REPORT

Site-Specific Seismic Hazard Assessment

Louvicourt Mine Tailings Management Facility

Submitted to:

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Distribution List

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EXECUTIVE SUMMARY

This report presents the results of a site-specific seismic hazard assessment (SSSHA) undertaken by WSP Canada (WSP) for the tailings storage facility (TSF) at Teck's closed Louvicourt Mine site in southwestern Québec. The assessment is for Dam 1D of the Louvicourt TSF (48.135ºN latitude and 77.595ºW longitude). Dam 1D was selected for the SSSHA because it is likely the critical structure for the overall stability of the TSF. The SSSHA includes probabilistic seismic hazard analysis (PSHA) used to estimate earthquake ground motions with annual exceedance probabilities (AEPs) of 1/2,475, 1/5,000, and 1/10,000. The SSSHA also provides earthquake acceleration time histories (EATHs) amplitude-scaled to the 1/10,000 AEP site-specific mean uniform hazard spectrum (UHS) from the PSHA.

The Louvicourt SSSHA is based on seismic source models developed for southeastern Canada by the Geological Survey of Canada (GSC) for the 6th Generation Seismic Hazard Model of Canada (CanadaSHM6). The tectonic setting, seismicity rates, and earthquake distribution within about 600 km of the Louvicourt TSF site were reviewed to confirm the suitability of the CanadaSHM6 seismic source models for the SSSHA. Earthquake ground motions were evaluated by applying the 17 NGA-East ground motion models (GMMs) and 2020 site amplification models developed for central and eastern North America (CENA). These GMMs and site amplification models supersede those used by GSC with the CanadaSHM6 source models. Site amplification was based on the measured time-averaged shear-wave velocity over 30 m below the bedrock (V_{S30}) of 1,853 m/s.

Table S1 lists the mean and selected fractile uniform hazard spectral ordinates developed from the site-specific PSHA at AEPs of 1/2,475, 1/5,000, and 1/10,000:

The site-specific PSHA results are higher than those reported in the 2020 National Building Code of Canada (NBCC) for the same site, ground conditions and the V_{S30} of 1,853 m/s. These differences are primarily because of our use of the 17 NGA East GMMs and recent site amplification models.

The site-specific PSHA results, including UHS and magnitude-distance-epsilon disaggregation, inform the development of representative EATHs for use in future geotechnical analyses. WSP developed EATHs at two fundamental periods important to the Louvicourt TSF site – a shorter fundamental period, T_S = 0.25 to 0.37 s, and a longer fundamental period, T_L = 1.15 s. Eight, two-horizontal-component EATHs from the NGA-West2 ground motion database were amplitude-scaled to match the 1/10,000 mean UHS within a period range of interest specific to each of the fundamental periods. Secondary intensity measures (IMs) were considered to establish the suitability of the selected EATHs.

Table S1: Site-Specific Horizontal Acceleration Response (5%-damped[1]) Spectral Ordinates for Selected Annual Exceedance Probabilities for the Louvicourt TSF Site, Québec, Canada (V_{S30} 1,853 m/s).

Annual Exceedance Probability (AEP)	Spectral Period (s)	5% damped, RotD50, Spectral Acceleration (g)					
		Mean	Fractile				
			5th	16th	50th (median)	84th	95th
1/2,475	PGA	0.099	0.041	0.046	0.083	0.128	0.204
	0.2	0.189	0.066	0.088	0.154	0.246	0.378
	0.5	0.114	0.036	0.052	0.088	0.152	0.198
	1	0.066	0.018	0.029	0.049	0.089	0.127
1/5,000	PGA	0.140	0.056	0.062	0.114	0.177	0.283
	0.2	0.261	0.086	0.116	0.205	0.331	0.508
	0.5	0.156	0.047	0.068	0.117	0.200	0.268
	1	0.092	0.023	0.038	0.066	0.120	0.170
1/10,000	PGA	0.193	0.072	0.083	0.147	0.235	0.376
	0.2	0.350	0.111	0.149	0.265	0.428	0.658
	0.5	0.206	0.062	0.087	0.150	0.258	0.340
	1	0.122	0.030	0.048	0.084	0.156	0.218

[1] "5%-damped" refers to the fact that the UHS describes the estimated elastic-response of inverted pendula to an earthquake ground motion with an assumed 5% damping of the response applied to represent the loss of energy in transmission. 5%-damping is the typical value used for earthquake ground motions and is incorporated in the GMMs implemented in this study. See Section 1.3 for further details.

1.0 INTRODUCTION

This report describes the data, methods, technical developments, and results of site-specific seismic hazard assessment (SSSHA) undertaken for Teck Resources Ltd's closed tailings storage facility (TSF) at Louvicourt Mine near Val d'Or, Québec, Canada (Figure 1). For the purposes of this assessment, seismic analysis was completed by WSP Canada Limited. (WSP) for a site at 48.135ºN latitude and 77.595ºW longitude ('the Louvicourt TSF site'). This location corresponds to Dam 1D of the TSF. Dam 1D was selected for the SSSHA because this is understood to be the critical structure for the overall stability of the TSF.

The SSSHA was undertaken for Teck Resources Ltd (Teck) as part of the work scope described in Teck's change order CO-03 dated September 15, 2023, and associated purchase order PO-353 dated April 29, 2022.

1.1 Scope of Work

The purpose of this SSSHA is to quantify earthquake ground motions with an annual exceedance probability (AEP) of 1/2,475, 1/5,000, and 1/10,000. These AEPs are approximately equivalent to return periods of 2,475-, 5,000-, and 1/10,000-years, respectively.

WSP undertook the following major tasks for the SSSHA:

- Acquisition and review of available information on historical earthquakes, regional tectonics, and potential faults within about 600 km of the Louvicourt TSF site.
- Review of seismic source models developed by the Geological Survey of Canada (GSC) and Natural Resources Canada (NRCan) for the 2020 National Building Code of Canada (2020 NBCC).
- Development of logic trees to capture epistemic uncertainty in the site-specific seismic source model inputs and ground motion models (GMMs).
- Completion of site-specific probabilistic seismic hazard analyses (PSHA) to produce mean and fractile hazard curves for selected spectral periods (peak ground acceleration [PGA], 0.2 seconds [s], 0.5 s, 1.0 s, and 2.0 s), and uniform hazard spectra (UHS) for selected AEPs (1/2,475, 1/5,000, and 1/10,000).
- Magnitude-distance-epsilon deaggregation of site-specific seismic hazard to identify the earthquake magnitudes and distances that make the greater contribution to the site hazard for the 1/10,000 AEP at PGA, 0.2 s, 0.5 s, and 1.0 s.
- Development of eight, two-horizontal-component earthquake acceleration-time histories (EATHs), matched to the 1/10,000 AEP uniform hazard spectral accelerations to support dynamic stability, settlement, and liquefaction analyses at the site, as needed by the project engineers.
- Preparation of this report for Teck's review and comment.

1.2 Terminology

The terminology used in PSHA is specialized. The use of synonymous terms can often lead to confusion. Table 1 lists key terms and alternative, similar terms that relate technical terms used in this report to other commonly used terms. A glossary of abbreviations found in this report can be found in Appendix A.

Table 1: Terminology Used in this Report.

Technical Term and Units	Alternative Similar Terms (units and definition may vary)
Spectral period (*seconds, s*)	Period, natural-period, period-of-vibration, natural frequency
Acceleration[1] (*percentage of gravitational acceleration, g*)	Peak horizontal acceleration, spectral acceleration
Annual exceedance probability (AEP)	Return period[2] (years), frequency, annual probability of exceedance (APE)
Uniform hazard spectrum (UHS)	Uniform hazard curve, acceleration response spectrum, response spectrum, spectral response spectrum, uniform hazard acceleration response spectrum, uniform hazard mean acceleration response spectrum
Ground Motion Model (GMM)	Ground motion prediction equation (GMPE), attenuation equation
Disaggregation	Deaggregation, de-aggregation
Areal Sources	Areal seismic sources, background sources, area sources. This term describes all sources that are not known or associated with mapped faults. Areal sources can be subdivided into gridded-area and uniform-area sources.

Notes:
1. The term ‘acceleration’ used in this report is the mean RotD50 horizontal peak acceleration response of a 5%-damped, single-degree-of-freedom system.

2. Return period is the inverse of annual exceedance probability (AEP).

1.3 Analysis Methods

A comprehensive seismic hazard assessment should in general account for the:

- Regional plate tectonic setting, and the geological and paleoseismic history of the major potential earthquake sources.
- Historical earthquake locations and occurrence rates and the three-dimensional distribution of earthquake hypocenters.
- Expected earthquake recurrence rates (from pre-instrumental and instrumental catalogues), and maximum magnitudes of earthquakes generated on known faults and other seismic sources.

- Characteristics of source-to-site earthquake ground motion attenuation, and near-source effects if any, on estimated ground motions as incorporated in state-of-practice ground motion models (GMMs).
- Effects of subsurface site ground conditions considered either by using GMMs that represent an average site response from global or regional observations, or by undertaking a site-specific seismic ground response analysis (SGRA).
- Aleatory variability in maximum earthquake magnitudes, and epistemic uncertainty in the ground motion models and other seismic hazard model inputs.

Preliminary notions of PSHA were provided by Cornell (1968). The PSHA method uses available historical seismic and geological data to characterize the seismic sources adjacent to the site of interest. Earthquake recurrence parameters are used to estimate the earthquake activity rate for each seismic source. The earthquake recurrence behavior for a seismic source is characterized by a frequency-magnitude relationship with the most common being the truncated exponential recurrence model that typically follows a log-linear frequency magnitude relationship as proposed by Gutenberg and Richter (1954) and expressed as:

$$\text{Log } N = a - b\, M$$

Where “N” is the cumulative number of earthquakes greater than or equal to M, the moment magnitude (Mw), per year (earthquake annual rate), and “*a*” and “*b*” are constants. The “*a*-value” represents the earthquake activity rate or number of events greater than zero magnitude. The “*b*-value” is the slope of the log-linear frequency magnitude relationship and controls the relative occurrence rates of different magnitude earthquakes. Lower *b*-value represent higher relative occurrence rate of larger earthquakes, and hence higher overall seismic hazard. In general:

- Earthquake *a*- and *b*-values are estimated based on the analysis of historical earthquake records, plate motion velocities, and average fault slip rates. The minimum earthquake magnitude used to calculate activity parameters is based on the completeness of available earthquake catalogues.
- The maximum earthquake magnitudes (M_{max}) are estimated based on observed earthquakes, historical estimates, and instrumentally recorded earthquakes, and/or empirical relationships between fault parameters, such as fault area and maximum or average single-event slip, and earthquake magnitude.
- The minimum magnitude for hazard calculation (M_{min}) is based on the expected minimum earthquake magnitude that may have some impact on the structures or facilities to be analyzed. The M_{min} for hazard calculation is not the same (and is generally larger) than the minimum magnitude used to calculate earthquake activity rates from the historical and instrumental earthquake catalogues. An M_{min} of Mw 4.8 is used for hazard calculations in this assessment.

GMMs are empirical earthquake ground motion attenuation relationships and/or theoretical models used to estimate the site ground motion given the magnitude, source-to-site distance, and site soil conditions. Typically, more than one GMM is selected and weighted in the PSHA analysis.

