Natural Resources Canada

Economic Assessment of Geoscience Information (GEM & TGI)

Final Report

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1. Executive Summary

1. Executive Summary

Over the past two decades, the Government of Canada has invested heavily in the Geo-mapping for Energy and Minerals ("GEM") program and the Targeted Geoscience Initiative ("TGI") program (collectively, the "Programs"). The purpose of the two Programs is to provide the industry with the next-generation public geoscience information, which can be used to improve the effectiveness and efficiency of mineral exploration, unlock the full potential of natural resources and promote responsible land use, among others.

Purpose of the Report

Ernst & Young LLP ("EY") was engaged by Natural Resources Canada ("NRCan") to assess the cumulative economic benefits stemming from geoscience information generated by the Programs from its inception until FY2018/19. In particular, the scope of this report includes the following:

- An assessment of the economic benefits associated with the Programs. Benefits are measured in terms of cost savings, gross output, gross domestic product ("GDP"), labour income and the number of full-time equivalent jobs created;
- An identification of the incremental benefits associated with the Programs; and
- An assessment of the qualitative value of the Programs through stakeholder consultations and a jurisdictional comparison.

Summary of the Findings

The methodology used to derive the economic benefits of the Programs consists of two components: (i) an economic valuation analysis using both a top-down approach and a bottom-up approach, and (ii) an economic impact analysis using an input-based approach.

The top-down approach estimates the economic benefits of the Programs through benchmarking existing research that have explored the potential value of public geoscience information. The bottom-up approach estimates the economic benefits of the Programs using outcomes from a survey conducted by EY targeting GEM and TGI users. We then triangulate the expected economic benefits by blending the results of both the top-down and bottoms up approach.

The input-based approach estimates the economic impacts associated with the operational spending of the Programs using a static input-output ("I-O") model.

Based on our analysis, the expected value for products generated by the GEM and TGI programs from its program inception until FY2018/19 is approximately **$436 million.** Moreover, using outcomes from the EY survey, it is estimated that approximately 32% of user projects took place because of the GEM and TGI programs, resulting in up to **$779 million** in incremental project spending. In total, these results suggest

Table 1. Economic Benefits of the GEM and TGI Programs to Date

	Economic Benefits (1)	Incremental Benefits (2)	Total Economic Benefits (1) + (2)	Multiplier
Total Estimated Value	$436M	$779M	$1.22B	7.3

Notes: Values are expressed in CAD 2018 dollars. Numbers have been rounded. Incremental benefits derived from the EY survey. The multiplier is a ratio of total economic benefits to total program spending. The total economic benefits reflect the cumulative impact of the geoscience information from inception until FY2018/19.

Sources: EY calculations.

that the GEM and TGI programs may have generated economic benefits of up to **$1.22 billion** to date (Table 1). This means that the value of the GEM and TGI programs to users was at least **7.3** times higher than the costs of the Programs. More importantly, as the economic benefit of public geoscience information is often long-lasting, outcomes generated by the GEM and TGI programs are expected to continue to benefit the Canadian economy moving forward.

Table 2. Economic Impacts of the GEM and TGI Programs

Impact	Output (CAD$, M)	GDP (CAD$, M)	Wages (CAD$, M)	FTEs (Person-Years)
GEM				
Direct	107.5	95.2	21.6	288
Indirect	19.5	52.9	3.3	96
Total	**127.0**	**148.1**	**24.9**	**384**
TGI				
Direct	33.3	26.1	4.4	30
Indirect	8.3	13.6	0.7	7
Total	**41.6**	**39.7**	**5.1**	**37**

Notes: Values for wages, GDP and output are in millions and 2015 CAD dollars. Numbers have been rounded. Impacts based on Statistics Canada 2015 economic multipliers.
Values in the total row represent total impacts associated with TGI and GEM spending.
Sources: Stakeholder data and EY calculations.

Moreover, the economic impacts associated with the operational spending of the Programs, presented in Table 2, suggest that:

- The GEM-1 and GEM-2 program spending together supported approximately **$127.0 million** in gross output, **$148.1 million** in GDP, **$24.9 million** in wages, and approximately **384** person-year full-time equivalent jobs; and
- The TGI-4 and TGI-5 program spending together supported approximately **$41.6 million** in gross output, **$39.7 million** in GDP, **$5.1 million** in labour income, and approximately **37** person-year full-time equivalent jobs.

2. Current State Overview

2.1. History of Public Geoscience Information in Canada

Geoscience information within Canada is administered through the Geological Survey of Canada ("GSC"), which is part of the Earth Sciences Sector of Natural Resources Canada. The GSC is Canada's oldest scientific agency, established in 1842 to help develop Canada's mineral industry. Today, the GSC is Canada's primary organization for geoscience information and research with a mandate of (i) providing sustainable development for Canada's mineral, energy and water resources, (ii) stewardship of Canada's environment, (iii) management of natural geological and related hazards and (iv) technology innovation.[1]

The GSC works in partnership with many stakeholders such as universities, research institutions, industry organizations, federal departments, provincial and territorial survey associations, and municipalities across Canada and around the world. The GSC is responsible for publishing hundreds of maps, open files, peer-reviewed papers and reports every year. The strategic priorities of the GSC are to:

- Modernize concepts to explore and map the vast terrestrial and offshore lands of Canada;
- Improve geoscience models to support mineral and energy exploration while informing environmental protection with robust and innovative geoscientific evidence about the land and resources;
- Understand the impact and risk of natural hazards and climate change to protect Canadians from disastrous events; and
- Address the uncertainties of the changing world by expanding the reach and impact of geoscientific knowledge.

According to the GSC Strategic Plan (2018-2023), the agency is guided by the core principle of serving the public good, which includes seeking to identify areas where research and geoscience information can contribute to the decision-making process and the greater good of both individuals and organizations.[2]

2.2. Benefits of Geoscience Information as a Public Good

Geoscience is defined as the study of the Earth and its various natural geological systems. This includes the study and investigation of the earth's minerals, soil, water and energy resources.[3]

Geoscience information provided by governments is often characterised as a public good because it is distinguishable by two primary characteristics: it is (i) *non-rivalrous,* and (ii) *non-excludable*. Non-rivalrous consumption means the use of the goods or services by one individual does not adversely impact the availability or use for anyone else. Non-excludability means that it is either impossible, inefficient or undesirable to prevent individuals from using the goods or services.

The geoscience information created by the Geo-mapping for Energy and Minerals ("GEM") program and the Targeted Geoscience Initiative ("TGI") program (collectively, the "Programs") satisfy the criteria of being *non-rivalrous,* in that multiple stakeholders can access the information simultaneously and that the use of such information by one user does not take away the privilege from the others. In terms of the *non-excludability*, the geoscience information is available for free, with no sign-up or membership fees required.[4]

The intention of the information created by the Programs is to increase the level of efficiency across some of Canada's most economically critical industries and sectors, thereby improving the society's overall welfare. For example, public geoscience information from either Program can be used to advance information in areas of public interest, such as land management, infrastructure planning and natural resources development. Further, when it comes to the mineral exploration and extraction activities, public geoscience information ("PGI" hereafter) can help reduce user's costs of acquiring similar information and balance conservation and responsible resource development. For example, PGI can be used to determine areas for potential drilling and blasting, along with land-use activities associated with high-grade roads, upgrades and wellsite pad construction.

