as natural gas provided from Peel Basin or Mackenzie Gas Pipeline
2. On-site coal-fired power plant: would require railway spur or haul road to a coal mine in Bonnet Plume Coalfield
3. Off-site coal-fired power plant: coal mine mouth power plant in Bonnet Plume Coalfield with power transmission line to Crest iron mine.

With respect to coal fired power generation, see the discussion on the Bonnet Plume Coal resources elsewhere in this document.

Transportation

Transportation of the large volumes of iron ore concentrate is the most significant issue facing the development of the Crest deposit. Access requirements for a future development at Crest are not clear and would normally be considered as part of a feasibility study.

Simple truck haulage is not a realistic scenario for this site. The most likely option would be a railroad. However, some developments are considering the usage of long-distance slurry pipelines: such a scenario would not be inconceivable for the Crest. If a slurry pipeline were used, it may be possible to provide overland transport during winter months only using an ice road (similar to that used for re-supply of the diamond mines in NWT), thereby alleviating the need for an all season road to the site. Possible transportation scenarios could include:

1. Railway from Crest to national railway network (e.g. Alaska-Canada rail link)
2. Railway from Crest to Alaskan port.
3. Railway from Crest to port on arctic coast
4. Slurry pipeline to central Yukon, with agglomeration (pelletization) and loading product to national railway network (e.g. Alaska-Canada rail link).
5. Slurry pipeline to Alaskan port.
6. Slurry pipeline to port on arctic coast.

Note that recent port studies being conducted by the Government of Yukon had identified a significant lack of space at Skagway making development of an iron ore port at that location very difficult. The Haines port does not have the same space constraints, and may offer an alternative.

Use of a railway has a distinct advantage that access control is much easier. Only authorized usage of the railway would be allowed, thereby alleviating many of the environmental impact issues associated with long-term public access to mining areas.

5.2 Wernecke Breccias (IOCG)

To date, no IOCG deposits have been adequately defined in the study area to produce a feasibility study level of detail. Therefore, the following scenarios are hypothetically defined, based on deposit size and typical mine development for similar deposits. To develop a IOCG mine in this remote part of the Yukon, it would likely need to be a larger size (e.g. upper 10%) deposit. Once that primary deposit was developed, it would be reasonable to assume one or two of the "average" size deposits would be developed subsequently. Therefore, two scenarios are shown, one for the median size deposit and one for the upper 10% size deposit.

5.2.1 Mining

Given the grades and size of these possible deposits, they would most likely be mined via open pit.

Table 4. Wernecke Breccia Mine Scenario

Mine Type	Median Size	Upper 10% Size
Deposit Size	3,600,000 tonnes	40,000,000 tonnes
Average ore grade	1.5% Cu, 1.5 g/t Au	1.5% Cu, 1.5 g/t Au
Assumed total ore mined per year	390,000 (1,100 tonne/day)	2,900,000 (6,750 tonne/day)
Assumed stripping ratio	4:1 waste:ore (4,400 tonnes/day waste rock moved)	2:1 waste:ore (13,500 tonnes/day waste rock moved)
Mine life based on assumed deposit size	9 years	16 years

[4]

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[4] "upper 10 percentile" refers to the 10% largest deposit of this kind found worldwide.

5.2.2 Milling

Milling would produce a copper concentrate. The physical quantity of gold is not large (e.g. gold bars produced on site, or gold in the concentrate does not constitute a large volume of material).

Table 5. Wernecke Breccia Milling Scenario

Mine Size	Median Size	Large Size
Assume Milling Method	Conventional flotation	Conventional flotation
Assumed recovery rate	95%*	95%*
Assumed concentrate grade	28%*	28%*
Total annual concentrate production	20,000 tonnes / year	120,000 tonnes / year
Assumed power consumption	3.7 MW (from Hartman 1992)	11 MW (from Hartman 1992)
Annual water consumption	3 L/s (45 gpm) **	18 L/s (260 gpm) **
Total tailings production	370,000 tonnes / yr	2,780,000 tonnes / yr

Notes: ** Assumed from O'Hare 1980*

*** Assumed from Finlayson Project pre-feasibility study (Hatch 2000) which proposed 40 m^3/hr of make-up water for a 4,250 tpd milling operation.*

5.2.3 General and Administration

Estimated mine staff for the two IOCG mine scenarios are estimated at 100 for the "median" mine scenario and 200 for the "large" mine scenario. The sites would be "fly-in:fly-out" style mine camps.