The seismic source models and GMMs are used in PSHA to estimate the likelihood (AEP) and intensity of earthquake ground motions for a site with given site ground conditions. PSHA outputs include:

- Mean hazard curves that describe earthquake ground motion intensity at a particular spectral period across a range of likelihoods. Fractiles hazard curves describe the uncertainty in the mean hazard curve estimate based on the uncertainties included in the seismic source model and the uncertainties within and between selected ground motion models.

- The UHS is the uniform-hazard, 5%-damped, mean, RotD50, peak-horizontal, spectral acceleration across a range of spectral-periods. The components of this definition are described below for clarity:
  - **Uniform-hazard.** Each point on the mean UHS has an equal likelihood of occurrence (e.g., AEP).
  - **5%-damped.** The UHS describes the estimated elastic-response of inverted pendula to an earthquake ground motion, damping can be applied to the response to describe the loss of energy in transmission. 5%-damping is the typically reported value and is incorporated in the GMMs implemented in this study. For some engineering applications alternative damping values are used.
  - **Mean.** The UHS plots mean spectral acceleration values at each spectral period resulting from the weighted range of hazard curves incorporated in the PSHA computation. The fractiles of the UHS describe the range of spectral accelerations at each spectral period, based on the uncertainties and variability incorporated in the PSHA.
  - **RotD50** is a statistically derived median value of the possible horizontal components of recorded earthquake ground motions (e.g., Boore et. al., 2006). Earthquake ground motions are recorded in three orientations, two horizontal and one vertical. The two horizontal components are typically different (one is larger than the other) depending on several factors including the orientation of the strong motion recording instruments. The RotD50 is a slightly different intensity measure from the geometric mean. RotD50 is adopted as the predicted earthquake intensity measure in the GMMs used in this study.
  - **Peak-horizontal spectral acceleration.** The UHS describes the peak-horizontal acceleration (as a fraction of the acceleration due to gravity, g, i.e., approximately 9.8 m/s) at each spectral period. This peak is only likely to be experienced once during an earthquake and for a short duration.
- PSHA results can also be used to identify earthquake magnitude and source-to-site distance pairs and/or specific seismic sources that are the major contributor(s) to the seismic hazard at the site of interest. Thus “disaggregation analysis” can be undertaken for any AEP and spectral period combination. The disaggregations presented in this assessment are enhanced by plotting the distribution of epsilon for each combination of distance and magnitude. Epsilon is the number of standard deviations in the GMMs and informs selection of earthquake scenarios from the PSHA.

Mean hazard curves and fractiles for selected AEPs, disaggregation of hazard at important spectral periods and AEPs, UHS for other than mean hazard, and sensitivity analyses are common PSHA outputs. Importantly, the frequency and inherent uncertainties of the occurrence rate of different magnitude earthquakes on a seismic source are directly accounted for in PSHA, as well as the spatial distribution of each earthquake magnitude within a seismic source. A comprehensive PSHA incorporates not only the inherent randomness of earthquake occurrence and seismic wave propagation (i.e., aleatory variability), but also the uncertainties associated with the choice of models and model parameters to characterize seismic sources and estimate earthquake ground motions (i.e., epistemic uncertainty). Epistemic uncertainty is commonly accommodated through a logic-tree approach in PSHA. Accordingly, no additional conservatism is normally added to the mean UHS from a comprehensive PSHA. The degree of conservatism is explicitly defined by the choice of the AEP.

1.4 Report Structure

This report presents the major inputs, analyses, interpretations, uncertainties, and conclusions of WSP's site-specific seismic hazard analyses. The report has the following major sections:

- **Section 1.0** is an introduction to the purpose and background of the study, general description of the work undertaken, and analytical methods used.
- **Section 2.0** describes the site ground conditions used for this assessment.
- **Section 3.0** describes the seismotectonic and geological setting of the site.
- **Section 4.0** describes the observed historical and instrumental seismicity around the site and the seismic sources used to model the seismicity.
- **Section 5.0** describes ground motion model (GMM) selection and weighting.
- **Section 6.0** describes the uncertainties incorporated in the seismic source models and ground motion models.
- **Section 7.0** provides results of the probabilistic seismic hazard analysis (PSHA).
- **Section 8.0** describes the earthquake acceleration time history (EATH) development.
- **Section 9.0** summarizes the main conclusions of this study.
- **Appendix A** provides the selected EATHs for the short period range of interest.
- **Appendix B** provides the selected EATHs for the long period range of interest.
- Outputs of the EATH development are provided as electronic copies with this report.

1.5 Limitations

WSP has prepared this document in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practicing under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this document. No warranty, express or implied, is made.

This document, including all text, data, tables, figures, and other documents contained herein, has been prepared by WSP for the sole benefit of Teck Resources Limited. The report represents WSP's professional judgment based on the knowledge and information available at the time of completion. Consequently, the results presented in this report should be reviewed when new data and/or new scientific theory become available. WSP is not responsible for any unauthorized use or modification of this document. All third parties relying on this document do so at their own risk.

The factual data, interpretations, suggestions, recommendations, and opinions expressed in this document pertain to the specific project, site conditions, design objective, development and purpose described to WSP by Teck Resources Limited. They are not applicable to any other project or site location. In order to properly understand the factual data, interpretations, suggestions, recommendations, and opinions expressed in this document, reference must be made to the entire document.

2.0 SITE GROUND CONDITIONS

A key input into any site-specific PSHA is the near-surface ground conditions at the analysis site. Near-surface ground conditions are incorporated into site-specific PSHA using the following parameters specified in most modern GMMs (Section 5.0):

- V_{S30}: The time-averaged shear-wave velocity for the upper 30 m below ground surface. When used along with seismic ground response analysis (SGRA) the V_{S30} is the time averaged shear-wave velocity for 30 m depth below the top of the seismic engineering bedrock.
- $Z_{1.0}$: The depth to a shear-wave velocity of 1,000 m/s.
- $Z_{2.5}$: The depth to a shear-wave velocity of 2,500 m/s.

While V_{S30} is used in most modern GMMs, the $Z_{1.0}$ and $Z_{2.5}$ parameters are only used in selected GMMs, such as those developed as part of the NGA-West2 project for active crustal sources.

2.1 Selection of V_{S30}

This SSSHA was undertaken for a V_{S30} of 1,853 m/s. This seismic ground condition was evaluated by Golder (2021) from geophysical investigations using the multichannel analysis of surface waves (MASW) method adjacent to the intersection between Dams 1C, 1D, and 4B of the TSF at Louvicourt Mine. This V_{S30} value was provided to WSP for use in the SSSHA.

3.0 SEISMOTECTONIC SETTING

This section presents a brief overview of the seismotectonic setting of the Louvicourt TSF site in southwestern Québec. The purpose is to describe the geological history and current earthquake distribution with a focus on the identification of any potential seismogenic structures capable of producing large earthquakes and strong ground shaking at the Louvicourt TSF site. This section includes a summary of the site geology based principally on publicly available information and summary information provided by Teck Resources Limited, including the existing geotechnical studies as described in Golder (2012).

3.1 Regional Geological Setting

The Louvicourt TSF site is in western Québec within the Canadian Shield physiographic province of Canada (Figure 1). The geomorphology of the region surrounding the site is controlled by distribution of Archean and Proterozoic basement rocks (more than 2.7 billion years [Ga] old in places), and Pleistocene (less than about the last 2.6 million years) glacial landforms such as fluvio-glacial outwash plains, eskers, and kames. The region has a gentle, undulating topography and includes numerous small lakes and local streams. The topography was developed by erosional processes occurring beneath the large continental glaciers of North America, and by subsequent localized deposition and erosion following the most recent retreat of glacial ice about 15,000 to 12,000 years ago.

The site is in a region of the Canadian Shield that is part of the North American Craton. Cratons are regions containing generally very old rocks (i.e., more than 1 Ga). Cratons are usually tectonically stable parts of the continental lithosphere that have persisted through several cycles of continental rifting and basin formation, followed by contraction with folding, faulting, and uplift of the sedimentary basins. Cratons typically consist of crystalline basement and highly metamorphosed rocks flanked by relatively younger, metamorphosed sedimentary rock units. The tectonic history of the Canadian Shield indicates that it is one of the oldest known cratons and contains rocks dating back several billion years (e.g., Whitmeyer and Karlstrom, 2007).

The Canadian Shield is inferred to have formed from the collision of Archean-age microcontinents during the Paleoproterozoic (2.5 to 1.6 Ga). The collision of these microcontinents initiated volcanic activity to form volcanic arcs that accreted to and intruded into the existing Archean tectonic plates (i.e., Greenstone belts). The microcontinents then combined to form the ancient continent of Laurentia. During the formation of Laurentia, major tectonic events resulted in zones of faulted, folded and metamorphosed sedimentary and igneous rocks. Whitmeyer and Karlstrom (2007) provide a comprehensive summary of the development and tectonic history of the Canadian Shield and North America.

Figure 2 shows the locations of the major geological provinces and sub-provinces in southwestern Québec. The boundary between the Abitibi and Pontiac sub-provinces of the Superior Province is marked by the major structural complex of the Cadillac-Larder Lake fault zone. Figure 2 shows that the few earthquake epicenters recorded in this region are widely distributed and generally not associated with these major mapped faults. While three epicenters near the site are located within the wider Cadillac-Larder Lake fault zone, earthquakes are absent in other parts of the fault zone. The nature of the fault zone rocks, their present-day tectonic setting within the Canadian Shield, a lack of earthquake epicenter alignments, and no geomorphic evidence for past surface fault rupture all suggest that Cadillac-Larder Lake fault zone and other major fault zones within the wider region are at present seismically and geologically inactive. Accordingly, these faults are not included as discrete seismic sources in the site-specific seismic source model developed for this study.

3.1.1 Historical Seismicity

Analysis of earthquake epicenters from the historical record (both anecdotal and instrumental) indicates that the site is within a region of relatively low historical earthquake occurrence (Figure 1). For example, only five earthquakes with moment magnitudes (Mw) more than 4.5 have been recorded within about 300 km of the Louvicourt TSF site. All but one of these earthquakes has a reported magnitude less than Mw 5, with the 1935 Timiskaming earthquake (Mw 6.1) being the largest historical event known from the wider region surrounding the site (Figure 1; approx. 190 km southwest of Louvicourt Mine).

3.2 Louvicourt Mine Site Geology

The local geological setting of the bedrock and the overburden of the site is presented in this section.

