PLANNING FOR CLOSURE – PORCUPINE GOLD MINES’ MINE CLOSURE PROGRAM

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ABSTRACT

This paper describes the closure program that is underway by Goldcorp Canada Ltd. at their Porcupine Gold Mines (PGM) operation in Timmins, Ontario. As part of the mine property acquisitions, PGM made a corporate commitment to work with the communities and other stakeholders to close out the legacy sites while PGM mines are in operation. This led PGM to institute a closure planning program that involved assessing the environmental and safety risks associated with each legacy site and then prioritizing and scheduling detailed site investigations, closure options development, closure plan submissions, and preliminary to detailed engineering design through to construction. The closure program considers all the PGM sites and, where possible, incorporates closure measures between sites such as the consolidation of tailings or utilizing historical tailings as paste fill material at another underground mine.

INTRODUCTION

The Porcupine camp in Timmins, Ontario has been operational for over 100 years consisting of more than 20 mines, many of which ceased operations in the 1950s and 1960s. Goldcorp, through its operating unit known as Porcupine Gold Mines (PGM), owns many former mine sites having obtained them through acquisitions of former and two current gold producing mines. The majority of PGM properties is located within the City of Timmins, Ontario limits and covers an area in excess of 100 km². The total PGM property area is approximately 38,000 hectares of mining claims. Figure 1 shows the locations of many of the mine sites within the Timmins area.
HISTORY OF MINES NOW OWNED BY PGM

Although gold in the Timmins area was noted by government geologists as early as 1896, it was not until 1909 that the first major gold discovery in the area was made by Harry Preston. That discovery developed into the Dome Mine. Later that same year, a few kilometres away, a prospecting party, discovered a gold vein that became the Hollinger Mine, which operated continuously from 1910 to 1968. (Placer Dome 2005).

In the same year, just north of the Hollinger find, the site of the McIntyre (Schumacher) Gold Mine was staked by Sandy McIntyre. McIntyre Porcupine Mines Ltd. was incorporated in 1911 to hold and develop the mine, and production began in 1912. In 1973, McIntyre Porcupine Mines Ltd. was purchased by Pamour Porcupine Mines Ltd. In subsequent years, the McIntyre Mine was owned and operated by Noranda and then Giant Yellowknife Mines. In the late 1980's, E.R.G. Resources (ERG), Giant Yellowknife Mines Resources Inc. established a tailings recovery plant on the McIntyre property to re-process tailings and recover their contained gold values. The plant started up in 1988 but financial problems led to operations being abandoned in late 1989.
In 1990, Royal Oak Resources purchased control of the Pamour Group of Companies from Giant Resources Limited of Australia. Royal Oak Mines Inc. was formed in 1991 by the amalgamation of several companies within the Pamour Group, including Giant Yellowknife Mines Ltd. Until 1999, the McIntyre and Hollinger Mine sites were owned by Royal Oak Mines Inc. In early 1999 financial difficulties forced Royal Oak Mines Inc. to file for protection from its creditors and an interim receiver was appointed to market the company’s assets. By the end of 1999, the Timmins-area assets of Royal Oak Mines, including the McIntyre and Hollinger sites, had been sold to one of the current owners, Kinross Gold Corporation. Kinross and Placer Dome (CLA) Ltd. formed the Porcupine Joint Venture (PJV) in July 2002, with Placer being the operator.

In May 2006, Goldcorp Canada Ltd. acquired 51% of the Porcupine Joint Venture (PJV) from Placer Dome and in 2007; Goldcorp Inc. acquired the remaining 49%, forming Porcupine Gold Mines (PGM 2010).