5.2.4 Infrastructure

Power

Given the distance of the Wernecke Breccia from the Yukon power grid and relatively low amount of power required, power would most likely be supplied by on-site diesel generators. In the case of the larger mine scenario, should coal be accessible nearby (e.g. Bonnet Plume Coalfield), a coal fired power plant maybe an option.

Transportation

Copper mines tend to produce a smaller quantity of concentrate relative to other base metal mines. However, transportation of concentrate does require overland transport. Trucked haulage of the concentrate would be the most likely scenario, and therefore would require a road to the public road system. As the concentrate quantities are relatively small, it could be possible to use winter roads and haul during winter months only, however this scenario is unlikely. Should a railway be built to the Crest deposit, the most logical option would be to connect to that transportation corridor (either via a rail spur or road) to transfer the concentrate to the railway.

5.3 Carbonate Hosted Pb-Zn

Because of the relatively small size of individual deposits, the most likely development scenario would be to mine several deposits in the district with milling at a central mill. This was the development scenario at Pine Point, NWT. Individual deposits could be mined either through open pit or underground mining methods.

In consideration of the “cluster” nature of the mine development, both “median” and “large” (upper 10%) size deposit scenarios are presented for both open pit and underground. However, only a single milling scenario is presented, representing a common mill for several individual deposits. For the mill, only the “large” mine scenario is presented since an individual “median” size deposit alone would unlikely to be developed.

5.3.1 Mining

Given the grades and size of these possible deposits, they would most likely be mined via open pit.

Table 6. Carbonate Hosted Pb-Zn Mine Scenario

Mine Size	**Median Size**		**Upper 10% Size**	
Mine Method	Open Pit	Underground	Open Pit	Underground
Deposit Size	3,000,000 tonnes	3,000,000 tonnes	12,000,000 tonnes	12,000,000 tonnes
Average ore grade*	3% Pb, 3.5% Zn	3% Pb, 3.5% Zn	3% Pb, 3.5% Zn	3% Pb, 3.5% Zn
Assumed total ore mined per year	350,000 (1,000 tonne/day)	350,000 (1,000 tonne/day)	1,000,000 (2,800 tonne/day)	1,000,000 (2,800 tonne/day)
Assumed stripping ratio	7:1 waste:ore (7,000 tonnes/day waste rock moved)	none	7:1 waste:ore (19,600 tonnes/day waste rock moved)	none
Mine life based on assumed deposit size	9 years	9 years	12 years	12 years

Notes: * *Grades assumed from Blende type ore deposit model summary compiled by Bradshaw 2006 (unpublished).*

5.3.2 Milling

Milling would produce a lead and zinc concentrate.

Table 7. Carbonate Hosted Pb-Zn Milling Scenario

Mine Size	Large Size Mill
Assume Milling Method	Conventional flotation
Assumed recovery rate	Pb: 93%, Zn: 85%*
Assumed concentrate grade	Pb: 53%, Zn: 53%*
Total annual concentrate production	110,000 tonnes / year (Pb & Zn concentrates combined)
Assumed power consumption	6.5 MW (from Hartman 1992)
Annual water consumption	7.5 L/s (111 gpm) **
Total tailings production	90,000 tonnes / yr

Notes: ** Assumed from O'Hara 1980*

*** Assumed from Finlayson Project pre-feasibility study (Hatch 2000) which proposed 40* m^3*/hr of make-up water for a 4,250 tpd milling operation.*

5.3.3 General and Administration

Estimated mine staff for the mine scenarios are estimated on the order of 100 to 200 people any of the carbonate hosted Pb-Zn mine and mill scenarios. The sites would be "fly-in: fly-out" style mine camps.

5.3.4 Infrastructure

Power

Given the relatively low amount of power required for these type of deposits, power would most likely be supplied by on-site diesel generators.

Transportation

Transportation of Pb-Zn concentrate requires overland transport. Trucked haulage of the concentrate would be the most likely scenario, and therefore would require a road to the public road system. If several small deposits were mined in the district and hauled to a central mill, then obviously haulage roads would be required to interconnect the various deposits. Should a railway be built to the Crest deposit, it would be logical to connect to that railway corridor (either via a rail spur or road) to transfer the concentrate to the railway.