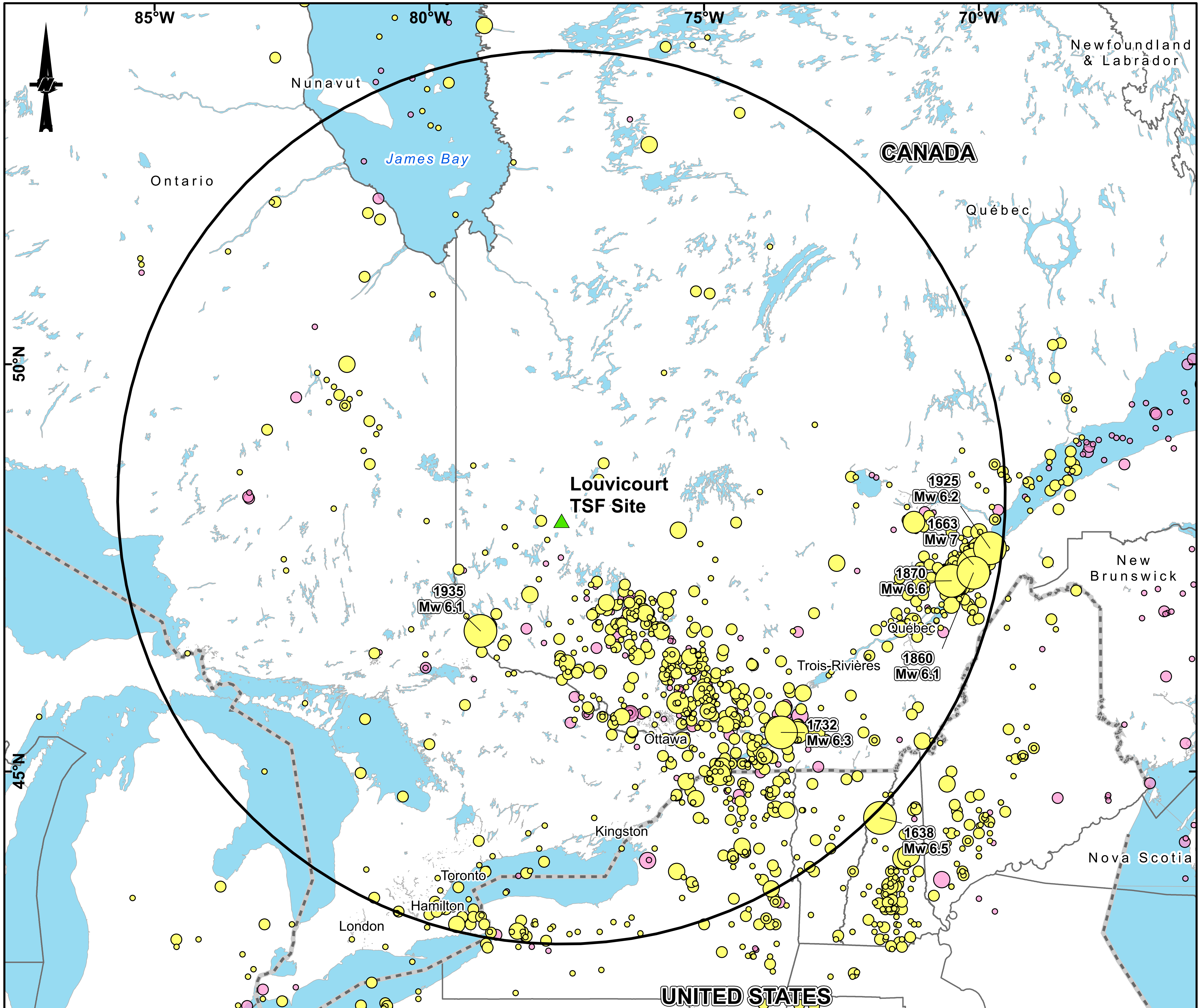
3.2.1 Bedrock Geology

Figure 3 shows the generalized bedrock geology at the Louvicourt Mine and TSF site and surrounding area. The Louvicourt TSF site is within a region of Archaean volcanic and intrusive rocks of the Archean Southern Abitibi greenstone belt that is part of the Superior Province of the Canadian Shield physiographic province (Figure 2). The site is near the southern margin of the eastern portion of the Abitibi Sub-province that comprises an older (Neoarchean) northern volcanic zone (2.730 to 2.710 Ga) and a relatively younger (Neoarchean) southern volcanic zone (2.705 to 2.698 Ga), separated by the regional Porcupine-Destor Fault Zone (e.g., Card and Poulsen, 1998). The Abitibi Subprovince is limited to the north by gneissic metamorphic and igneous plutons of the Opatica Sub-province, and to the south by metasediments and intrusive rocks of the Pontiac Sub-province.

The contact between the Pontiac Sub-province and the rocks of the Abitibi greenstone belt is the east-west striking Cadillac-Larder Lake fault zone (Figure 2). The Louvicourt Mine and TSF site is located within the wider Cadillac-Larder Lake fault zone about 10 km north of the main sub-Province contact (Figure 2). Where exposed and mapped in the foundation excavations for Dam 1 in 1993, the bedrock is relatively closely jointed, intruded by diabase (dolerite) dykes up to several meters wide, and cut by numerous faults and shear zones that have predominately northwest-southeast and north-northwest-south-southeast strikes (Golder, 2012). Faults mapped in the foundation exposures have moderate to steep dips. These faults presumably represent localised deformation associated with the development of the nearby Cadillac-Larder Lake fault zone.

3.2.2 Surficial Geology

Figure 4 shows the generalized surficial geology at the Louvicourt Mine and TSF site and surrounding area, as described by Veillette et al. (2010). Surficial deposits cover most of the TSF site. At Dam 1, surficial deposits were stripped off when less than 2 m thick, and bedrock was exposed in parts of the key trench (as described in Section 3.2.1). Surficial deposits underlie the Dam 2 foundations and were derived from the deposition and erosion that occurred beneath the large continental Pleistocene glaciers of North America. These glaciers most recently melted and retreated northward about 15,000 to 12,000 years ago. Surficial sediments at the site are associated with various glacial and fluvioglacial environments, including till, lacustrine deep, shallow and littoral deposits, and post-glacial accumulations of silt and organic deposits (Figure 4). The superficial deposits are laterally variable in thickness, ranging from a thin veneer to more than 20 m thick (Golder, 2012).



LEGEND

- Louvicourt TSF Site
- 600 km Radius

Historical Earthquake Epicentres - SHEEF2010

Earthquake Magnitude (Mw)

- 2.5 - 3.0
- 3.1 - 4.0
- 4.1 - 5.0
- 5.1 - 6.0
- 6.1 - 7.0

Historical Earthquake Epicentres - Post-SHEEF2010

Earthquake Magnitude (Mw)

- 2.5 - 3.0
- 3.1 - 4.0
- 4.1 - 5.0

0 50 100 200 300 400
Kilometres

REFERENCE(S)

1. SHEEF2010 EARTHQUAKES: HALCHUK ET AL. (2015)
2. POST-SHEEF2010 EARTHQUAKES: NRCAN NATIONAL EARTHQUAKE DATABASE (2023)
3. COORDINATE SYSTEM: WGS 1984 WEB MERCATOR AUXILIARY SPHERE
4. SERVICE LAYER CREDITS: WORLD LIGHT GRAY CANVAS BASE, TOPOBATHY HILLSHADE

CLIENT
TECK RESOURCES LTD

PROJECT
SITE-SPECIFIC SEISMIC HAZARD ASSESSMENT
LOUVICOURT MINE TAILINGS MANAGEMENT FACILITY

TITLE
HISTORICAL EARTHQUAKE EPICENTRES IN REGION SURROUNDING THE LOUVICOURT TSF SITE IN SOUTHEASTERN CANADA

CONSULTANT

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DESIGNED	NC
PREPARED	NC
REVIEWED	AH
APPROVED	AH

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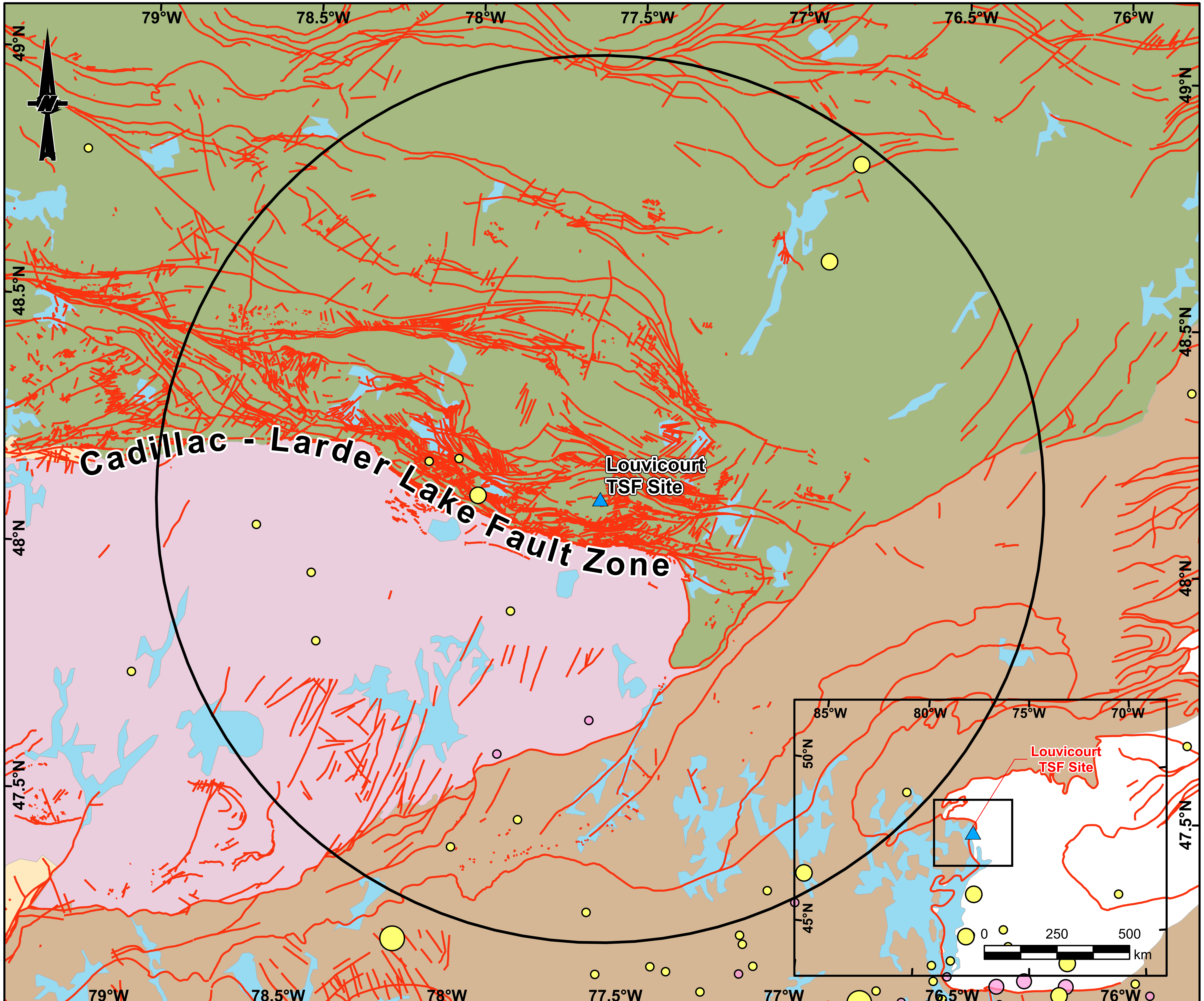

LEGEND

- Louvicourt TSF Site
- 100 km Radius

Historical Earthquake Epicentres - SHEEF2010

Earthquake Magnitude (Mw)

- 2.0 - 3.0
- 3.1 - 4.0
- 4.1 - 5.0

Historical Earthquake Epicentres - Post-SHEEF2010

Earthquake Magnitude (Mw)