There are four (4) main areas of mining within the Timmins camp. The southern group of mines includes the Dome, Preston, Paymaster, Aunor, Delnite and Naybob. The northern group includes McIntyre, Hollinger, Coniaurum, Schumacher, Crown and Vipond Mines. To the north-east are the Pamour, Hallnor, Broulan, Bonetal, Banner, Reef, Hugh-Pam, Bonwhit, Hoyle, Owl Creek and Hoyle Pond mines. East of Timmins there is two historical sites, Goldhawk and Nighthawk Lake Mines. Table 1 provides a summary of operations, number of associated mine openings, waste rock and tailings volumes as well approximate gold recovery.
Table 1. Summary of PGM Current and Historical Mines Operations

<table>
<thead>
<tr>
<th>Location</th>
<th>Start Operations</th>
<th>Stopped Operations</th>
<th>footprint (ha)</th>
<th>Surface Rights</th>
<th>Operations (OP/UG)</th>
<th>Mine Openings to Surface</th>
<th>Crown Pillars</th>
<th>Waste Rock (Mt)</th>
<th>Tailings (Mt)</th>
<th>Ore Mined (Mt)</th>
<th>Gold (oz) Other minerals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Done Mine</td>
<td>1912</td>
<td>operational</td>
<td>2500</td>
<td>UG</td>
<td>14</td>
<td>98.9</td>
<td></td>
<td>36</td>
<td>72.6</td>
<td>16,000,000</td>
<td></td>
</tr>
<tr>
<td>Pembina Mine</td>
<td>1915</td>
<td>1968</td>
<td></td>
<td>UG</td>
<td>22</td>
<td>14</td>
<td></td>
<td>36</td>
<td>72.6</td>
<td>16,000,000</td>
<td></td>
</tr>
<tr>
<td>Hollinger Mine</td>
<td>1911</td>
<td>1998</td>
<td></td>
<td>UG</td>
<td>14</td>
<td>14</td>
<td></td>
<td>36</td>
<td>72.6</td>
<td>16,000,000</td>
<td></td>
</tr>
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<td>Vipond Mine</td>
<td>1911</td>
<td>1941</td>
<td>302</td>
<td>UG</td>
<td>139</td>
<td>many</td>
<td></td>
<td>2.4</td>
<td>15,909,749</td>
<td>414,567</td>
<td></td>
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<td>Schumacher Mine</td>
<td>1910</td>
<td>1918</td>
<td></td>
<td>UG</td>
<td>some</td>
<td>na</td>
<td></td>
<td>1.4</td>
<td>27,182</td>
<td>30</td>
<td></td>
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<tr>
<td>Porcupine Crown Mine (McNauley Mine)</td>
<td>1911</td>
<td>1923</td>
<td></td>
<td>UG</td>
<td>some</td>
<td>na</td>
<td></td>
<td>0.2</td>
<td>138,330</td>
<td>4</td>
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<tr>
<td>Little Pearl Tailings Pond</td>
<td>1910</td>
<td>1920s</td>
<td>15.7</td>
<td>UG</td>
<td>na</td>
<td>na</td>
<td></td>
<td>1.4</td>
<td>na</td>
<td>100,000</td>
<td></td>
</tr>
<tr>
<td>HTMA &amp; McIntyre Concentrate Dumps</td>
<td>1912</td>
<td>1989</td>
<td>256</td>
<td>UG</td>
<td>30</td>
<td>147,200</td>
<td>21</td>
<td>34</td>
<td>10,000,000</td>
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<tr>
<td>McIntyre Mine</td>
<td>1911</td>
<td>1961</td>
<td>58</td>
<td>UG</td>
<td>8</td>
<td>4.5</td>
<td>4.1</td>
<td>1,100,000</td>
<td>1,690,560</td>
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<td>Hallnor</td>
<td>1939</td>
<td>1982</td>
<td>133</td>
<td>UG</td>
<td>7</td>
<td>5.8</td>
<td>3.8</td>
<td>240,660</td>
<td>240,660</td>
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<td>Borden (Bowman Porcupine)</td>
<td>1938</td>
<td>1953</td>
<td>600</td>
<td>UG</td>
<td>5</td>
<td>na</td>
<td>2.3</td>
<td>10</td>
<td>989,092</td>
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<tr>
<td>Reef (Bowman Reef)</td>
<td>1938</td>
<td>1965</td>
<td></td>
<td>UG</td>
<td>4</td>
<td>na</td>
<td>0.3</td>
<td>52,292</td>
<td>52,292</td>
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<td>Bonneval</td>
<td>1939</td>
<td>1953</td>
<td></td>
<td>UG</td>
<td>1</td>
<td>na</td>
<td>0.0001</td>
<td>na</td>
<td>na</td>
<td>67,940</td>
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<tr>
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<td>1939</td>
<td>1953</td>
<td></td>
<td>UG</td>
<td>1</td>
<td>na</td>
<td>0.2</td>
<td>191,004</td>
<td>191,004</td>
<td>191,004</td>
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<tr>
<td>Hugh-Pam</td>
<td>1939</td>
<td>1965</td>
<td></td>
<td>UG</td>
<td>3</td>
<td>na</td>
<td>0.5</td>
<td>119,004</td>
<td>119,004</td>
<td>119,004</td>
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<tr>
<td>Pameur</td>
<td>1939</td>
<td>1999</td>
<td>1410</td>
<td>UG/OP</td>
<td>9</td>
<td>23.0</td>
<td>47.5</td>
<td>4,281,000</td>
<td>4,281,000</td>
<td>4,281,000</td>
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<td>Hoyle Mine</td>
<td>1939</td>
<td>1945</td>
<td></td>
<td>UG/OP</td>
<td>2</td>
<td>na</td>
<td>0.6</td>
<td>2,500,000</td>
<td>2,500,000</td>
<td>2,500,000</td>
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<tr>
<td>Gold Hawk</td>
<td>1939</td>
<td>1945</td>
<td></td>
<td>UG/OP</td>
<td>8</td>
<td>na</td>
<td>0.6</td>
<td>2,000,000</td>
<td>2,000,000</td>
<td>2,000,000</td>
<td></td>
</tr>
<tr>
<td>Owl Creek</td>
<td>1939</td>
<td>1949</td>
<td>60</td>
<td>UG/OP</td>
<td>2</td>
<td>4.4</td>
<td>na</td>
<td>1.5</td>
<td>233,671</td>
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<td>James Okemsha</td>
<td>1939</td>
<td>1949</td>
<td></td>
<td>UG/OP</td>
<td>15</td>
<td>na</td>
<td>0.6</td>
<td>3,697</td>
<td>3,697</td>
<td>3,697</td>
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<tr>
<td>Littek Hill</td>
<td>1939</td>
<td>1949</td>
<td></td>
<td>UG/OP</td>
<td>1</td>
<td>na</td>
<td>0.6</td>
<td>14,000,000</td>
<td>14,000,000</td>
<td>14,000,000</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td>7,488</td>
<td></td>
<td>333</td>
<td>37</td>
<td>147,326</td>
<td>136</td>
<td>43,060,398</td>
<td>43,060,398</td>
<td></td>
</tr>
</tbody>
</table>