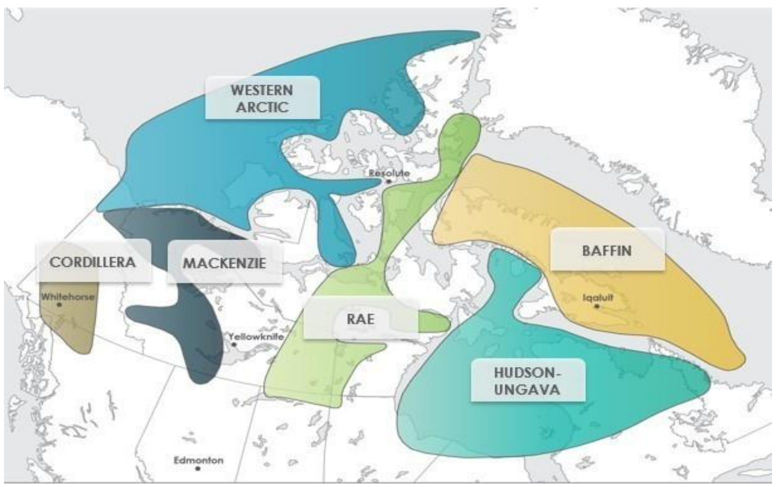
The next section provides an overview of each Program and examples of their outcomes.

2.3. Program Overview

GEM Program

The GEM program was lunched in two phases. The GEM-1 (GEM phase one) was launched in 2008 as a 5-year, $100-million geological mapping program to develop geological information in Canada's North. In August 2013, the Government of Canada extended the GEM program (GEM - phase two, or "GEM-2") by another seven years. The primary purposes of the GEM program are to: (i) provide researchers with advanced geological knowledge of Northern Canada; (ii) support exploration of the natural resources in Canada's North; and (iii) facilitate decision making on land use planning. The program is conducted in collaboration with Canada's various provinces and territories and is carried out in six different locations, which includes the Western Arctic, Baffin, Rae, Hudson Ungava, Cordillera and Mackenzie regions, depicted in Figure 1.

Figure 1. GEM Project Areas



Source: Natural Resources Canada.

Key activities and goals under the GEM program include the following:

- Collect new field data by applying modern techniques in airborne geophysics and cutting-edge geochemistry methods;
- Use state-of-the-art geological science and technologies to document various geological structures, create new maps and develop models and regional frameworks;
- Engage communities and local governments to participate in field projects;
- Expand publicly available geoscience information about Northern Canada, including the identification of areas with high potential for gold, nickel, platinum-group elements, rare metals, base metals and diamonds;
- Develop partnerships between Canada's private and public sectors; and
- Ensure that jobs can be created in rural and remote Northern communities through the exploration and development of natural resources.

The geological information generated by the GEM program has been used by private sector stakeholders in Canada and globally to help reduce the risks and costs associated with mineral and oil & gas exploration, as well as to promote economic development.[5]

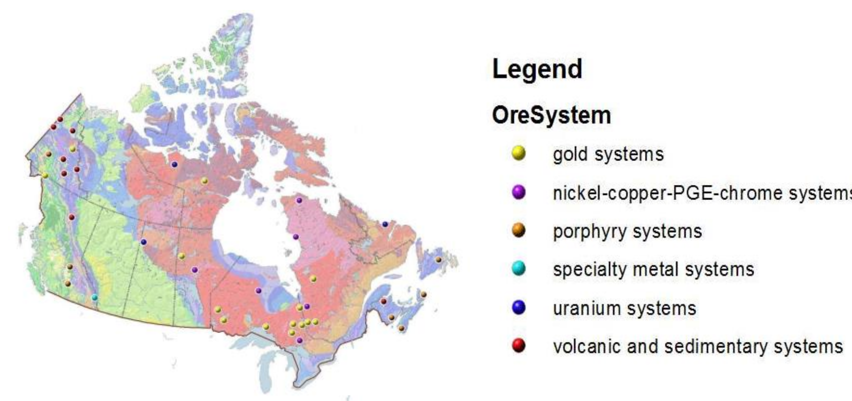
TGI Program

The TGI program is designed to provide industry stakeholders with advanced geoscience knowledge and innovative exploration techniques. The primary objectives of the TGI program are to:

- Use more robust methods to determine whether geological systems contain deeply buried ore and provide innovative exploration vectors to ore deposits;
- Reduce the risks and costs of mineral exploration;
- Resolve geological processes that extract ore metals from their sources, transport them and control their eventual deposition;
- Develop new and improved geoscience knowledge and techniques to enhance modelling and detection of Canada's major mineral systems; and
- Train students to increase the number of highly qualified personnel available for the mineral industry.

Unlike the GEM program, the TGI program takes on a thematic, knowledge-based approach across Canada. This allows researchers to access the best suited areas, districts and deposits across Canada, which is intended to stimulate the development of the next-generation geoscience knowledge. Specifically, the program is broken down into six key projects, representing Canada's major mineral systems, including (i) Uranium, (ii) Porphyry, (iii) Gold, (iv) Nickel-Copper-PGE-Chrome, (v) specialty metals, and (vi) Volcanic and Sedimentary Systems, depicted in Figure 2. Each of the projects is then divided into a series of sub-projects with distinct focuses.[6] Under the TGI program, there are funding available that are in the form of grants and bursaries to proposals that support initiatives within the sub-projects.

Figure 2. TGI Areas of Interest



Source: Natural Resources Canada.

Program Outcomes

Over the course of the Programs, TGI and GEM have led to several outcomes, in the form of research activities, publications, surveys, etc., that are expected to benefit some of Canada's critical sectors, including the oil & gas, mineral exploration, mining and education, among others. Some of the outcomes from the Programs include, but are not limited to:

Examples of GEM Program Outcomes

- 68 research activities;
- 1,250 publications;
- 55 regional geophysical surveys;
- 775+ geological & geophysical maps; and
- 1,100+ technical information sessions to industry, governments and NGOs.

Examples of TGI Program Outcomes

- 1000+ public geoscience knowledge publications;
- 75+ industry collaborations;
- 500+ public and stakeholder science presentations;
- 150+ students trained; and
- 48 research grants distributed.

3. Methodology

3.1. Methodology Overview

3.1. Methodology Overview

The purpose of this study is to perform the following:

- Assess the economic benefits associated with the GEM and TGI programs. The benefits are measured in terms of cost savings, gross output, GDP, labour income and the number of full-time jobs supported;
- Identify the incremental benefits associated with the Programs; and
- Assess the qualitative value of the Programs.

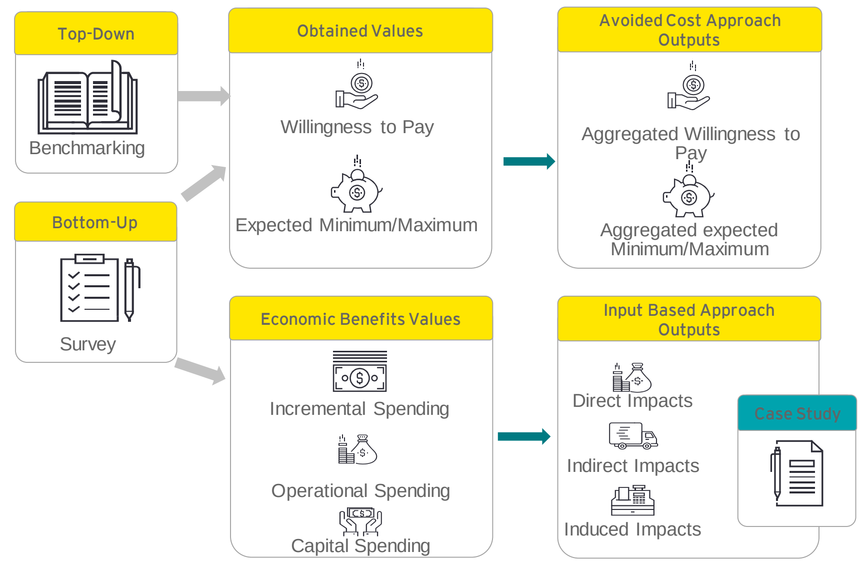
To derive the economic benefits resulting from the geoscience information generated by the Programs, the methodology consists of two components: (i) an economic valuation using an avoided cost approach and (ii) an economic impact analysis using an input-based approach. Each approach is carried out using information from the GEM-1 and GEM-2 programs, along with the TGI-4 (TGI phase 4) and TGI-5 (TGI phase 5) programs. A visual description of the two approaches is presented in Figure 3. Using both the avoided cost and input-based approach, the *incremental benefits* associated with the Programs are estimated, in addition to the anticipated direct and indirect economic impacts on the national economy.