- 2.0 - 3.0
- 3.1 - 4.0
- Mapped Bedrock Fault

Geological Provinces

- Grenville Province
- Sud Province
- Superior Province, Pontiac Sub-Province
- Superior Province, Abitibi Sub-Province

0 20 40

Kilometres

REFERENCE(S)

1. SHEEF2010 EARTHQUAKES: HALCHUK ET AL. (2015)
2. POST-SHEEF2010 EARTHQUAKES: NRCAN NATIONAL EARTHQUAKE DATABASE (2023)
3. GEOLOGICAL PROVINCES AND REGIONAL FAULTS: SIGEOM
4. COORDINATE SYSTEM: NAD 1983 UTM ZONE 18N

CLIENT

TECK RESOURCES LTD

PROJECT

SITE-SPECIFIC SEISMIC HAZARD ASSESSMENT
LOUVICOURT MINE TAILINGS MANAGEMENT FACILITY

TITLE

HISTORICAL EARTHQUAKE EPICENTERS, GEOLOGICAL PROVINCES, AND MAJOR REGIONAL FAULTS SURROUNDING THE LOUVICOURT TSF SITE

CONSULTANT

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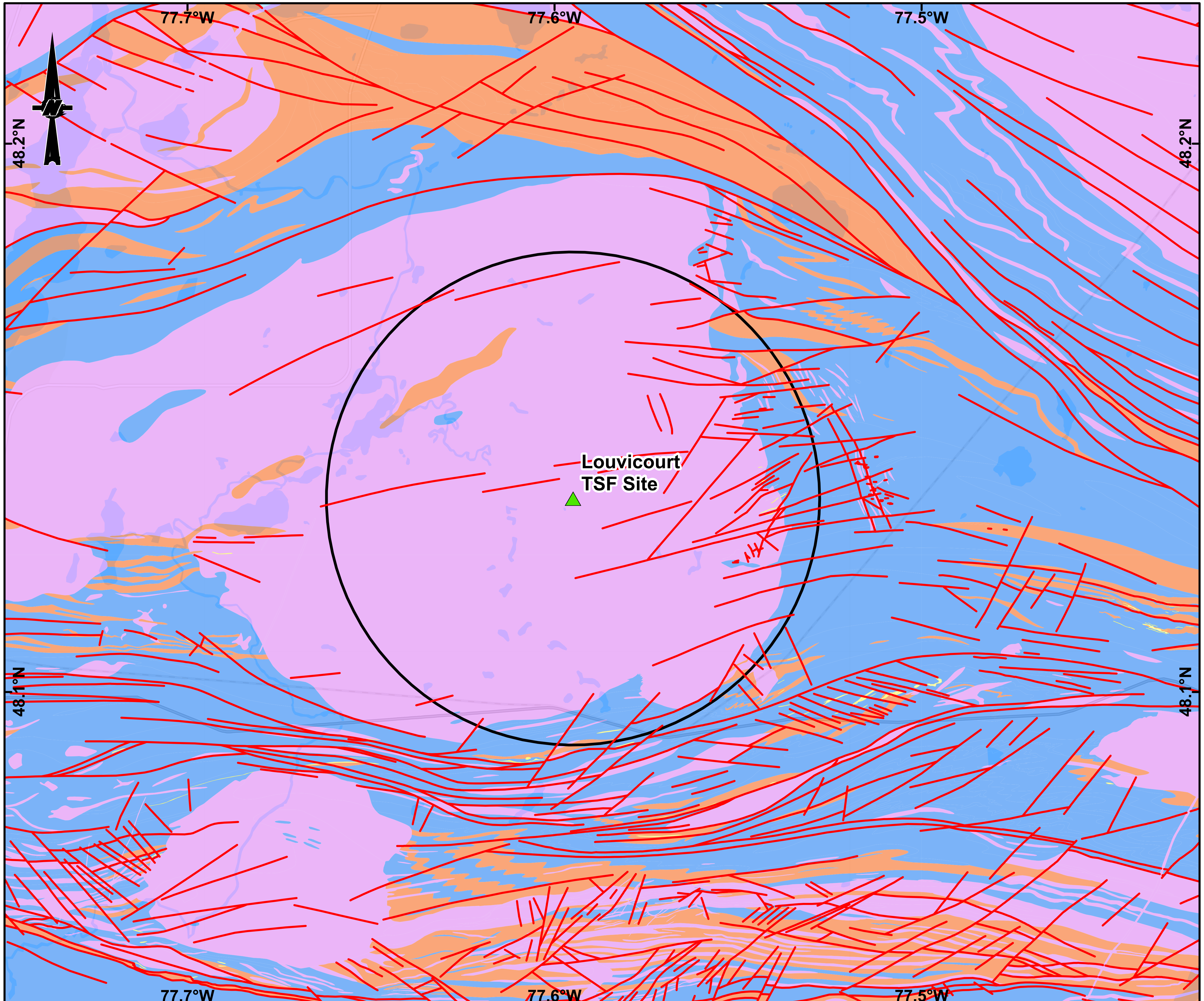

LEGEND

- Louvicourt TSF Site
- 5 km Radius
- Regional Fault

Bedrock Geology

- Sulfite Rocks
- Intrusive Rocks
- Volcanoclastic and Sedimentary Rocks
- Volcanic Rocks

0 1 2 3 4 5
Kilometres

REFERENCE(S)
1. BEDROCK GEOLOGY: SIGÉOM
2. COORDINATE SYSTEM: WGS 1984 WORLD MERCATOR

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PROJECT
SITE-SPECIFIC SEISMIC HAZARD ASSESSMENT
LOUVICOURT MINE TAILINGS MANAGEMENT FACILITY

TITLE
BEDROCK GEOLOGY SURROUNDING THE LOUVICOURT TSF SITE

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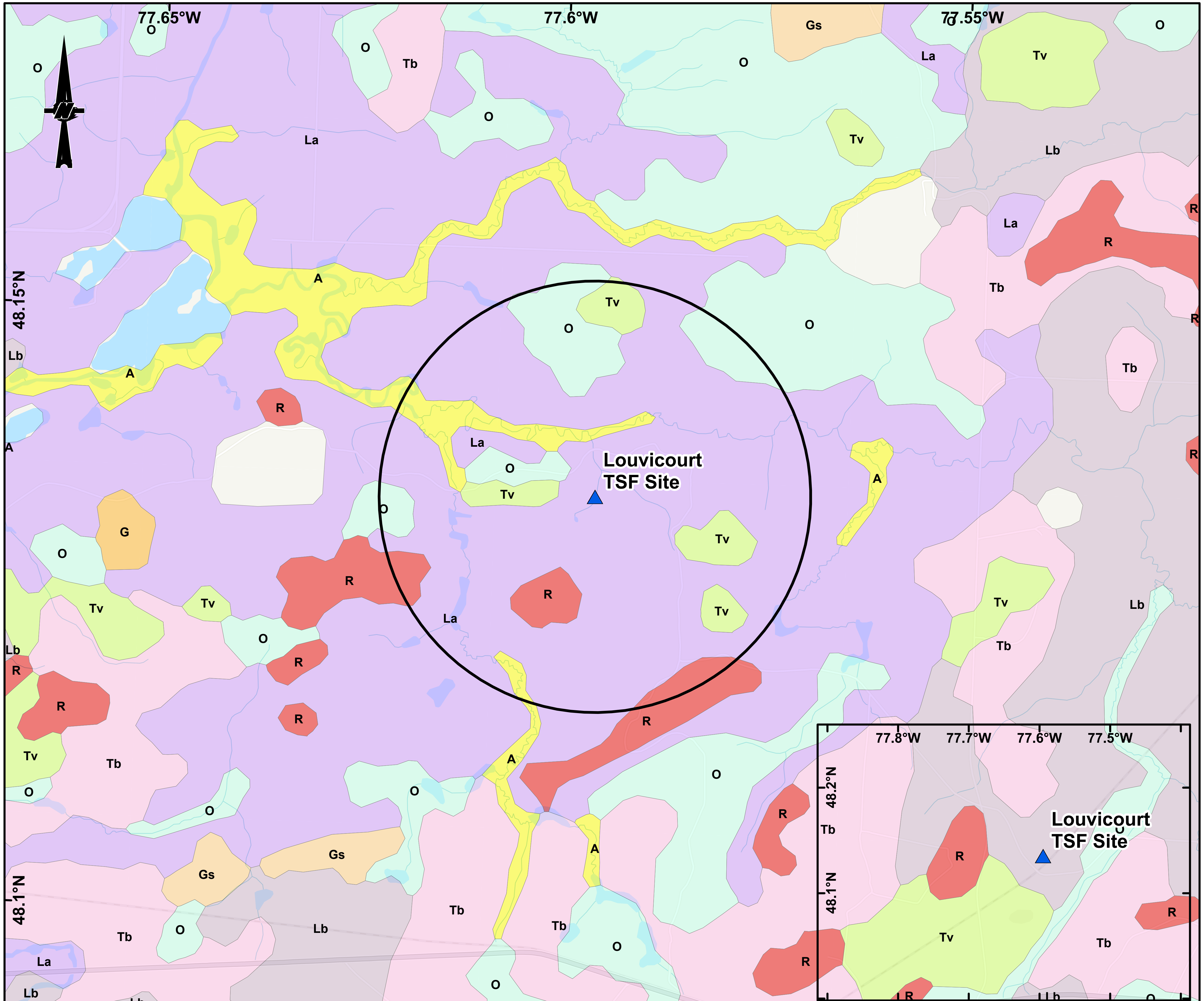
	DESIGNED	NC
	PREPARED	NC
	REVIEWED	AH
	APPROVED	AH

PROJECT NO.	PHASE	REV.	FIGURE
21494974	5000	0	3



LEGEND

- ▲ Louvicourt TSF Site
- 2 km Radius

Surficial Geology

- 0 : Organic Silt and Peat
- A : Recent Alluvium
- Lb : Shallow Lake Sediments
- La : Deep Lake Sediments
- G : Gravel
- Gs : Proglacial Lake Sediments
- Tb : Till (generally continuous)
- Tv :Till (discontinuous)
- R : Bedrock

0 1 2
Kilometres

REFERENCE(S)
1. SURFICIAL GEOLOGY: VEILLETTE, J.J., PARADIS, S.J. ET THIBAUDEAU, P. (2010)
2. COORDINATE SYSTEM: NAD 1983 UTM ZONE 18N

CLIENT
TECK RESOURCES LTD

PROJECT
SITE-SPECIFIC SEISMIC HAZARD ASSESSMENT
LOUVICOURT MINE TAILINGS MANAGEMENT FACILITY

TITLE
SURFICIAL GEOLOGY SURROUNDING THE LOUVICOURT TSF SITE

CONSULTANT

YYYY-MM-DD	2024-01-15
DESIGNED	NC
PREPARED	NC
REVIEWED	AH
APPROVED	AH

PROJECT NO.	PHASE	REV.	FIGURE
21494974	5000	0	**4**

4.0 SITE-SPECIFIC SEISMIC SOURCE MODEL

In seismic hazard studies, a seismic source model is developed to represent defined seismotectonic regions considered capable of producing moderate to large earthquakes. The seismic source model defines known active and potentially active seismic sources that can contribute to the earthquake ground motions at the site. These sources can be large and/or small areas of historical earthquake epicenters, tectonic terrains, or geophysical regions. Earthquake sources associated with the rupture areas of large historical earthquakes are considered, where applicable, as are faults where there is evidence of surface displacement during the Upper Pleistocene stage of the Pleistocene Epoch (i.e., about the last 126,000 years). The seismic source model is defined in terms of parameters that include source location, source geometry, faulting mechanisms, maximum earthquake magnitudes, probability of existence, and earthquake recurrence models.