Notes:  
na = not applicable  
n/a = not available  
1 date available to 2004  
2 tungsten extraction unknown amount  
3 copper tonnes  
4 first 60 years of operation  
5 silver ounces

CLOSEUPROGRAM

Goal of the Closure Program  
PGM has an extensive mine closure program that has been underway for approximately 10 years and is expected to run for several more years largely dealing with legacy mines that Goldcorp acquired as part of their expansion in the Timmins area. The goal of the closure program is to remediate the legacy and closed mines while current and future mines are in production with the funding for these closure projects coming from the Timmins operations.  

Many of the legacy sites were no longer in operation when amendments to the Ontario Mining Act R.S.O. 1990 and subsequent development of mine closure regulation, Ontario Regulations (O.Reg.) 240/00, were instituted. When Kinross Gold acquired the assets of the then bankrupt Royal Oak Mines in 1999, an agreement with the MNDM was struck to assist with rehabilitation of high risk hazards, mostly mine workings, as well as to provide closure plans or closure plan amendments to meet the current O.Reg. 240/00 requirements over a period of several years.  

To date fourteen (14) closure plans covering all of the mines under the ownership of PGM have been developed and filed to meet the new regulations. Closure Plan Amendments are continually developed as the closure planning process progresses and closure designs develop. PGM provides a voluntary schedule
of amendments based on anticipated material changes to existing closure plans. Given the number of closure plans in various stages, this allows the MNDM to organize resources in advance.