In addition to the economic benefits, EY undertook stakeholder consultations and a jurisdictional scan to demonstrate the qualitative value of the GEM and TGI programs.

Avoided Cost Approach

The avoided cost approach estimates the value of the GEM and TGI products based on the costs that are "avoided" by users as a result of the information already being available for free through the Programs. To derive the avoided costs, a combination of two sub-approaches is

Figure 3. Bottom-Up, Top-Down and Input-Based Approaches



Sources: EY illustration.

employed, which are (i) a bottom-up survey-based approach, and (ii) a top-down benchmarking-based approach.

(i) Bottom-up Approach

The bottom-up approach is based on the analytical framework laid out in *Bhagwat and Ipe* (2000). Details regarding the underlying methodology are presented in Appendix **A.2.** In summary, the bottom-up approach involves conducting a survey to understand the users of the PGI products ("TGI and GEM products" and "PGI products" are interchangeable in this report), impacted projects, applications and related benefits. To properly gauge the cost savings associated with either Program, questions incorporated within the survey center around the following topics:

- Stakeholder's sector of operation;
- Products and services used, i.e., maps, data sets, reports, open files, etc.;
- Applications of the PGI products;
- The degree of usefulness or importance of the PGI products; and
- Quantification of the avoided costs.

To estimate the avoided costs specifically, the survey asks respondents to provide:

- Estimated potential expenditures associated with collecting the information provided by the Programs had they not been available for free;
- Estimated savings as a result of having access to a wide range of PGI products; and
- User's willingness-to-pay ("WTP") for the PGI products they used.

Intuitively, had the Programs not existed, an average user would only collect geoscience information that is essential to his or her project, the spending that an average user would make thereby is used as a proxy to estimate the minimum value. In contrast, when all the required geoscience information is readily available through the Programs, a user may extract all the relevant information and produce outputs or studies of higher values. Hence, the amount of money saved because of the Programs is used as a proxy to estimate the maximum value. In addition, as a public good, public geoscience information is non-excludable. Hence, an average user's willingness-to-pay may represent only a fraction of the value ascribed by the user as the user knows the information and knowledge acquired may be used by other users.

Together, the statistics collected are used to estimate an aggregated value of the benefits stemming from the Programs using the following equation:

$$\textit{Estimated Aggregate Benefits} = \textit{Expected Value}\,(V_{min}, V_{max}, WTP) \times \textit{Total Number of Users}$$

where V_{min} and V_{max} represent the minimum and maximum value an average user ascribes to the PGI products respectively.

The total number of users associated with the Programs is derived using product download information obtained from the GSC. In the same survey, users were also asked to provide information with respect to the attribution of the Programs for their projects. Specifically, users were asked to estimate the share of projects that would not have been undertaken in the absence of the GEM or TGI programs, along with the estimated costs of such projects.

(ii) Top-down Approach

The top-down approach estimates the economic benefits associated with either Program by using existing research on the economic benefits of publicly available geoscience information. The steps involved in this approach are:

1. Review existing industry, academic, and public research that has evaluated the economic benefits of public geoscience information. Studies were selected based on objective criteria, including: (i) the use of comparable methodology, (ii) similarity in the outcomes of interest, (iii) comparability of stakeholder groups and applications.
2. Adjust relevant findings from identified studies to appropriately estimate the benefits of the Programs within the Canadian economy. Factors considered include: (i) product variation and quality, (ii) total number of product users, and (iii) potential costs

associated with collecting the required geoscience information had it not been available for free.

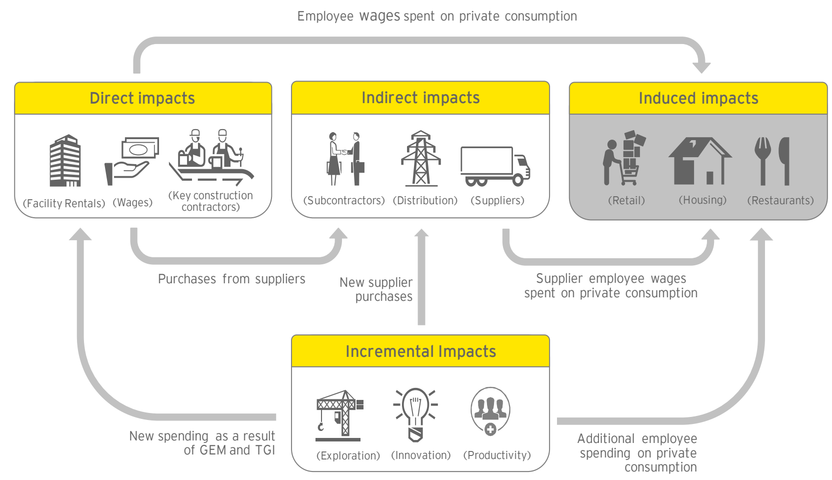
3. All identified factors were then standardized and applied to the Programs use and outcomes in the Canadian context to properly assess their potential economic benefits.

Input-Based Approach

A static input-output ("I-O") model is a tool used to estimate the economic contributions associated with the operational spending of the Programs. To assess the economic contributions, EY employed an input-based approach using Statistics Canada's Input-Output Tables. Economic contributions associated with the Programs are captured through three distinct channels: direct, indirect and induced impacts. These impacts individually and collectively represent how activities associated with the Programs ripple throughout the national economy. Figure 4 presents an illustrative example of how these impacts are interconnected. Each of these impacts are defined as follows:

- **Direct impacts** are the economic impacts supported directly by the Programs. These impacts represent "value-added" contributions to the economy and are derived by each Program's direct spending on line items such as employee salaries, facility rentals, travel spending, etc.;
- **Indirect impacts** are the economic impacts from business activities supporting the operations of the Programs. The indirect impacts include the impacts from suppliers' spending when purchasing goods and services from other suppliers. For the Programs, this could include, for example, the purchasing of lab equipment used for GEM or TGI-related activities; and
- **Induced impacts** are the economic impacts that occur when benefited employees from the stimulated direct and indirect economic activities associated with the Programs spend their additional wages and salaries on consumer goods and services. The induced activities are assumed to be primarily in service or consumer-related industries such as retail, transportation, accommodation, food and beverage and banking and finance. This consumer spending circulates in the economy and, in turn, results in additional jobs and salaries that are also considered part of the induced impacts. Induced impacts can be estimated based on any number of rounds or iterations of additional income resulting in increased spending, economic activity, and further additional income.

Figure 4. Direct, Indirect and Induced Economic Impacts



Sources: EY illustration.

As induced impacts are often estimated based on a number of iterations of the stimulated economic activities, they may have a tendency to overstate the size of the economic impacts, especially when the assumptions within the model do not necessarily reflect regional spending patterns. Although induced impacts are real economic impacts, they can be difficult to reasonably quantify, and their inclusion can potentially overstate the overall economic contribution of a specific event. Therefore, induced economic impacts have been excluded from consideration for this economic contribution assessment.

The I-O Economic Framework

Fundamentally, the I-O model translates spending into direct impacts which in turn drive the indirect economic impacts; these levels of impacts collectively define the total economic impacts of the Programs. The impacts are expressed in terms of the following economic indicators:

- **Gross Output**: The total economic activity of new goods and services because of activities occurring within a particular area.
- **Gross Domestic Product ("GDP")**: GDP, or value added, is a measure of the value of all final goods and services produced in a specific region;
- **Wages or labour income**: A component of the value-added that measures total employee compensation and proprietor income; and
- **Full-time equivalent employee ("FTEs")**: Refers to the total number of employees that are converted to full-time equivalence based on the average full-time hours worked.