The seismic source model implemented for this PSHA is the sixth-generation seismic hazard model of Canada (CanadaSHM6) developed by NRCan to estimate seismic hazard values for the 2020 NBCC. In this study, the CanadaSHM6 seismic source models as described by Kolaj et al. (2023) are implemented without modification. As described below, the decision to implement the CanadaSHM6 sources without modification was made following investigation of the suitability of the existing earthquake occurrence rates associated with the sources.

4.1 Earthquake Locations and Activity Rates

Development of a SSSHA requires a comprehensive understanding of the spatial and temporal distribution of observed earthquakes for the region surrounding a site. Figure 1 shows the distribution of the larger (moment magnitude [Mw]≥2.5) pre-instrumental and instrumental earthquakes in the region surrounding the Louvicourt TSF site. While the larger earthquakes provide the general pattern of significant and damaging earthquakes, a more detailed analysis of the seismicity distribution in location, time, and magnitude is required for seismic hazard assessment.

The Seismic Hazard Earthquake Epicentre File (SHEEF2010; Halchuk et al., 2015) was developed by GSC to allow the estimation of earthquake occurrence rates for the fifth-generation seismic hazard model of Canada (CanadaSHM5). The SHEEF2010 catalogue was subsequently used by GSC to parameterize the CanadaSHM6 seismic source models. The catalogue includes events with an original catalogue magnitude of 2.5 of higher. SHEEF2010 contains earthquake records from 1627 up to the end of 2010. The catalogue is not declustered. Figure 1 shows the location and magnitude of historical earthquakes in southeastern Canada and northeastern USA. Figure 2 shows the epicenters located within about 100 km of the Louvicourt TSF site.

When developing recurrence parameters for seismic hazard analysis, it is important to understand the period for which the earthquake catalogue is complete. The completeness period of the catalogue varies with earthquake magnitude. Table 2 lists the year of catalogue completeness estimated for each magnitude bin (Mw 0.5 bin width) using the Stepp (1972) procedure.

Table 2: Estimated Completeness Periods for the SHEEF2010 Catalogue (Halchuk et al., 2015).

Magnitude Range (Mw)	Catalogue Completeness Year
3.0 ≤ Mw < 3.5	1925
3.5 ≤ Mw < 4.0	1900
Mw ≥ 4.0	1860

Earthquakes of Mw 2.5 and greater from January 2011 to present for the region within about 1,000 km of the Louvicourt TSF site were obtained from the National Earthquake Database online earthquake catalogue. This catalogue is subsequently called the “post-SHEEF2010 catalogue” in this assessment. The post-SHEEF2010 earthquakes were reported in various measures of earthquake magnitude and were, therefore, converted to Mw following the conversion relations provided in Halchuk et al. (2015). Figure 5 shows the magnitude-frequency distribution for the SHEEF2010 and post-SHEEF2010 catalogues, and a catalogue that combines the two. The close agreement between the SHEEF2010 and summed catalogues indicates that earthquakes from January 2011 to present day within about 1,000 km of the Louvicourt TSF site have an insignificant effect on the earthquake recurrence parameters near the site. As a result, changes to the CanadaSHM6 seismic source models are considered unnecessary. The CanadaSHM6 source models, therefore, are used for this assessment as published by Kolaj et al. (2023).

Figure 5: Magnitude-frequency distribution of earthquakes within about 1,000 km of the Louvicourt TSF Site for the SHEEF2010 Catalogue (Yellow Line), the post-SHEEF2010 (Purple Line) catalogue, and a summed catalogue of the two (Black Dashed Line).

4.2 Canadian National Seismic Source Model

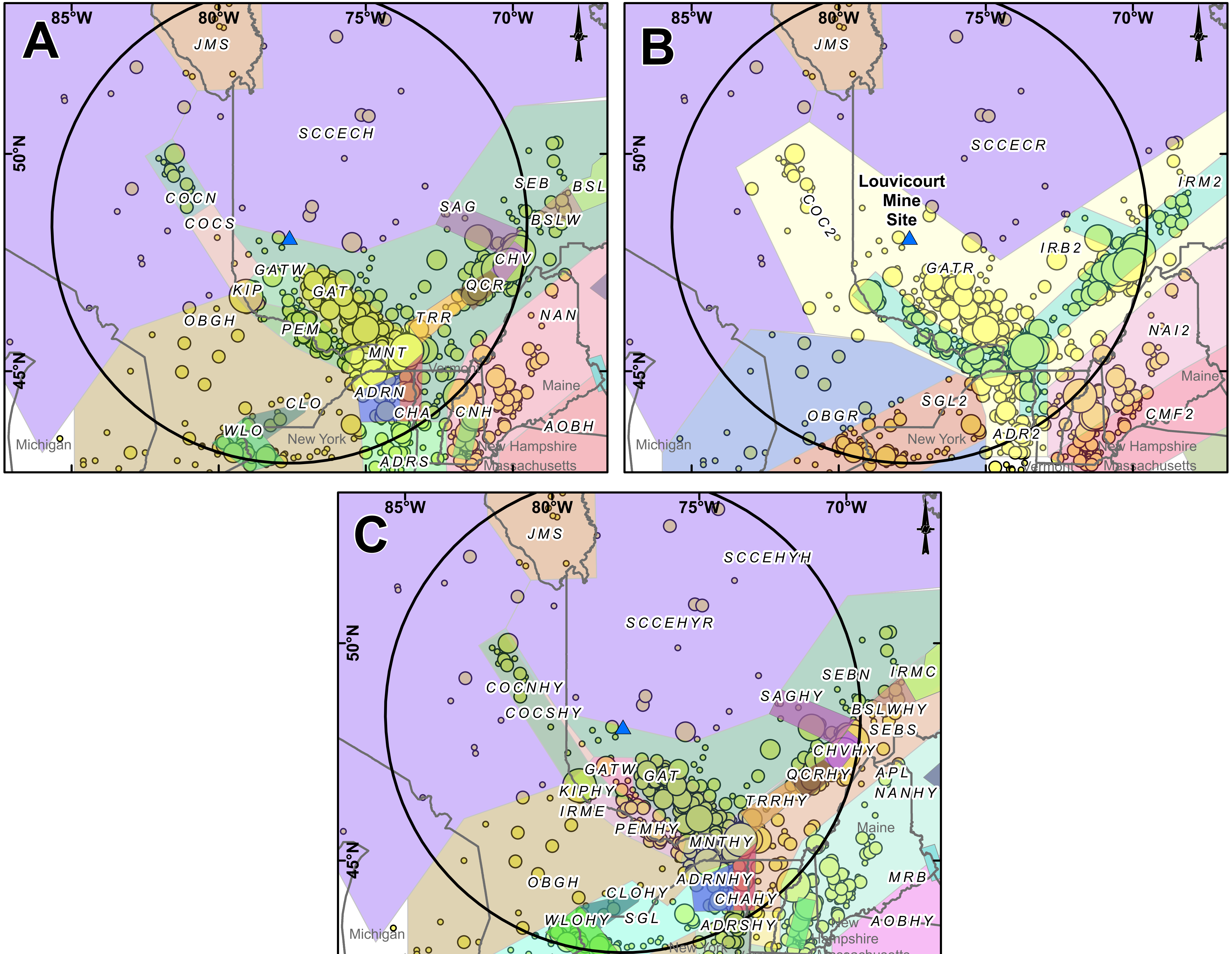
The seismic source model used in this assessment is adopted from the CanadaSHM6 source models described by Kolaj et al. (2023; Natural Resources Canada [NRCan] Open File 8924). CanadaSHM6 is the latest national consensus seismic hazard model for Canada. CanadaSHM6 consists of three regional models based on their location:

- Southeastern Canada
- Western Canada
- Eastern Arctic Canada

The Louvicourt TSF site is located within the southeastern (SE) part of the CanadaSHM6 model. For SE Canada, the seismic source models and earthquake recurrence parameters included in CanadaSHM6 are unchanged from those developed by Halchuk et al. (2015) for CanadaSHM5. Halchuk et al. (2014) provides details on the development of the SE Canada seismic sources and their relative weights. Kolaj et al. (2020) provides specific details for implementation of CanadaSHM6 in SE Canada.

The SE CanadaSHM6 source model comprises three separate sub-models: the Historical (H2), Regional (R2), and Hybrid (HY) sub-models, as shown in Figure 6a, Figure 6b, and Figure 6c, respectively. Source parameters in the H2 sub-model are based on historical earthquake locations and magnitudes. The R2 sub-model was developed using the regional geological criteria as the basis for selection of the seismic source parameters, and the HY sub-model was developed using both historical earthquake data and regional geological parameters. Weights of 0.4, 0.2, and 0.4 are assigned in CanadaSHM6 to the H2, R2, and HY sub-models, respectively.

Each seismic source in the SE Canada model consists of a given area that is assigned a set of parameters to represent the characteristics and rate of earthquake occurrence in that area. The three alternative sub-models in SE Canada each have varying model parameters and relative weights for each parameter. The weighted parameters are implemented using a logic tree approach to capture uncertainties in the seismic modelling process. The logic tree approach is discussed further in Section 6.0.



LEGEND

- Louvicourt TSF Site
- 600 km Radius

Historical Earthquake Epicentres - SHEEF2010

Earthquake Magnitude (Mw)

- 2.5 - 3.0
- 3.1 - 4.0
- 4.1 - 5.0
- 5.1 - 6.0
- 6.1 - 7.0

0 500 1,000

Kilometres

REFERENCE(S)

1. SOURCE ZONE NAMES: KOLAJ ET AL. (2023). SEE TEXT.
2. SHEEF2010 EARTHQUAKES: HALCHUK ET AL. (2015)
3. COORDINATE SYSTEM: WGS 1984 WORLD MERCATOR
4. SERVICE LAYER CREDITS: WORLD LIGHT GRAY CANVAS BASE: ESRI, HERE, GARMIN, USGS, EPA, NPS, NRCAN

CLIENT

TECK RESOURCES LTD

PROJECT

SITE-SPECIFIC SEISMIC HAZARD ASSESSMENT
LOUVICOURT MINE TAILINGS MANAGEMENT FACILITY

TITLE

SEISMIC SOURCE ZONES FROM THE CANADASHM6 SOUTHEASTERN CANADA MODEL: A) HISTORICAL (H2), B) REGIONAL (R2), AND C) HYBRID (HY) SUB-MODELS

CONSULTANT		
	YYYY-MM-DD	2024-01-15
	DESIGNED	NC
	PREPARED	NC
	REVIEWED	AH
	APPROVED	AH

PROJECT NO.	PHASE	REV.	FIGURE
21494974	5000	0	6

5.0 GROUND MOTION MODELS

Ground motion models (GMM) are used in seismic hazard analysis to estimate the source-to-site attenuation of earthquake ground motions at PGA and at other spectral periods as a function of the earthquake magnitude, source-to-site distance, local site ground conditions, and other factors. The GMMs are typically empirically derived, with the calculated acceleration values usually assuming 5% of critical damping, as in this assessment. The sections below describe the how GMMs were evaluated and selected for this assessment.