Project Organization
PGM Closure Program is managed by a team consisting of an environmental engineer and project supervisor under the direction of the environmental manager. PGM has a partnership with AMEC Earth and Infrastructure (AMEC) managed by a senior associate geotechnical engineer out of the Fredericton, New Brunswick office with a team of engineers and scientists mainly located in eastern Canada. Together the PGM-AMEC team has worked on various mine closure projects over the past 10 years. This partnership provides a dedicated team with intimate knowledge of the sites and excellent working relationships.

Planning and Budgeting
Planning for the closure program looks outward for more than 20 years, which is the expected life of the operating mines. Beginning as early as March each year, PGM begins an annual review of the Strategic Business Plan (SBP) which considers operating cash flow from the operating (and potentially operating) mines for a particular business case. The first 5-years are considered the most important period however the SBP extends to the end of mine life. At the same time, the closure team rolls their list of prioritized closure activities into the SBP. Activities are reviewed annually and as individual site detailed plans are developed, the costs and schedule are incorporated into the SBP. The SBP allows PGM management to understand expected budget requests prior to budget season which begins in August.

A somewhat separate, though still related, process is the annual closure liability audit, or Asset Retirement Obligations, which typically occurs in October. The ARO process ensures PGM is accurately reporting their expected liabilities which end up in the company’s financial statements. As project details are garnered through the year, liability estimates are reviewed for accuracy and updated as necessary to ensure estimates remain up to date.

The overall process is iterative as mine operations adjust their strategic planning, site investigations are undertaken, or site conditions change, and the closure activities are re-prioritized.

Closure Issues
Because of the wide range of sites, there are a variety of closure issues. The typical issues are as follows:

Environmental
- Stability of tailings dams, waste rock piles and open pits.
- Acid generating and/or metal leaching potential. The main constituents of concern (COC) associated with gold mining in Timmins are arsenic and cyanide, although northern Ontario geology lends itself to nickel, copper, zinc, lead and iron, that can also be associated with metal leaching. The majority of the tailings and waste rock at the PGM sites are non-acid generating with leachate pH values near or slightly above neutral, although there are some areas of concern that have potential acid generation and/or metal leaching concerns.
Safety
- Infrastructure (although most of the sites have had the infrastructure removed prior to 2003).
- Open shafts.
- Vent raises.
- Stopes and crown pillars.

Community
- Community use of sites to be closed.
- Interaction with adjacent landowners.
- Ownership of property that has been affected by previous mining activities.

Legal and Compliance
- Surface water, ground water and sediment quality.
- Air quality including noise and vibration from operating mines.
- Land use and ecological risk.
- Vegetation requirements.

Prioritization of Closure Activities
The prioritization of the closure activities has evolved over the past 10 years. The first formal risk assessment process that was used to support prioritization was conducted in 2008. A risk registry was developed to rank the individual sites, based on available information, to identify safety and environmental hazards and risks for the individual sites. Each site was analyzed for safety and environmental hazards. Community and legal and compliance issues were also considered. The risk registry has been updated and modified since 2008.

As corporate and local management priorities dictate, several mine closure projects are on-going at various stages on an annual basis, including site investigations, design and engineering and construction works. For an individual closure project, schedules may be adjusted or re-prioritized within the overall PGM Closure Program. One challenge is to manage the closure planning process so that efforts are conducted without being wasted if there is a change in the direction of the project.

Project Communication
The Closure Program team interacts with other key stakeholders within PGM from the environmental group and senior and corporate management of Goldcorp to obtain input to the closure criteria and closure options. By doing so, the mine closure projects can be developed in-line with legislated standards and local and corporate management strategies.

PGM communicates with the MNDM, Ontario Ministry of Environment (MOE) and Ministry of Natural Resources (MNR) during various stages of the closure program. This promotes discussions on mine closure projects options and objectives and allowing regulators time to provide input to closure project measures.
As many of the mine sites are within the City of Timmins limits and, in some cases, houses near the sites, PGM communicates mine closure measures to the public through open house forums. As well, PGM discusses closure projects with City of Timmins officials to provide input and feedback on the projects and future land use.

First Nations (FN) communities are also important stakeholders. PGM regularly provides information updates on closure projects and engages discussions with the various communities.