To estimate the total economic benefits of the activities associated with the GEM and TGI programs, Statistics Canada's most recent economic multipliers from 2015 are used. These multipliers reflect how the interdependency between all sectors in the economy is tracked. Specifically, each of these multipliers is a number that describes the size of the total economic impacts for a given level of spending. Statistics Canada's I-O tables are used by both public and private sector organizations and other researchers and is based on a widely accepted methodology for estimating economic impacts.

Stakeholder Engagement

Stakeholder consultations with NRCan researchers were conducted to better understand the applications and the resulting benefits of the PGI products. The stakeholder consultation process consisted of a 30-minute phone call with 16 NRCan researchers over the course of one week. Respondents were selected based on their experience in conducting geological research with NRCan and their familiarity and practical experience through their tenures as lead researchers on the Programs. An interview guide was shared ahead of the scheduled interview to provide the researchers with sufficient time to formulate their responses. The views shared by the stakeholders are kept anonymous, as such, findings from the interviews are the result of synthesis of information gathered across all participants.

The interview was conducted using a combination of open and close-ended questions, allowing the stakeholders to expand on their responses as appropriate. The questions were formulated to be objective and independent to minimize biased results.

Jurisdictional Comparison

As part of the analysis, the merits and performance of the GEM and TGI programs were assessed against similar programs within other jurisdictions around the world. The selected comparative jurisdictions include Australia and the United States. Both jurisdictions are selected due to the size of their mining and mineral exploration industries relative to Canada's, as well as their overall attractiveness for mining investment.

4. Economic Analysis

4.1. Economic Assessment

The following section outlines the estimates of the economic benefits of the GEM and TGI programs. The top-down approach estimates the economic benefits by synthesizing existing research that have explored the potential value of the public geoscience information. The bottom-up approach derives the economic benefits using the survey outcomes. The input-based approach estimates the economic impacts resulting from the operational spending of the Programs.

Top-Down Approach

In order to carry out a benchmarking analysis, three academic research reports are reviewed. The reports are selected based on a variety of objective criteria, including the use of comparable methodology, similarity in outcomes of interest and comparability of stakeholder groups and applications, each of which is applicable to the Programs. A review of these reports is presented in Appendix **A.2**. In summary, the reviewed studies estimate economic benefits by deriving the minimum value, maximum value and willingness-to-pay ("WTP") ascribed to public geoscience information by an average user. These three metrics are defined as follows:

- **Minimum Value:** the minimum value ascribed to the GEM and TGI products by an average user;
- **Maximum Value:** the maximum value ascribed to the GEM and TGI products by an average user;
- **Willingness-to-Pay:** the amount of money an average user is willing to pay for the GEM or TGI products he or she used.

Using calibration techniques, estimated user minimum value, maximum value and WTP are ascribed for both GEM and TGI-generated information (Table 3). Results suggest that for GEM-generated information, the minimum value assigned by an average user falls between the range of $23,714 to $24,931. Meanwhile, the range for the maximum value is estimated to be between $45,422 and $47,756. Lastly, the user WTP for GEM-generated information falls between $5,639 and $5,928.

Combining product download counts and the information drawn from the EY survey, the estimated number of users that leveraged GEM-generated information is approximately 11,965. Therefore, the aggregate minimum value on the GEM program is around $284 million to $ 298 million, while the aggregate maximum value from the use of

Table 3. Estimated Economic Value of the Programs – Top-Down

GEM	Estimated Values (CAD$) (1)	Estimated Number of Users (2)	Aggregate Estimates (CAD$) (1) X (2)
Minimum Value	23,714 - 24,931	11,965	284M-298M
Maximum Value	45,422 - 47,756	11,965	543M-571M
Willingness-to-Pay	5,639 - 5,928	11,965	67M-71M
Expected Value	**25,565**	**11,965**	**306M**
TGI	**Estimated Values (CAD$) (1)**	**Estimated Number of Users (2)**	**Aggregate Estimates (CAD$) (1) X (2)**
Minimum Value	5,804 - 6,415	12,391	72M-79M
Maximum Value	10,828 - 11,384	12,391	134M-141M
Willingness-to-Pay	1,732 - 1,821	12,391	21M-23M
Expected Value	**6,331**	**12,391**	**78M**

Notes: Estimated number of users is derived from stakeholder download information. Estimated values and Aggregate estimates are expressed in CAD 2018 dollars. Numbers have been rounded. TGI figures reflect those from TGI-4 and TGI-5 only.

Sources: Stakeholder data and EY calculations.

GEM information is estimated to be approximately $543 million to $571 million. Lastly, the aggregate WTP for such information falls between $67 million to $71 million. Through triangulating the three estimated values, the expected value of the GEM program is approximately $306 million.

Similar estimates are derived for the TGI program, where individual estimates for minimum and maximum values are between $5,804 and $6,415, and $10,828 and $11,384 respectively. Moreover, an average user's WTP for such information falls between $1,732 and $1,821. Using the estimated number of TGI users, which again is obtained from program download counts and survey outcomes, estimates for the aggregate minimum value falls between $72 million to $79 million, while the aggregate maximum value is between $134 million to $141 million. Lastly, the aggregate WTP is estimated to be between $21 million to $23 million. Likewise, by triangulating the minimum, maximum and WTP, the expected value of the TGI programs outcomes is approximately $78 million.

Bottom-Up Approach

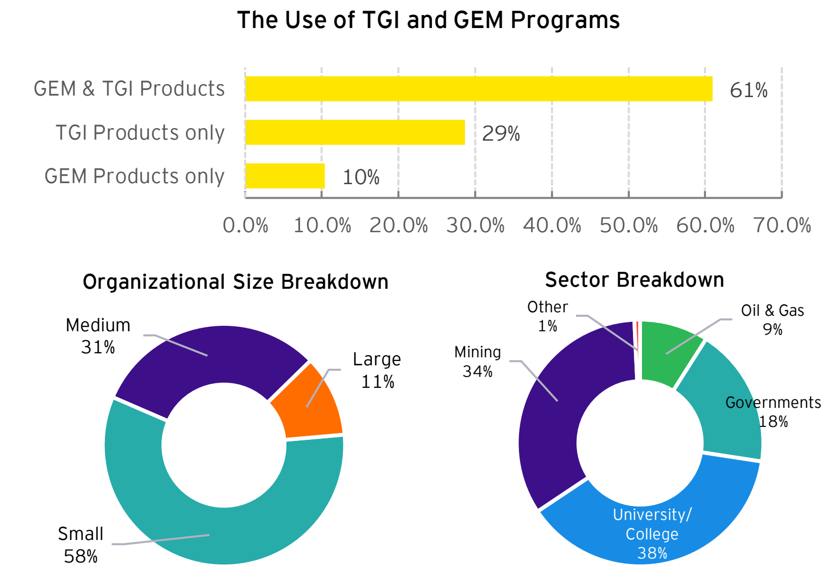
Following the analytical framework outlined in the methodology section, a survey was administered to understand the composition of the PGI users, the applications and the potential benefits.

The survey consisted of 22 questions, including numeric and multiple-choice questions. The survey had a response rate of over 40% from participants in various industries. A breakdown of respondents' sector and organizational size as well as statistics on their use of the TGI and GEM programs are provided in Figure 5.

Qualitative Value of the TGI and GEM-generated Information

Respondents were asked to provide background information relating to their organizational size, the sector of operation and the use of the Programs (Figure 5). Given that the scope and/or coverage of the TGI

Figure 5. Summary Statistics of the Survey



Notes: Organizations with 1-19 employees are categorized as small, 20-499 are categorized as medium, 500 and above are categorized as large.