5.1 GMMs used for CanadaSHM6

CanadaSHM6 considered the preliminary suite of 13 GMMs developed for NGA-East (Goulet et al., 2017a,b). The goal of the NGA-East project was to create a ground motion characterization model for Central and Eastern North America (CENA) comprising a set of mutually exclusive and collectively exhaustive GMMs (that is, the individual GMMs do not overlap and together represent the full range of ground motions). The resulting preliminary suite of NGA-East GMMs comprised 13 different models defined for 25 ground-motion intensity measures with frequency-dependent weighting factors. Each model is weighted to reflect the joint distribution of median ground motion estimates at different magnitude-distance scenarios for a given frequency and their fit to observed ground-motion data. The preliminary 13 NGA-East GMMs have now been superseded, as noted in the addendum to PEER Report 2017-03 (Goulet et al. 2017a,b).

CanadaSHM6 uses two suites of GMMs with the following weights (Kolaj et al., 2019):

- The AA13 median and standard deviation ground motions from CanadaSHM5. Weighted 50%.
- The preliminary (superseded) 13 NGA-East median ground motions with the standard deviation model from CanadaSHM5 AA13 GMMs. Weighted 50%.

5.1.1 AA13 GMMs

The AA13 GMMs used in CanadaSHM5 (Atkinson and Adams, 2013) represent several different approaches to model ground motion attenuation in eastern North America (ENA). There are five ENA models: Pezeshk et al. (2011), Atkinson and Boore (2006), as revised in Atkinson and Boore (2011), Atkinson (2008), as revised in Atkinson and Boore (2011), Silva et al. (2002) single-corner (variable stress) and double-corner (with saturation).

The AA13 GMMs use the moment magnitude and closest source-to-site rupture plane as inputs and are applicable to magnitudes ranging from Mw 4.8 to Mw 8.0, and for source-to-site distances of up to 600 km. Aleatory variability in the AA13 GMMs is represented by a standard deviation (sigma) model that attempts to capture the natural variability of hypothetical future events.

The standard deviation model developed with the AA13 GMMs consists of sigma values that vary based on spectral period and is lower than other standard deviation models (e.g., Boore and Atkinson, 2008, or NGA-East standard deviation models) to avoid any double-counting of aleatory variability and epistemic uncertainty.

5.1.2 NGA-East GMMs

The preliminary 13 NGA-East GMMs (Goulet et al., 2017a) were developed for a reference hard-rock site condition with an average shear-wave velocity in the upper 30 m (i.e., V_{S30}) of 3,000 m/s. The GMMs use the moment magnitude and the closest source-to-site rupture plane as inputs. The GMMs are applicable to magnitudes ranging from Mw 4 to Mw 8.2, and for source-to-site distances of up to 1,500 km. Variations in the expected ground motion are quantified and applied in the GMMs by use of a standard deviation (sigma) model, or the total ergodic standard deviation model, which includes between-event variability and single-station within-event variability. Each component of ground motion variability was analyzed and compared to ground motion variability in other regions, particularly the western United States (WUS). The final models derived for each component of ground motion variability are largely based on NGA-West2 relationships for shallow crustal earthquakes in active tectonic regions (Abrahamson et al., 2014; Boore et al., 2014; Campbell and Bozorgnia, 2014; Chiou and Youngs, 2014), residuals analysis, and standard deviation models. The final GMMs are both magnitude-and period-dependent.

Since the limited CENA dataset was used to develop the NGA-East GMMs, standard deviation models from other regions, including the western USA and Japan, were used to inform the extrapolation of CENA standard deviations to large magnitudes and frequencies outside of the 1 Hz to 10 Hz frequency range. The standard deviation models published in NGA-East have high sigma values and lead to a large discrepancy between median and mean ground motions. As such, the NGA-East standard deviation models were not implemented with the median ground motions for CanadaSHM6 for this site-specific SHA.

5.2 GMMs used for this Site-Specific Assessment

For this assessment WSP has used the final suite of 17 GMMs developed for the Next Generation Attenuation for Central and Eastern North America (CENA) project (NGA-East, Goulet et al. 2018) to calculate median ground motions along with the standard deviation model from Atkinson and Adams (2013) (AA13). These 17 GMMs supersede the preliminary set of 13 NGA-East GMMs (described above) that were implemented in CanadaSHM6.

The 17 NGA-East GMMs reflect the most up-to-date published and vetted GMMs developed for stable continental regions (SCRs) in central and eastern North America. The NGA-East median ground motions are suitable to model earthquake ground motion attenuation for this assessment because they were developed with a robust process for a tectonic region (i.e., SCR) like that surrounding the Louvicourt TSF site. The final 17 NGA-East GMMs are used in this assessment in conjunction with the AA13 standard deviation model as implemented in CanadaSHM6.

5.3 Site Amplification Model

For southeastern Canada, CanadaSHM6 uses the site amplification factors applied in CanadaSHM5 with the AA13 GMMs and a site model that combines two existing amplification models for the preliminary 13 NGA East GMMs. The CanadaSHM6 site amplification models are described in detail by Kolaj et al. (2019).

Since the development of CanadaSHM6, the NGA-East GMMs have been used to update the US National Seismic Hazard Maps for the CENA Region (Petersen et al., 2020). Recommendations for the ergodic site amplification model in the CENA were provided by Stewart et al. (2020) and Hashash et al. (2020) to produce the earthquake ground motion intensity measures for site conditions with a V_{S30} less than the 3,000 m/s reference hard-rock condition, as adopted for the NGA-East GMM development.

For this assessment we have applied equally weighted Stewart et al. (2020) and Hashash et al. (2020) site amplification models to adjust the site condition from the NGA-East reference hard-rock condition with a V_{S30} of 3,000 m/s to the site-specific V_{S30} condition of 1,853 m/s.

6.0 SOURCE MODEL AND GMM UNCERTAINTY

Epistemic uncertainty is the uncertainty associated with the simplified and imprecisely known scientific model of a natural process. This uncertainty is typically parameterized by considering alternative model input parameters to the PSHA (e.g., Abrahamson 2006, 2009). The input model parameters include the seismic source models, their recurrence parameters and maximum earthquake magnitudes, hypocentral depth, and the ground motion models. Epistemic uncertainty is commonly accommodated through a logic-tree approach.

For this assessment, WSP has adopted the input parameters, logic tree, and weighting values implemented for CanadaSHM6. In CanadaSHM6, the two magnitude-frequency distribution (MFD) branches of the logic tree, comprising three alternative recurrence parameter (*a*- and *b*-values) branches and three alternative Mmax branches, were collapsed into a single MFD branch for computational efficiency. While collapsing these two branches in the logic tree had a negligible impact on median hazard values produced using CanadaSHM6, it limits the ability to perform a detailed analysis of the fractiles or model input sensitivity tests.

Figure 7 shows the logic tree implemented in this assessment. Parameters and weights for the CanadaSHM6 seismic source models are taken from Kolaj et al., (2023). Period- and model-dependent weights for the final suite of 17 NGA-East GMMs are implemented as recommended by Goulet et al., (2018).

Figure 7: Logic Tree for the Seismic Hazard Assessment of the Louvicourt TSF Site.

7.0 SEISMIC HAZARD RESULTS

The PSHA calculations were carried out using the software OpenQuake v3.16.3 for the Louvicourt TSF site located at 48.135ºN latitude and 77.595ºW longitude and for a V_{S30} of 1,853 m/s to represent the site ground conditions of the local bedrock. Analyses were completed for a minimum earthquake magnitude of Mw 4.8 (the same minimum magnitude used in CanadaSHM6) and for a maximum of five standard deviations above and below the mean (i.e., epsilon ±5).

7.1 Probabilistic Results

This section describes the results from the PSHA, including hazard curves, mean uniform hazard spectra, and disaggregation results for selected spectral periods.

7.1.1 Site-Specific Hazard Curves

Figure 8 shows mean hazard curves for PGA and spectral periods (5%-damped) of 0.2 s, 0.5 s, 1.0 s, and 2.0 s for annual exceedance probabilities ranging from 0.1 to 0.0001 or approximately equivalent return periods of 10 to 10,000 years. The hazard curves were developed for an estimated V_{S30} of 1,853 m/s for the bedrock ground conditions at the Louvicourt TSF site. The hazard curves indicate that the mean 1/2,475 AEP, 1/5,000 AEP, and 1/10,000 AEP PGAs are 0.099 g, 0.140 g, and 0.193 g, respectively.

The uncertainties associated with each hazard curve are presented as fractiles along with mean hazard curves in Figure 9. Hazard curve plots include the median (50th fractile) with one standard deviation (16th and 84th fractiles) and two standard deviations (5th and 95th fractiles) to indicate uncertainty in the mean value.

Figure 10 shows hazard curves calculated for different seismic sources. These plots show the dominant contributing sources to the total seismic hazard at different AEPs and spectral periods. The 10 sources with the largest contribution to seismic hazard at the site are shown on each plot, and the summation of all other sources is also shown. The largest hazard contribution is associated with the Charlevoix (CHV) seismic source zone in the H2 (Historical) sub-model of CanadaSHM6. The CHVHY source, which is the equivalent Charlevoix source zone in the HY (Hybrid) sub-model, is the second largest contributor, with the Gatineau (GAT) source zone the third largest contributor.

Figure 8: Mean Hazard Curves for PGA, and Spectral Periods of 0.2 s, 0.5 s, and 1.0 s (V_{S30} = 1,853 m/s).

Figure 9: Mean Hazard Curves with Fractiles for PGA, and Spectral Periods of 0.2 s, 0.5 s, 1.0 s, and 2.0 s (V_{S30} = 1,853 m/s).

Figure 10: Hazard Curves from Different Seismic Sources for PGA, and Spectral Periods of 0.2 s, 0.5 s, 1.0 s, and 2.0 s (V_{S30} = 1,853 m/s). Source Name Abbreviations are from CanadaSHM6 (Kolaj et al., 2023).

7.1.2 Uniform Hazard Spectra

Figure 11 shows mean site-specific UHS for the 1/2,475, 1/5,000, and 1/10,000 AEPs for a V_{S30} of 1,853 m/s. The definition of the UHS is described in detail in Section 1.3.

Figure 12, Figure 13, and Figure 14 show the mean UHS along with the 5th, 16th, 50th (median), 84th, and 95th fractiles for 1/2,475 AEP, 1/5,000 AEP, and 1/10,000 AEP, respectively. Table 3, Table 4, and Table 5 list the spectral ordinates for the UHS and fractiles for 1/2,475 AEP, 1/5,000 AEP, and 1/10,000 AEP, respectively.

We note that the mean and fractile UHS exhibit a small 'bump' at approximately 0.1 s spectral period. This is attributed primarily to the shape of the ground motion models applied in this assessment, and also partly to the varying contribution of different seismic source zones to the hazard at the Louvicourt TSF site at shorter and longer spectral periods.

Figure 11: Uniform Hazard Spectra for AEPs of 1/2,475, 1/5,000, and 1/10,000 at the Louvicourt TSF Site (V_{S30} = 1,853 m/s).