PGM has several joint venture partnerships on inactive properties, typically with junior exploration groups looking to improve resources estimates. PGM works with the JV partners to ensure there is a clear understanding of the liabilities associated with the potential resources as well as what is a reasonable distribution of ownership.

The Closure Program can be challenging to manage, with limited resources and constantly shifting priorities. This requires the PGM/AMEC team to communicate frequently and work very closely together. On a weekly basis, individual project issues and progress are discussed to ensure the focus remains on track. Monthly, the team management meets to review overall program controls and management, and short term goals. On a quarterly basis, PGM and AMEC management participate in a closure program meeting to review high level project directions, long term changes in strategic business plans and project requirements for the upcoming quarter and forecasting into the future 12 months.

**Project Innovation**

Porcupine Gold Mines is also focused on reducing its impact on the environment through research and innovation in the area of sustainable development, as well as the development of synergies with other resource-base industries.

PGM initiatives includes the use of pulp biosolids as soil covers (as discussed below), energy management, bio-fuels research, and preserving fish populations at Three Nations Lake. Revegetation also considers Traditional Ecological Knowledge and public involvement. These initiatives have been undertaken at the Delnite Tailings facility, the Hollinger Tailings Management Area, the Hallnor Tailings facility and the Coniaurum tailings management area.

PGM is looking at ways to restore sites to a condition that matches the surrounding landscape, rather than just establishing a low maintenance surface, such as establishing naturally appearing drainage channels.

**CLOSURE PLANNING TOOL**

PGM and AMEC have developed a comprehensive Closure Planning Tool that has been used on several sites to help support decision making on the preferred closure solutions and direct efforts in a focused manner.

The sites are characterized with site investigations including groundwater, surface water, and geochemical assessments that lead into human health and ecological health risk assessments (HHRA or EHRA) for more complicated sites. Conceptual level options are developed and assessments are undertaken to
address various options for closure measures on a technical, environmental and socio-economic levels. Generally, a few options may be deemed technically more desirable compared to other options and the preferred closure solution can be straightforward. However, many of PGM’s sites are complex and more comprehensive tools are required.

PGM and AMEC have developed the tool based on the Kepner Tregoe (K-T) decision analysis process. It has been used to evaluate potential closure that may include the reuse or relocation of tailings and waste rock, cover systems for tailings and waste rock piles, water management, waste treatment. This decision analysis process first defines the decision statement or overall objective of the closure project. Project criteria are identified including health and safety, environmental and technical criteria that the closure must meet. A closure option that does not meet all of the defined criteria is then stricken from further consideration. Objectives are identified to evaluate the closure options, first, on a technical, environmental and socio-economic basis to alleviate bias towards costs. Each objective is provided a numerical weighting with respect to the other objectives. Each objective is then further broken down into ratings based on the range of the ability of an objective to be met.

Individual options are provided the numerical rating score based on how well the objective is met. The objective rating is multiplied by the objective weighting to calculate scores. The options overall scores and rankings are determined from a technical perspective, the preferred options. Generally, the top 2-3 ranked options will then undergo a high level risk assessment and development of conceptual cost estimates. This provides further assessment of the options from a technical, risk and costs perspective, to identify the preferred option which is then developed further to address information gaps and provides pre-feasibility design for tighter cost estimating. Closure option rankings may be altered at this stage such that a lower ranked and less costly option maybe become the preferred option.

There are circumstances where the closure project criteria may not be well defined, for example, a recent review of the Metal Mining Effluent Regulations (MMER) (Environment Canada 2002) as well as updates to the Ontario Provincial Water Quality Objectives (PWQO) (MOEE 1994) based on draft interim limits could potentially result in more stringent water quality limits in the future. Other potential changes in closure project criteria are related to the global economic conditions and changing gold prices that may alter the potential for reserve extractions within an existing closed mine. Delays in regulatory feedback on site specific closure criteria also contribute to circumstances where closure criteria could be altered. Under these circumstances, the closure options assessments are undertaken, with different project criteria and developed as scenarios. The options rankings between the scenarios may change as the conceptual closure options may not meet the differing criteria in the same order.