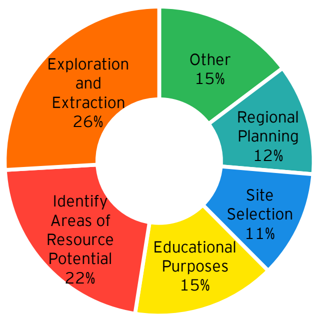
Sources: EY illustration.

and GEM programs often complements each other, close to 61% of the respondents used products from both programs. In addition, a majority of the respondents were small to medium sized organizations. In terms of the industrial sector, close to 38% of the respondents were in the university/college sector, while mining, and governments comprised 34% and 18% of the respondents respectively. The survey results are weighted to ensure that the sample collected can closely resemble the population of the PGI users. A detailed description of the sample weights construction is presented in the Appendix A.3.

The survey also asked respondents about their applications of the PGI products and the associated usefulness of the products (Figure 6). Exploration and extraction as well as identifying areas of resource

Figure 6. Common Use of PGI Products and Associated Usefulness

Common Use Breakdown



Usefulness	%
Provide information that would otherwise need to be collected	23%
Improve search and development efforts	18%
Increase accuracy of exploration activities	18%
Reduce time and costs for related project(s)	18%
Increase credibility of reports and studies produced	11%
Other	12%
Total	**100%**

Sources: EY illustration.

potential were two of the most frequent applications, representing close to half of all applications. Additionally, the PGI products were commonly used for educational purposes, site selection and regional planning among others. Moreover, close to 23% of respondents noted that the GEM and TGI products provided them with information that would otherwise need to be collected, while approximately 18% of them highlighted that PGI helped improve their research and development efforts, increased the accuracy of exploration activities and reduced time and costs for related projects.

When asked about the ways to collect comparable geoscience information in the absence of the Programs, approximately 46% of the respondents indicated that they would perform their own field work, while 14% would hire a consultant or seek the needed information from private sources. On the other end of the spectrum, close to 30% of the respondents revealed that it would not be possible to collect similar information on their own. Moreover, respondents were asked to estimate the share of the total project costs that would have been allocated to collect similar geoscience information in the absence of the Programs. Depending on the sector of operation and applications, a considerable variation is observed in the responses. On average, respondents estimated that close to 15% of the total project costs would have been used to collect the required geoscience information.

Another important aspect of the survey was to understand the attribution of the PGI products. Specifically, respondents were asked to estimate the share of projects that would not have been undertaken in the absence of the GEM or TGI programs, along with the estimated costs of such projects. On average, respondents indicated that up to 32% of their projects would not have been undertaken in the absence of the Programs. It should be noted, however, that considerable variation is observed in the responses. Small to medium sized organizations, as well as organizations in the university/college sector indicated that they would be less likely to undertake projects had the Programs not been available, while others indicated that they would likely undertake the projects regardless. Furthermore, respondents estimated that the median costs of such projects were approximately $100,000. This suggests that the GEM and TGI-generated information may result in up to **$779 million** in project spending (Table 4).

Quantitative Value of the TGI and GEM-Generated Information

Following the methodology laid out in *Bhagwat and Ipe (2000)*, each respondent was asked to provide the maximum, minimum and the most likely values relating to their (i) willingness to spend to collect comparable geoscience information had the Programs not been available; (ii) expected saving in costs from the use of GEM or TGI product(s); and (iii) willingness-to-pay for the TGI or GEM product(s) they used.

The data collected are used to estimate an aggregate value of the benefits stemming from the Programs. Results from the bottom-up approach suggest that the minimum value of PGI products ascribed by

Table 4. Estimated Economic Value of the Programs

Economic Benefits	Estimated Values (CAD$) (1)	Estimated Number of Users (2)	Aggregate Estimates (CAD$) (1)X(2)
Minimum Value	15,028	24,356	366M
Maximum Value	34,269	24,356	835M
Willingness-to-Pay	4,372	24,356	106M
Expected Value	**17,890**	**24,356**	**436M**
Incremental Benefits	Share of Projects Undertaken Because of the Programs	Median Project Costs	Incremental Project Spending
Estimated Value	32%	$100,000	**$779M**

Note: Estimated number of users is derived from user download information. Estimated values and aggregate estimates are expressed in CAD 2018 dollars. Numbers have been rounded. Response rates for GEM-only and TGI-only users were too low to derive estiamtes with confidence.

Sources: EY calculations.

an average user is approximately $15,000. Moreover, the maximum value is around $40,000, while the WTP is approximately $5,000.

In aggregate, by triangulating estimates from the bottom-up approach and the top-down approach, it is estimated that the expected value of the GEM and TGI programs is approximately **$436 million** (Table 4). Combining with the attribution of up to **$779 million**, the total economic benefits generated by the GEM and TGI programs are approximately **$1.22 billion**. It should be noted that the estimated values presented above only account for the value of the PGI products to a single user. A user may use these products for more than one project or distribute them within the organization. Hence the estimated values may potentially be larger. Detailed breakdowns of the estimated values by organizational size and sector are presented in Appendix A.4.

Input-Based Approach

Program Spending

The following section describes in detail the operational spending used to derive the economic contributions resulting from the GEM and TGI programs. The spending information was provided by stakeholder representatives from GSC and NRCan. Operational spending refers to the day-to-day maintenance and administrative costs associated with either Program, and includes line items, such as salary and benefits, transportation rentals and leases, travel expenditures and professional services, etc. Operational spending also includes the grant and contribution funding distributed by the Programs.

GEM Program

Operation and maintenance ("O&M") spending for the GEM program is collected for FY2008/09 through FY2018/19. Total O&M spending over this period was approximately $123.0 million. This accounted for spending within the program's major projects, maintenance and purchase of lab equipment and expenditures of the GEM Coordination Office ("GCO"). The purpose of the GCO is to support the GEM Steering Committee, which has overall responsibility for the execution of the GEM program. The GEM program also provided approximately $6.1 million in grants and contributions ("G&C's") to categories described

Table 5. Summary of TGI and GEM Program Spending

Spending Category	TGI	GEM
Operation and Maintenance Spending	$34.1M	$123.0M
Salaries	*$4.4M*	*$21.6M*
Gants and Contributions	$3.6M	$6.1M
Total Spending	**$37.7M**	**$129.1M**

Note: Values are expressed in CAD 2015 dollars, numbers are rounded. Salaries is a subset of O&M and include GEM personnel, GEM student and casual employee salaries.

Sources: Stakeholder data and EY calculations.

below. In total, operational spending associated with the GEM program was approximately $129.1 million (Table 5).

The grants administered by the GEM program fall into one of three categories:

- **Geoscience**

Geoscience grants are administered to successful proponents who help develop the long-term capacity of the Canadian geoscience sector and address pressing resource needs in the North.

- **Multidisciplinary Projects**

Grants for multidisciplinary projects are given to proponents who support the development of innovative approaches and tools that facilitate the use of GEM-generated information by the Northerners.

- **Territorial Colleges**

Grants for territorial colleges are given to northern institutions with successful proposals to develop innovative approaches and tools that facilitate the use of GEM data and information by Northerners.

TGI Program

O&M spending associated with the TGI program is collected for FY 2010/11 through FY2019/20. Total O&M spending over this period was approximately $34.1 million. It included costs associated with the program's major and sub-projects. In addition, the TGI program also administered approximately $3.6 million in grants over this period, which were predominantly handed out to academic intuitions to support mineral exploration in established or emerging mining camps. In total, operational spending associated with the TGI program was approximately $37.7 million (Table 5).