Figure 12: 1/2,475 AEP Mean UHS and Selected Fractiles.

Table 3: Uniform Hazard Spectral Ordinates for 1/2,475 AEP with Selected Fractiles.

Spectral Period (s)		5% damped, RotD50, Spectral Acceleration (g)					
		Mean	Fractile				
			5th	16th	50th	84th	95th
1/2,475 AEP	PGA	0.099	0.041	0.046	0.083	0.128	0.204
	0.02	0.143	0.062	0.076	0.125	0.177	0.287
	0.03	0.172	0.076	0.095	0.152	0.218	0.320
	0.05	0.207	0.085	0.109	0.182	0.263	0.406
	0.075	0.210	0.091	0.115	0.180	0.274	0.313
	0.1	0.192	0.084	0.090	0.155	0.251	0.319
	0.15	0.205	0.092	0.117	0.183	0.263	0.383
	0.2	0.189	0.066	0.088	0.154	0.246	0.378
	0.3	0.160	0.049	0.071	0.125	0.207	0.320
	0.4	0.133	0.044	0.060	0.104	0.174	0.271
	0.5	0.114	0.036	0.052	0.088	0.152	0.198
	0.75	0.085	0.024	0.038	0.065	0.113	0.150
	1	0.066	0.018	0.029	0.049	0.089	0.127
	1.5	0.044	0.012	0.019	0.032	0.059	0.081
	2	0.033	0.010	0.014	0.026	0.045	0.066
	3	0.019	0.005	0.008	0.014	0.027	0.039
	4	0.013	0.003	0.005	0.010	0.019	0.023
	5	0.010	0.002	0.004	0.007	0.014	0.017
	7.5	0.006	0.002	0.002	0.005	0.008	0.011
	10	0.004	0.001	0.001	0.003	0.006	0.007

Figure 13: 1/5,000 AEP Mean UHS and Selected Fractiles.

Table 4: Uniform Hazard Spectral Ordinates for 1/5,000 AEP with Selected Fractiles.

Spectral Period (s)		5% damped, RotD50, Spectral Acceleration (g)					
		Mean	Fractile				
			5th	16th	50th	84th	95th
1/5,000 AEP	PGA	0.140	0.056	0.062	0.114	0.177	0.283
	0.02	0.206	0.083	0.105	0.173	0.249	0.403
	0.03	0.247	0.105	0.131	0.211	0.303	0.455
	0.05	0.296	0.113	0.143	0.248	0.365	0.572
	0.075	0.297	0.122	0.164	0.249	0.379	0.427
	0.1	0.271	0.111	0.121	0.218	0.345	0.438
	0.15	0.286	0.121	0.162	0.255	0.362	0.523
	0.2	0.261	0.086	0.116	0.205	0.331	0.508
	0.3	0.221	0.063	0.094	0.167	0.278	0.433
	0.4	0.183	0.057	0.079	0.137	0.231	0.364
	0.5	0.156	0.047	0.068	0.117	0.200	0.268
	0.75	0.117	0.032	0.050	0.086	0.151	0.204
	1	0.092	0.023	0.038	0.066	0.120	0.170
	1.5	0.061	0.016	0.025	0.043	0.081	0.109
	2	0.046	0.013	0.018	0.034	0.060	0.088
	3	0.027	0.007	0.010	0.019	0.036	0.052
	4	0.019	0.004	0.007	0.014	0.025	0.032
	5	0.014	0.003	0.005	0.010	0.019	0.024
	7.5	0.008	0.003	0.003	0.006	0.011	0.015
	10	0.006	0.001	0.002	0.004	0.008	0.010

Figure 14: 1/10,000 AEP Mean UHS and Selected Fractiles.

Table 5: Uniform Hazard Spectral Ordinates for 1/10,000 AEP with Selected Fractiles.

Spectral Period (s)		5% damped, RotD50, Spectral Acceleration (g)					
		Mean	Fractile				
			5th	16th	50th	84th	95th
1/10,000 AEP	PGA	0.193	0.072	0.083	0.147	0.235	0.376
	0.02	0.287	0.114	0.140	0.230	0.337	0.541
	0.03	0.343	0.143	0.173	0.293	0.413	0.631
	0.05	0.411	0.150	0.197	0.327	0.490	0.772
	0.075	0.406	0.159	0.206	0.326	0.500	0.567
	0.1	0.368	0.143	0.160	0.286	0.453	0.584
	0.15	0.383	0.155	0.210	0.332	0.471	0.685
	0.2	0.350	0.111	0.149	0.265	0.428	0.658
	0.3	0.296	0.079	0.119	0.215	0.356	0.565
	0.4	0.243	0.073	0.100	0.175	0.298	0.468
	0.5	0.206	0.062	0.087	0.150	0.258	0.340
	0.75	0.155	0.041	0.063	0.110	0.196	0.258
	1	0.122	0.030	0.048	0.084	0.156	0.218
	1.5	0.082	0.021	0.032	0.056	0.105	0.142
	2	0.062	0.021	0.023	0.044	0.078	0.112
	3	0.037	0.009	0.013	0.025	0.047	0.067
	4	0.025	0.006	0.009	0.017	0.032	0.043
	5	0.019	0.004	0.007	0.013	0.025	0.032
	7.5	0.012	0.003	0.004	0.008	0.015	0.020
	10	0.008	0.002	0.003	0.005	0.010	0.013

7.1.3 Disaggregation of Seismic Hazard

Magnitude-distance disaggregation is commonly used to identify the seismic sources that are the most significant contributors to the total probabilistic hazard at specific spectral periods and likelihoods. In addition to the hazard curves by source (e.g., Figure 10) that show the combined effect of earthquake likelihood, magnitude and source-to-site distance from each seismic source, WSP disaggregated the hazard by earthquake magnitude and source-to-site distance. The magnitude-distance disaggregation is a joint probability mass distribution that describes the contribution from all seismic sources based on the magnitude and source to site distance at selected combinations of spectral period and likelihood. The magnitude-distance disaggregations in this assessment are enhanced by also plotting the distribution of epsilon for each combination of distance and magnitude. Epsilon is the number of standard deviations by which a ground motion from a given source at a given magnitude-distance combination is above or below the median predicted by the ground motion models.

Disaggregation plots for PGA and spectral periods of 0.2 s, 0.5 s, and 1.0 s for AEPs at 1/2,475, 1/5,000, and 1/10,000 are presented in Figure 15, Figure 16, and Figure 17, respectively.

The mean and mode of the magnitude-distance joint probability mass distribution supports the selection of scenario earthquake used in earthquake acceleration time history development. Table 6 lists the mean, median, and mode of the magnitude, distance, and epsilon values, for each couplet of selected AEPs and at selected spectral periods.

Figure 15: Magnitude-Distance-Epsilon Disaggregation of the 1/2,475 AEP Mean Acceleration at PGA (upper left) and Spectral Periods of: 0.2 s (upper right), 0.5 s (lower left), and 1.0 s (lower right).

Figure 16: Magnitude-Distance-Epsilon Disaggregation of the 1/5,000 AEP Mean Acceleration at PGA (upper left) and Spectral Periods of: 0.2 s (upper right), 0.5 s (lower left), and 1.0 s (lower right).

Figure 17: Magnitude-Distance-Epsilon Disaggregation of the 1/10,000 AEP Mean Acceleration at PGA (upper left) and Spectral Periods of: 0.2 s (upper right), 0.5 s (lower left), and 1.0 s (lower right).

Table 6: Average Distance, Magnitude, and Epsilon from Magnitude-Distance Disaggregation of Hazard from all Sources.

AEP	Spectral period (s)	Distance Bin			Magnitude (Mw) Bin			Epsilon[1]		
		Mean	Median	Mode	Mean	Median	Mode	Mean	Median	Mode
1/2,475	PGA	140 - 160	140 - 160	160 - 180	6.6 - 6.8	6.8 - 7.0	7.2 - 7.4	1.0	1.5	0.5
	0.2	160 - 180	160 - 180	160 - 180	6.8 - 7.0	6.8 - 7.0	7.0 - 7.2	1.1	1.5	1.5
	0.5	220 - 240	180 - 200	160 - 180	7.0 - 7.2	7.0 - 7.2	7.0 - 7.2	1.0	1.5	0.5
	1.0	260 - 280	200 - 220	160 - 180	7.0 - 7.2	7.0 - 7.2	7.2 - 7.4	1.1	1.5	1.5
1/5,000	PGA	140 - 160	140 - 160	140 - 160	6.8 - 7.0	7.0 - 7.2	7.2 - 7.4	1.0	1.5	1.5
	0.2	140 - 160	140 - 160	140 - 160	6.8 - 7.0	7.0 - 7.2	7.2 - 7.4	1.0	1.5	1.5
	0.5	200 - 220	160 - 180	160 - 180	7.0 - 7.2	7.0 - 7.2	7.0 - 7.2	1.2	1.5	1.5
	1.0	240 - 260	180 - 200	160 - 180	7.2 - 7.4	7.2 - 7.4	7.2 - 7.4	1.0	1.5	1.5
1/10,000	PGA	120 - 140	120 - 140	160 - 180	6.8 - 7.0	7.0 - 7.2	7.2 - 7.4	1.1	1.5	1.5
	0.2	140 - 160	140 - 160	160 - 180	7.0 - 7.2	7.0 - 7.2	7.2 - 7.4	1.3	1.5	1.5
	0.5	180 - 200	160 - 180	160 - 180	7.0 - 7.2	7.2 - 7.4	7.2 - 7.4	1.2	1.5	1.5
	1.0	220 - 240	180 - 200	160 - 180	7.2 - 7.4	7.2 - 7.4	7.2 - 7.4	1.3	1.5	1.5

Note:

1. Epsilon values are based on the range of values for the median-distance and median-magnitude.

7.1.4 Comparison with CanadaSHM6

WSP completed this SSSHA with the CanadaSHM6 seismic source model and weights without modification from those published by Kolaj et al., (2023). We have applied these source models with the most recent version of the NGA-East GMMs described Goulet et al. (2018). The suite of GMMs originally implemented with the CanadaSHM6 source models to calculate seismic hazard values for the 2020 NBCC is a different combination of GMMs to those applied in this assessment. The results of this assessment, therefore, differ from the results presented as part of the 2020 NBCC.

Table 7 shows accelerations for selected spectral accelerations calculated using OpenQuake for AEPs of 1/475 and 1/2,475, for a site ground condition of V_{S30} = 1,853 m/s. We note that the 2020 NBCC does not provide results at AEPs of 1/5,000 and 1/10,000, so a comparison of results for these likelihoods is not presented. The results of this assessment are up to 43% greater than those from the 2020 NBCC. The increase is mostly caused by our use of the 17 NGA-East GMMs and the Stewart et al., (2020) and Hashash et al., (2020) site amplification factors in this assessment.

While there are moderate to large percentage differences between this assessment and the 2020 NBCC, the absolute differences in earthquake accelerations are relatively small. That is, the hazard at the Louvicourt TSF site remains relatively low when compared to other parts of southeast Canada and more active regions in western Canada. The differences are because of evolving GMM development and uncertainties associated with the appropriate sigma models. WSP considers that the acceleration values provided in this assessment are the best available estimate at this time, but changes can be expected in the future as the GMMs and site amplification factors continue to be refined.