This process also guides on-going site investigations, discussions with management or regulators and, engineering and design work. There are generally several aspects of a site’s closure measures that may be independent from other aspects of a closure project such that they are not dependent on the key closure criteria and objectives. This process has provided PGM an improved basis for deciding whether work that should be done (investigations or designs) is at risk of being wasted due to changes in direction.
EXAMPLES OF SYNERGIES

Because of the range of sites, both closed and operating, and the proximity of PGM’s sites to other mine operations in the Timmins area, there have been a number of opportunities to benefit from the synergies of these sites to achieve closure. Some examples are:

- Use of rockfill from mine operations as construction materials (rip-rap, erosion protection).
- Use of tailings from closed sites as an ingredient for paste backfill in operating mines.
- Use of tailings from closed sites as cover material for acid generating tailings.
- Use of geochemically stable flotation tailings as cover material or acid consuming material over acid generating leach tailings.
- Possible development of a third party mill or modifications to the Dome Mill to be able to reprocess tailings from historical facilities.
- Use of historical open pits to store tailings and waste rock.
- Open pit operations to remove historic crown pillars and associated hazards.

In addition, PGM has developed an agreement with a local timber company to use pulp biosolids as a soil cover. This has reduced the pressure on the timber company’s landfills and provided a nutrient rich organic material that supports vegetation on the closed sites. The biosolids are initially seeded to establish ground cover and promote a self-sustaining environment that encourages the natural encroachment of other natural grass, shrub and tree species. This, in turn, has attracted wildlife, including several black bears. At the completion of the Coniaurum tailings management area closure measures, honeybee hives were located in the area to increase pollination and promote vegetation establishment and provide an opportunity for a small local business (Timmins 2013).

COMPLETED CLOSURE PROJECTS

To date, PGM has completed dozens of mine closure projects. Beginning in the early 2000’s, the focus was to ensure the area surrounding the Hollinger and McIntyre mines were safe for the public in terms of access to mine workings. A large effort was undertaken over the course of 5 years to secure dozens of shafts, raises, open stopes and unstable crown pillars. Following this success, tailings dams and depositions have been remediated at their Coniaurum, Hollinger Tailing Management area and Hallnor mines. Partial mine closure projects include the remediation of mine openings, waste rock piles and tailings facilities at several other sites including, Dome waste rock piles, Pamour tailings facilities and east waste rock pile, McIntyre tailings and the Delnite tailings facility and Aunor B tailings facility. Various stages of design are currently underway for the Naybob Mine, Pamour, Aunor-Delnite, McIntyre and Broulan Reef mines to prepare for the next stages of closure.
Figure 2A (left) shows the Coniaurum tailings facility in 2005 prior to closure measures and Figure 2B (right) shows the facility in 2007 after phase 1 closure measures were complete. Photos from PGM.

Figure 3A (left) shows the Hollinger tailings facility (HTMA) in prior to closure and Figure 3B (right) shows the facility in 2011 after 2 years of closure measures. Photos from Timmins Press 2013.

**PROGRESSIVE RECLAMATION**

Progressive reclamation of individual site hazards, such as capping or fencing mine openings, are often conducted prior to site closure projects commencing and conducted on an annual basis, where possible.

**MINE CLOSURE RECOGNITION**

Since 2008, Porcupine Gold Mines have been running educational tours of the reclaimed sites and working with the local Aboriginal community on the application of traditional knowledge and practices to modern rehabilitation techniques (Timmins 2013).
In addition, in 2011, PGM was awarded the Tom Peters Memorial Mine Reclamation Award, an award sponsored by the Ontario Mining Association and Canadian Land Reclamation Association and the Ministry of Northern Development Mines for its work on the Coniaurum facility.

In 2013, PGM was awarded the Timmins Chamber of Commerce with a Nova Award for Environmental Excellence for the HTMA reclamation project and the Tom Peters Memorial Mine Reclamation Award for the same project.

Although, awards are appreciated PGMs priorities and views on receiving awards are summarized as follows:

We appreciate the awards and notices—but for us, what’s most important is the public recognition that we’re getting it right in our direction and our achievements as a good corporate citizen (Goldcorp 2013).

REFERENCES


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Timmins Tourism Website (Timmins) 2013. www.tourismtimmins.com/discover-timmins/beyond-mining/