Economic Impacts

The direct and indirect economic impacts associated with the GEM and TGI program spending are displayed in Table 6. These impacts are also inclusive of the spending associated with the grants and contributions handed out by both programs over their duration. Results suggest that O&M spending, along with the G&C's associated with the GEM program, supported approximately $127.0 million in gross output, $148.1 million in GDP, $24.9 million in wages, and 384 person-year full-time equivalent jobs. Regarding the TGI program, O&M and G&C activities supported approximately $41.6 million in gross output, $39.7 million in GDP, $5.1 million in labour income, and approximately 37 person-year full-time equivalent jobs.

Table 6. Economic Impacts of the GEM and TGI Programs

Impact	Output (CAD$, M)	GDP (CAD$, M)	Wages (CAD$, M)	FTEs (Person-Years)
GEM				
Direct	107.5	95.2	21.6	288
Indirect	19.5	52.9	3.3	96
Total	**127.0**	**148.1**	**24.9**	**384**
TGI				
Direct	33.3	26.1	4.4	30
Indirect	8.3	13.6	0.7	7
Total	**41.6**	**39.7**	**5.1**	**37**

Notes: Values for wages, GDP and output are in millions and 2015 CAD dollars. Numbers have been rounded. Impacts based on Statistics Canada 2015 economic multipliers. Values in the total row represent total impacts associated with TGI and GEM spending.

Sources: Stakeholder data and EY calculations.

4.2. Stakeholder Engagement

Stakeholder consultations were conducted with 16 NRCan researchers via teleconference in early December 2019. NRCan researchers, whose work was instrumental in generating public geoscience information, were engaged to discuss the following topics:

- Industry breakdown of the PGI users;
- Applications of the PGI products; and
- The degree of usefulness or importance of the PGI products.

Outcomes

As part of the discussions with stakeholders, the key themes explored are presented below.

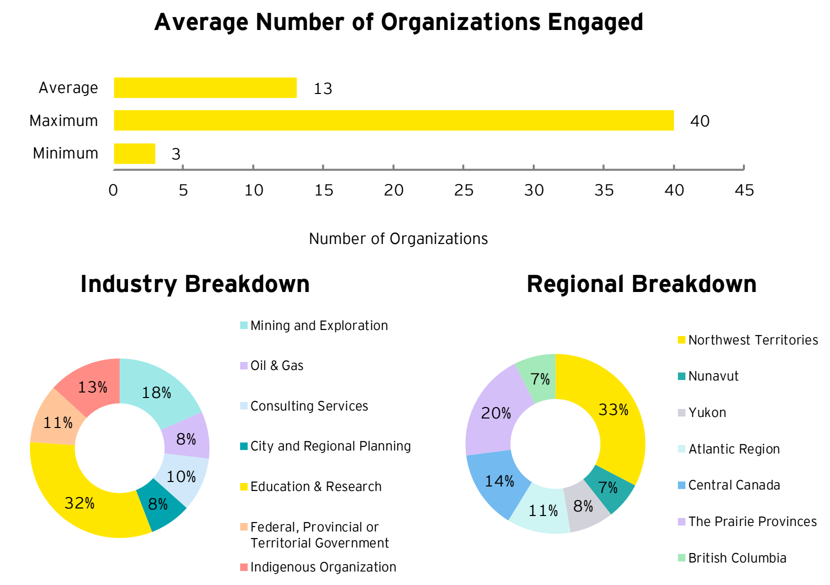
Organizations Using PGI Products

Respondents were asked to estimate the average number of Canadian organizations they were typically engaged with on an annual basis, and to provide an industry and province-wide breakdown if possible. With considerable variation in the ranges provided by the respondents, summary statistics on regional and industry breakdowns are displayed in Figure 7. On an annual basis, NRCan researchers reported to have engaged with a minimum of 3 and a maximum of 40 organizations. These organizations had a wide distribution across industries, with a majority in the education and research sector. Additionally, respondents highlighted that nearly half of these organizations operated in Northern Canada.

Common Uses of PGI Products

In this section of the interview, respondents were asked to identify the most common uses of information that was generated from their

Figure 7. Annual Engagement with Organizations



Sources: EY illustration.

research projects. Specifically, respondents were asked to rank the most common uses, and provide details relating to the use of information by organizations if possible. The most common uses as identified by respondents, were:

- Infrastructure Development

Respondents observed that organizations in charge of planning and executing infrastructure development projects in the territories made use of the PGI products to understand permafrost conditions, drift thickness, and other geological conditions as they relate to the construction of roads and bridges. Information on gravel and aggregate helps organizations to select route on certain terrains and understand the resulting material requirements. For instance, in the planning of the Inuvik-Tuktoyaktuk Highway in the Northwest Territories, PGI products helped planners to optimally allocate gravel resources along the planned route, resulting in better endurance of the highway. Respondents also highlighted that information on cases such as coastal erosion helped organizations make informed decisions on large scale projects such as port development.

- Identifying Areas of Resource Potential

Respondents highlighted that several sectors leveraged PGI products to identify areas with resource potential. Specifically, detailed information relating to specific mineral reserves helped territorial governments to carry out long-term planning for exploration. For instance, the Yukon Geological Survey is working to compile a territory-wide repository of surficial geology maps, which is available for use for all sectors. Respondents also highlighted that many mining and exploration companies use PGI products and associated learning from workshops and interactions with NRCan researchers to make decisions on areas of interest, particularly with respect to which areas to conduct staking activities.

- Exploration and Extraction

In terms of exploration and extraction, it is indicated that having access to geology maps and detailed geophysical surveys and reports produced by NRCan projects helps mining and exploration companies augment their existing knowledge. Respondents observed that the information is often vital to the exploration and extraction activities, as they help users identify areas with resource potential, as well as provide information relating to the quality of an exploration target.

- Educational Purposes

Given the high degree of integration of the Programs with academia, the use of PGI products for educational purposes was highlighted by the majority of respondents. Respondents noted that participation of student researchers in geoscience knowledge and innovation programs could facilitate execution of key research in remote areas by the academic sector. Moreover, respondents highlighted that the logistical and informational support provided by the Programs to students and professors pursuing research in the field could lower costs of conducting research. Having free access to maps, datasets, field guides, and in some cases, samples collected from the field, researchers were able to conduct independent studies without incurring high costs of travel, residence and hardware that are required in remote areas. Respondents noted that in some cases, with ongoing partnerships with local communities and governments, dedicated community outreach publications were also created on fossils, which served an educational purpose for the locals.

- Land Use

Respondents observed that governments, regulatory bodies, water boards, and oil & gas lease organizations, among others made use of PGI products to make important land use decisions. Having access to PGI products allowed them to understand areas with high risk and possible engineering difficulties relating to bedrock. Researchers had also observed that broader land use decisions, such as identifying areas that were suited for national parks, were facilitated as a result of access to surficial maps.

Organization-Level Spending

The interview further allowed respondents to freely comment on the sizes of user projects, the importance of PGI products to the execution of user projects, and any broader takeaways or observations relating to organizational spending on the generation or collection of geoscience information.

Specifically, respondents were asked to estimate the size of the projects (proxied by the total project costs) that typically made use of PGI products. A wide variation was observed in the reported project sizes, which can be attributed to user's sector of operation. Large mining and exploration companies, for example, often operate with budgets up to hundreds of millions of dollars, whereas a small operation, or a university research project, would have funding in the range of $5,000 to $10,000.

Importance of PGI Products to User's Projects

Researchers were asked to estimate, in their view, the importance of the public geoscience information to user projects. Specifically, respondents were asked to assign a score between 1 and 10, with a score of 1 indicating that the information had no influence on the project(s), and 10 indicating that the information was a primary reason for carrying out the project(s). The average score for PGI products, as reported by NRCan researchers, was 5.3 out of 10. Respondents noted that the sector of operation was an important factor when assigning a score of importance. For large scale operations in mining and exploration, PGI products may serve as a nudge in the right direction and augment existing knowledge. However, even if this information did not exist, the projects would still be executed as planned. Researchers assigned a global minimum score of 2 in this case. A caveat to such cases would be that PGI products helped inform decisions relating to precision and accuracy, but not to the decision relating to the project's execution. On the contrary, for regulatory authorities and governments, and researchers in the academic sector who would otherwise not have the resources to collect similar geoscience information, PGI products would be instrumental in the decision to carry out projects. In such cases, a global maximum score of 10 was reported.