5.4 Coal

Given the very remote location of the coal deposits, significant transportation challenges face any future plans to export these coals from the Yukon. In addition, coal must compete for with other potential energy sources, such as hydro-electric for future domestic power generation.

The most likely development scenario of the Bonnet Plume Coal deposits would be to provide power for the Crest Iron mine. With respect to power generation for Crest, two scenarios can be envisioned:

1. Coal mined feeds a mine-mouth power plant. An electrical line then conveys the power to Crest mine site.
2. Coal mined is transported (either by truck or railway spur) to the Crest mine site, where it is burned to generate power. This scenario has the additional benefit of utilizing the waste heat from the power plant for heating the mine and mill buildings.

5.4.1 Mining

A pre-feasibility study was completed for the Illtyd Creek deposit in 1981. This study assessed both underground and surface mine options. In the case of the Illtyd Creek deposit, the pre-feasibility study found that an underground mine would be more viable for that deposit. For the purposes of the coal mine scenarios, both an underground and surface coal mine scenario is shown. Various parameters are generally adapted from the Illtyd Creek pre-feasibility study.

It should be highlighted that surface coal mining often uses a technique that allows for progressive reclamation of the pit. As the coal mining progresses, waste rock is stripped off the coal and used to backfill the area previously mined, thereby reclaiming the coal pit.

Table 8. Coal Mine Scenario

Mine Type	Surface Mine	Underground
Median Deposit Size	100,000,000 tonnes	100,000,000 tonnes
Mining Recoverable Tonnes	12,000,000 tonnes at 6:1 strip ratio.	12,000,000 tonnes
Assumed production rate	500,000 tonnes/yr	500,000 tonnes/yr
Assumed saleable coal ratio	85%	85%
Assumed total coal mined per year	600,000 (1,700 tonne/day)	600,000 (1,700 tonne/day)
Assumed stripping ratio	6:1 waste: ore (10,200 tonnes/day waste rock moved)	none
Mine life based on reported deposit size	20 years	20 years

Note that given the flat lying, laterally extensive nature of the deposit, mining with progressive reclamation similar to that used in open-cast coal mining may be possible with this deposit. The progressive reclamation would backfill the pit behind mining with waste rock, thereby restoring the landscape as the mine progresses through the deposit area.

5.4.2 Coal Processing

For an on-site power plant, the coal may require minimal to no processing. Should the coal be shipped off-site, it will require "cleaning" to reduce ash content.

Table 9. Coal Processing Scenario

Assume Milling Method	Coal washing
Assumed recovery rate	85%
Total annual coal production	500,000 tonnes/year
Assumed power consumption	None (generated on-site)
Annual water consumption	Unknown (pre-feasibility study does not specify water usage)
Total refuse production	100,000 tonnes / yr

Most refuse from the coal cleaning plant would likely be returned as backfill to the mine pit or underground.

5.4.3 General and Administration

Estimated mine staff for the surface mine scenario is estimated to be between 100 and 150 people. For the underground scenario, personnel requirements are estimated between 150 and 200 people. The mines would be "fly-in/fly-out" style mine camps.

5.4.4 Infrastructure

Power
Mine power would likely be supplied by an on-site, coal fired power plant.

Transportation
Most likely, coal would be transported for power/heat generation either to the Crest Mine site or a nearby Wernecke Breccia mine site. Coal transport would be by truck or rail to said mines. Alternatively, the power plant could be located at the coal mine, and the power transmitted to the metal mine sites. There would likely be a service road between the coal mine power plant site and the respective metal mine site.

6. Conclusion

As the Peel River planning region is remote, exploration has been limited and the geology and minerals are not well understood. The area is known to contain significant mineral resources, particularly for iron, copper, lead, zinc and gold. For example, the Crest iron deposit is one of the largest in North America and the Bonnet Plume coal deposits contain 85% of Yukon's known coal reserves. The planning region also contains areas with potential for further discoveries in the future.

There are four different kinds of mining operations that could be proposed in the area in the future: iron ore; coal; iron-oxide copper gold; and a lead-zinc mining operation. It is important to note that no mining will take place without several important conditions being met. These include: finding a suitable deposit; sufficient metal prices; appropriate technology for mining processing; infrastructure necessary to support the mining operation. In addition, environmental and regulatory requirements would also have to be met.

The regulatory requirements in the Peel River vary depending on the specific location and potential impact of a proposal. There are a number of federal, Yukon and Northwest Territories Statutes that may be involved.

7. Closure

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