Respondents were also asked to comment on the proportion of projects that were made possible directly as a result of access to PGI products. Respondents indicated that an average of 40% of such projects were made possible due to having access to PGI products but highlighted that these projects tended to be smaller in scale and academic in nature. The researchers mentioned that most projects would in fact be executed based on the necessity, albeit with less information and hence in a less efficient manner.

Other general observations by respondents included the uniqueness of such information and its extremely high costs if generated privately or through paid sources.

4.3. Jurisdictional Comparison

The following section outlines similar programs to both GEM and TGI within select global jurisdictions. For the purposes of this report, programs in Australia and the United States are selected to compare to the GEM and TGI programs. Both jurisdictions are selected due to the similar size of their mining and mineral exploration industries to those of Canada, as well as their overall attractiveness for mining investment.[7] More importantly, the scope and applications of their geoscience programs and initiatives closely resemble that of the GEM and TGI programs.

Australia

Public geoscience information in Australia is administered by Geoscience Australia ("GA"), the national public geoscience organization and Australia's key advisor on all aspects related to geoscience, geology and geography. Recently, recognition of Australia's dependence on the endowment of mineral and energy resources has led to the launch of the UNCOVER initiative to help further develop mineral exploration capabilities across the country. The initiative brought together industry participants, researchers across government and academia, and other relevant stakeholders to develop a shared strategic vision, and prioritize activities to advance exploration geoscience.[8] The priorities developed through the initiative led to the establishment of the Exploration for the Future initiative by the Australian Government, which dedicated AUD $100.5M between 2016 and 2020, through GA, to help stimulate resource exploration investments in Australia.[9]

The purpose of the initiative is to reveal and develop under-explored regions in Northern Australia and parts of Southern Australia with significant potential.[10] Exploration for the Future's programming is broadly divided into three major categories: Energy, Minerals, and Groundwater. Funding through the initiative allows researchers to utilize cutting edge techniques to gather new intelligence on untapped resources hidden beneath the earth's surface. Activities within this initiative involve data acquisition using geophysical surveys, geochemical sampling, hydrological mapping and stratigraphic drilling. Moreover, the program actively targets greenfield regions and other areas with high impact potential. Specific program deliverables under the initiative include:[11]

- Release of pre-competitive information;
- Delivering integrated resource assessments for northern Australia;
- Delivering geological studies of the progression and resource potential of on-shore and off-shore energy systems;
- Delivering assessments of the energy potential of the Geological and Bioregional Assessments Program; and
- Delivering new offshore exploration acreage opportunities from Energy Systems pre-competitive program in annual Offshore Petroleum Exploration Acreage Release.

United States

The United States Geological Survey ("USGS") provides reliable geoscience information to describe and understand the earth, minimize loss of life and property from natural disasters, manage water, biological, energy and mineral resources and enhance and protect quality of life. Much like the Geological Survey of Canada, the USGS is responsible for funding and managing several programs and products with direct geoscience applications to minerals and energy resource exploration and development. This includes map designing, data collection and aggregation, energy assessments and other activities. The Mineral Resources Program ("MRP") and Energy Resources Program ("ERP") are two specific initiatives funded by the USGS that are similar in nature and scope to the GEM and TGI programs. The MRP is designed to provide information on non-fuel mineral resource potential, production, consumption and describe how these minerals interact with the environment. The MRP supports data collection and research on non-fuel mineral resources that are critical to the United State's economic sustainability and national security through geologic, geochemical, geophysical, and remote sensing surveys.[12] Conversely, the focus of the ERP is to provide tools and data to help better manage and assess geological energy resources in the US, namely, oil, natural gas, coal, coalbed methane, gas hydrates, geothermal resources, and uranium.

Program and Initiatives Comparison

Total spending for each of the relevant geoscience agencies and initiatives identified across the select jurisdictions is displayed in Table 6. Among the broader geoscience organisations, total expenditure in 2018 was approximately CAD $200 million for GA, close to $1.5 billion for the USGS and $75.4 million for the GSC. While smaller in size than the USGS in absolute terms, GA had the highest spending per $1 million in GDP, and was almost triple the size of the GSC's expenditure relative to the size of the national economy. It is important to note, however, that in addition to a dedicated component towards natural resources, GA's strategic components also include community safety, marine jurisdictions, as well as location-enabling technologies. The organization's emphasis on GPS technologies was further demonstrated when the Australian Government dedicated AUD $224.9M over four

Table 7. Annual Public Geoscience Spending by Comparators, 2018

Programs and Initiatives	Spending ($CAD, Millions)	Spending per $1M GDP ($CAD)
Australia		
Geoscience Australia	199.6	113.6
'Exploring for the Future'	25.8	14.7
United States		
U.S. Geological Survey	1,514	65.5
'Mineral Resources Program'	65.1	2.8
'Energy Resources Program'	40.7	1.8
Canada		
Geological Survey of Canada	75.4	38.4
'TGI'	5.6	2.8
'GEM'	10.5	5.4

Notes: Values are expressed in CAD 2019 dollars and represent annual budget amounts. Spending for 'Exploring for the Future' is based on an even distribution of funds across four years. Annual expenditure for initiatives in 2018 is similar to spending patterns in preceding years.

Sources: EY calculations, Geological Survey of Canada's Strategic Plan 2018-2023, U.S. Geological Survey FY2020 Budget Justifications, and Australian Government – Department of Industry, Innovation and Science 2018-19 Annual Report.

years in its 2018-19 budget to develop a Satellite-Based Augmentation System and upgrade the Global Navigation Satellite System network.

The MRP and ERP programs within the USGS are the largest geoscience initiatives dedicated to mineral and energy resources across the identified jurisdictions. However, the USGS also administers other dedicated programs with geoscience applications such as the Core Science Systems, which includes the national geospatial program. Although smaller in total expenditure, spending through the TGI and GEM programs is collectively larger than the MRP and ERP, relative to the size of each country's economy. Between the three jurisdictions, GA's Exploring for the Future initiative has the highest spending dedicated to its program relative to the national GDP.

5. Appendices

A.1. Input-Output Model: Assumptions and Restrictions

The following appendix outlines the assumptions and restrictions associated with the I-O model used to perform the economic impact analysis in this Report. The I-O model is subject to limitations both in concept and implementation. Like any economic model, the I-O model is conceptually an abstraction that attempts to be complex enough to accurately capture and estimate the most significant impacts to the real-life economy caused by economic activities, yet simple enough to be analytically and intuitively meaningful.

An I-O model reflects the observed interdependency between all sectors of the economy. For Canada, Statistics Canada reports for the 236 industrial sectors in the economy: (1) how each sector relies on the other 235 sectors for inputs to their production; and (2) how each sector supplies its products and services to each of the remaining 235 sectors. While an I-O model provides a consistent and innovative way of measuring the economic effects of an economic activity, one should be aware of the assumptions and limitations imposed on the model's underlying approach. Some of these assumptions include:

- The relationship between industry inputs and outputs is linear and fixed, meaning that a change in demand for the outputs of any industry will result in a proportional change in production;
- The model assumed constant returns to scale, and cannot account for economies/diseconomies of scale or structural changes in production technologies, an assumption that does not necessarily hold in the actual economy;
- Prices are fixed in the model; thus, the model is unable to account for elasticities, or more formally, how one economic variable change in response to another;
- I-O models are static, and therefore do not consider the amount of time required for changes to happen. Changing the timeframe would not affect the magnitude of the estimates;
- There are no capacity constraints, and all industries are operating at full capacity. This implies that an increase in output results in an increase in demand for labour (rather than simply re-deploying existing labour). It also implies that there is no displacement that may occur in existing industries as new projects complete;
- I-O models assume that the technology and resource mix (ratios for inputs and production) is the same for all firms within each industry, i.e., the 236 industry categories reported in Statistics Canada's input-output table. As such, our analysis describes industry average effects;
- The model assumes that the structure of the economy remains unchanged, and any structural changes in the economy since 2015 will therefore lead to changes to the multipliers, which could be implemented once Statistics Canada release updated input-output tables. As such, the further the year of analysis is away from the year of the input-output tables used, the greater the uncertainties;
- The model does not consider the economic impacts or opportunity costs associated with using resources elsewhere. In the case of this analysis for example, funds used to purchase lab equipment may be allocated to other areas. Using these funds for alternative uses would generate their own economic impacts, which could potentially be larger or smaller. However, the model will not be able to capture this difference.

- Results from the I-O model should not be interpreted as causal impacts, that is, one should not take the economic impacts presented in this report at verbatim. We cannot say with certainty that X dollars of capital or operational spending will produce X number of FTEs or have an X amount of impact on GDP; and
- The model does not consider substitutions amongst inputs, and that each industry in the model is regarded as having a single production process.

As per the assumptions above, the structure and limitations of I-O models lend themselves to measuring the impacts of projects that are shorter term in nature; generally, they are used to look at shocks to the economy. For long term analysis, time series and general equilibrium models are more appropriate.

A.2. Previous Research Review

Bhagwat and Ipe (2000)* and *Garcia-Cortes et al. (2005)

Using an avoided cost approach, *Bhagwat and Ipe* (2000) found that the 1: 24,000 scale geological maps of the State of Kentucky contributed between approximately USD $27.7 million to USD $3.5 billion to the local economy between 1972 and 1999. Using a similar approach, *Garcia-Cortes et al.* (2005) found that the impact of geological maps offered through the MAGNA program contributed between €256 million to €3.3 billion to the Spanish economy from 1972 to 2003. To derive these estimates, the authors estimate individual user's minimum, maximum and WTP values for using public geoscience information, which are presented in Table 8. The maps' aggregate economic values are determined by multiplying each of these figures by the number of users.

Table 8. Bhagwat & Ipe (2000) and Garcia-Cortes (2005) Estimates

Bhagwat and Ipe (2000)	Estimated Value (USD$) (1)	Estimated Number of Users (2)	Aggregate Estimate (USD$) (1) X (2)
Minimum Value	27,776	81,000	2,249.9M
Maximum Value	43,527	81,000	3,525.7M
Willingness-to-Pay	342	81,000	27.7M
Garcia-Cortez et al. (2005)	**Estimated Value (EURO€) (1)**	**Estimated Number of Users (2)**	**Aggregate Estimate (EURO€) (1) X (2)**
Minimum Value	7,579	165,576	1,254.9M
Maximum Value	20,170	165,576	3,339.7M
Willingness-to-Pay	1,549	165,576	256.5M

Notes: Figures for Bhagwat and Ipe (2000) are in 1999 US dollars.
Figures for Garcia-Cortes (2005) are in 2003 Euro dollars.

Sources: Bhagwat and Ipe (2000) and Garcia-Cortes et al. (2005).

Kleinhenz and Associates (2010)

Likewise, the economic contributions of publicly available geoscience information had also been examined within the State of Ohio, where *Kleinhenz and Associates* (2010) examines the impact of geological information available through the Ohio Geological Survey ("OGS"). Specifically, the authors examined these impacts through the following channels:

- Benefits based on the cost of replacement;
- Benefits based on the proportion of the project costs;
- Aggregate industry benefits; and
- The total economic contributions of the OGS-generated information on the economy in Ohio.

With respect to benefits derived from replacement costs and the proportion of the total project costs, the authors find that the aggregate

Table 9. Economic Contributions from OGS Spending

Economic Impact	Output (USD$ M)	Wages (USD$ M)	FTEs
Direct	3.16	2.77	28
Indirect	0.42	0.16	5
Induced	2.16	0.69	18
Total	5.74	3.62	51

Notes: Figures for output and wages are expressed in 2010 US dollars and are rounded.
Authors did not report GDP contributions from OGS operations.

Sources: Kleinhenz and Associates (2010).

benefits of the OGS-generated information fall between approximately USD $575 million and USD $1.54 billion. In terms of industry benefits, the OGS-generated information contributed approximately USD $28.6 million to organizations within the State of Ohio in 2010. Lastly, using a standard input-output model, the direct, indirect and induced economic impacts from OGS related spending are presented in Table 9.

For 2010, OGS spending contributed approximately USD $ 5.7 million in gross output, USD $ 3.6 million in labour income and sustained 51 full-time equivalent jobs.

A.3. Bottom-Up Methodology

In order to collect necessary information from key stakeholders of the Programs, an online survey was administered that asked respondents to provide information with respect to the following key themes:

- Background information;
- Cost saving;
- Spending; and
- Willingness-to-pay.

Following *Bhagwat and Ipe* (2000), using individual survey responses, the aggregate minimum, maximum and WTP values for all users of the Programs are estimated using the following formula:

$$\overline{V_i} * N$$

Where $\overline{V_i}$ represents the mean user expected spending, expected saving and WTP values for information generated from the TGI and GEM programs, while N represents the number of program users. To determine individual expected values, the survey asked respondents to provide subjective estimates of their lowest, highest and most likely spending, cost savings and WTP associated with the GEM and TGI-generated products. From there, the expected value for each of the three metrics is calculated as follows:

$$EV = \int_b^a V f_v(V) dv$$

Where *EV* represents the expected value of the GEM and TGI-generated products to an average user, a represents an individual user's subjective maximum values and b represents the individual user's subjective minimum values. Finally, $f_v(V)$ represents the assumed distribution of individual users expected values, which in this case is represented by a triangular distribution.

To ensure the sample collected is as close of a representation as the actual industry population using the GEM or TGI-generated information, sample weights are constructed and applied to each individual response. The sample weight in this case can be thought of as the frequency that a sampling unit appears in the target population. Specifically, these weights are constructed through a technique called iterative proportional fitting ("IPF"). IPF adjusts the weights of the sample data based on known population characteristics, in this case, a respondent's sector of operation and organizational size. Sampling weights are estimated through an iterative process until the marginal distribution of the survey sample converges to that of the population.

A.4 Survey Results

Table 10. Estimated Economic Value of the Programs by Organizational Size

	Small (1-19)	Medium (20-499)	Large (500 and above)
Minimum Value	$ 10,000	$ 2,333	$ 6,667
Maximum Value	$ 10,000	$ 10,000	$ 33,333
Willingness-to-Pay	$ 6,667	$ 1,667	$ 4,333
Expected Value	**$ 8,889**	**$ 4,667**	**$ 14,778**

Notes: Estimated values are expressed in CAD 2018 dollars. Numbers have been rounded. Organizations with 1-19 employees are categorized as small, 20-499 are categorized as medium, 500 and above are categorized as large.

Sources: EY calculations.

Table 11. Estimated Economic Value of the Programs by Sector of Operation

	Academic Sector	Private Sector	Public Sector
Minimum Value	$ 6,667	$ 10,000	$ 15,000
Maximum Value	$ 33,333	$ 10,000	$ 2,333
Willingness-to-Pay	$ 5,000	$ 6,667	$ 16,667
Expected Value	**$15,000**	**$8,889**	**$11,333**

Notes: Estimated values are expressed in CAD 2018 dollars. Numbers have been rounded. Private sector consists of oil&gas, mineral exploration, mining and other private-sector Industries.

Sources: EY calculations.

A.5. References and Comments

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