Table 7: Comparison of Mean Spectral Acceleration from This Assessment and from the 2020 NBCC, for Selected Spectral Periods (V_{S30} = 1,853 m/s).

Spectral Period (s)	Mean Acceleration, 1/2,475 AEP (g)		Percentage Change, 2020 NBCC to This Assessment
	2020 NBCC[1]	This Assessment[2]	
PGA	0.0852	0.0992	+16.5%
0.2	0.132	0.189	+43.1%
0.5	0.0849	0.114	+34.7%
1.0	0.0497	0.0661	+33.1%
2.0	0.0252	0.0329	+30.7%

Notes:

1. GMMs used in 2020 NBCC: 13 preliminary NGA-East (Goulet et al. [2017a,b]), weighted 50%, and Atkinson and Adams (2013), weighted 50%.
2. GMMs used in this assessment: 17 final NGA-East (Goulet et al., 2018), weighted 100%.

8.0 EARTHQUAKE ACCELERATION TIME HISTORY DEVELOPMENT

WSP developed two suites of eight, two-horizontal-component earthquake acceleration time histories (EATHs) to support advanced geotechnical stability analyses of the Louvicourt TSF. Earthquake ground motions were selected and amplitude-scaled to represent the mean UHS for the 1/10,000 AEP (i.e., the target spectrum) for the site seismic ground conditions of V_{S30} = 1,853 m/s. Various secondary intensity measures (IMs) of the scaled ground motions were also considered in the final selection of input ground motions.

The Louvicourt TSF contains embankments of differing height and stiffness, and, therefore, varying fundamental periods. WSP was provided with two fundamental period values; one shorter period (T_S) in the range 0.25 s to 0.37 s, and one longer period (T_L) of approximately 1.15 s. A suite of eight, two-horizontal-component EATHs has been developed for each of the short and long fundamental periods.

Each suite of EATHs was selected using the following approach:

1. The 1/10,000 AEP hazard disaggregation results (Figure 17, Table 6) were reviewed, and a representative set of causal parameters (i.e., earthquake magnitude and rupture distance) selected.
2. Target secondary IMs consistent with the 1/10,000 AEP hazard were estimated using an earthquake scenario based on the input parameters listed below. The causal parameters (magnitude and rupture distance) are as highlighted in Figure 17 and Table 6. The other input parameters were assumed based on our judgement of reasonable values for earthquakes occuring in stable continental regions such as southeastern Canada.
   - Magnitude (Mw) = 7.3
   - Rupture distance (r_{rup}) = 170 km
   - Hypocentral depth (z_{hypo}) = 20 km
   - Depth to top of rupture (z_{tor}) = 10 km
   - Rupture plane dip (δ) = 90°

   The secondary IMs considered were cumulative absolute velocity (CAV), Arias intensity (AI); and the 5% to 75% AI and 5% to 95% AI significant durations (D_{5-75} and D_{5-95}, respectively). These secondary IMs are known to influence earthquake geotechnical engineering behaviour. Target secondary IMs were conditioned to the target spectrum at the two fundamental periods identified.
3. A catalogue of candidate ground motion records with generally similar causal parameters was developed from the PEER NGA-West2 (Ancheta et al., 2014) and NGA-East databases (Goulet et al., 2021).
4. Candidate ground motions were amplitude-scaled to be in general agreement with the target spectrum. A suite of eight ground motions was selected for each fundamental period, with a focus on the fit of the horizontal geometric mean response with the horizontal target spectrum across each of the period ranges of interest.
5. The secondary IMs of each of the selected, scaled horizontal ground motion records were compared with the estimated conditional IM values.

6. The selected suite of ground motions was accepted once the geometric mean of the horizontal components agreed with the target spectrum within the period range of interest and the empirical IMs compared reasonably well with the conditional IM values.

8.1 Ground Motion Selection Criteria

Ground motion selection criteria used in EATH development are presented in this section.

- **Target spectrum:** The mean UHS for the 1/10,000 AEP.
- **Conditioning period, T*:** For the short fundamental period, T_S* was taken as 0.31 s (i.e., the centre of the range 0.25 s to 0.37 s). For the long fundamental period, T_L* was taken as 1.15 s.
- **Period range of interest:** For the short fundamental period, a period range of interest of 0.062 s to 0.62 s (i.e., 0.2T_S* to 2.0T_S*) for scaling of candidate ground motions. For the longer fundamental period, a period range of interest of 0.23 s to 2.3 s (i.e., 0.2T_L* to 2.0T_L*) was adopted for scaling of candidate ground motions.
- **Causal parameters:** The magnitude and distance used for motion selection and estimation of IMs were selected based on the disaggregation results presented in Section 7.1.3. Figure 17 shows that the largest contribution to the 1/10,000 AEP seismic hazard at the Louvicourt TSF site is from earthquakes with magnitudes of about Mw 6.8 to Mw 7.5 and source-to-site distances of about 100 to 200 km, for both the shorter spectral periods (e.g., 0.2 s) and longer spectral periods (e.g., 1.0 s). Table 6 shows that mean, median, and mode values for the magnitude and distance generally agree at the shorter and longer spectral periods as well. Based on these results, ground motions were selected based on the modal disaggregation scenario of Mw 7.3 and 170 km source-to-site distance.
- **Secondary IMs:**
  - Median and lognormal standard deviation (σ) of the secondary IMs were estimated for the causal parameters listed above using the ground motions models listed in Table 8 and Table 9.
  - AI and CAV were conditioned to the 1/10,000 AEP hazard at each of T_S* and T_L* following the approach described by Baker et al. (2021). Conditioning involves the use of epsilon (ε), which is the number of standard deviations for the spectral acceleration at T* to be equal to the hazard level. The ε was estimated to be 1.5 for both the short and long fundamental periods, based on the 1/10,000 AEP hazard disaggregations (Table 6).
  - The shaking duration IMs of $D_{5\text{-}75}$ and $D_{5\text{-}95}$ were not conditioned for each of the T_S* and T_L* because they are period-independent IMs.
  - Table 8 lists the conditional median values of AI and CAV. The unconditional median values of $D_{5\text{-}75}$ and $D_{5\text{-}95}$ are listed in Table 9. Figure 20 and Figure 21 show the distributions of all secondary IMs.

Table 8: Ground Motion and Conditional Correlation Models of AI and CAV for Time History Selection.

Intensity Measure	Ground Motion Model	Conditional Correlation Model	Conditional Median Value	
			T_S* (0.31 s)	T_L* (1.15 s)
SA (T*)	See Section 5.2	Not Applicable	0.296 (ε = 1.5)	0.122 (ε = 1.5)
Arias Intensity, AI	Farhadi and Pezeshk (2020)	Bradley (2015)	0.098 (m/s)	0.073 (m/s)
Cumulative Absolute Velocity, CAV	Farhadi and Pezeshk (2020)	Bradley (2012)	5.46 (m/s)	5.10 (m/s)

Table 9: Ground Motion Models of $D_{5\text{-}75}$ and $D_{5\text{-}95}$ for Time History Selection.

Intensity Measure	Ground Motion Model	Median Value (Period-Independent)
Significant Duration, $D_{5\text{-}75}$	Bommer et al. (2009)	5.66 (s)
Significant Duration, $D_{5\text{-}95}$	Bommer et al. (2009)	10.50 (s)

8.2 Candidate Ground Motion Records

The PEER NGA-West2 database was used to create a catalogue of prospective ground motions ranging in magnitude from Mw 6.0 to Mw 7.8 and source-to-site distance from 0 to 200 km for each period range of interest, consistent with the disaggregation results. The PEER NGA-East database was also consulted but lacked ground motions records with magnitudes greater than Mw 5.85. Relatively loose bounds were used for earthquake magnitude and distance because the ground motion selection process explicitly considered secondary IMs. By explicitly considering the secondary IMs, it is less important to target specific causal parameters such as earthquake magnitude (e.g., Baker et al., 2021). The site parameters, therefore, were not limited in creating the prospective ground motion catalogues to increase the number of prospective motions in the catalogue. Similarly, while scale factors applied to prospective ground motions were generally kept within the range 0.5 to 4.0, the scale factor was considered less important than the comparison of secondary IMs and the fit of selected ground motions to the target spectrum.

8.3 Ground Motion Selection Results

Table 10 and Table 11 list the key parameters of the two suites of eight, two-horizontal-component time histories selected for T_S and T_L, respectively.

Figure 18 and Figure 19 show the geometric means of the suites of selected scaled ground motions compared to the target 1/10/000 AEP UHS, respectively. The figures show that the geometric mean of each suite of ground motions agrees well with the target spectra because it falls between 90% and 130% of the target spectra within the period range of interest.

Table 12 and Table 13 list selected intensity measures for each component for the suites of motions selected for T_S and T_L, respectively. The intensity measures of the suites of selected motions generally agree with the theoretical values listed in Table 8 and Table 9. Figure 20 and Figure 21 show the cumulative probability of empirical and estimated conditional intensity measures for AI, CAV, D_{5-75}, and D_{5-95}. Figure 20 and Figure 21 show that the IMs of the selected motions are generally well matched to their theoretical values. However, the IMs of the scaled motions appear higher relative to the target IMs (i.e., average values of scaled IMs are slightly greater than the median of the respective target IMs).

As discussed in Section 8.1, the ground motion selection process focused on selecting motions that matched the target spectrum and generally agreed with estimated conditional IMs. Consequently, the selected suites of ground motions for T_S and T_L include records with shorter source-to-site distances than suggested by the magnitude-distance-epsilon disaggregation results presented in Section 7.1.3. The shorter source-to-site distances allowed a better fit to the target spectrum, while still agreeing with the estimated conditional IMs. The selection of records with shorter source-to-site distances is commonly used when applying earthquake ground motions from plate boundary areas to intraplate stable continental regions such as that surrounding the Louvicourt TSF site in southeast Canada.

A major reason why the source-to-site distances of selected records are shorter than the disaggregation results is in part because of the difference between the Louvicourt TSF site condition (V_{S30} = 1,853 m/s) and the relatively less stiff plate boundary ground conditions where the prospective ground motions were recorded. Moderate- to high-frequency ground motions are attenuated faster by weaker seismic ground conditions (i.e., lower V_{S30}) compared to stiffer ground conditions. Additionally, moderate- to high-frequency ground motions are attenuated faster than lower frequency ground motions. To capture the high-frequency (short-period) ground motions indicated by the 1/10,000 AEP UHS at the Louvicourt TSF site, records with shorter source-to-site distances were required. Some records with larger scale factors were also required to obtain a good match to the target spectrum in the shorter period range of interest (notably, RSNs 1833 and 2927 in Table 10). We anticipate that suitable candidate ground motions from intraplate conditions would have source-to-site distances that are more consistent with the disaggregation results. Regardless, the selected motions have engineering IMs that are consistent with the hazard based on intraplate conditions, so we consider that they are suitable for engineering analyses at the Louvicourt TSF site.

Appendix A and Appendix B present the selected, scaled EATHs for the short and long period range of interest, respectively. Digital records from the EATH development accompany this report.

Table 10: Suite of Selected EATHs Scaled for the Short Period Range (0.062 s to 0.62 s) at the Louvicourt TSF Site.

ID	Record Sequence Number	Earthquake Designation or Name	Year	Recording Station Name	Source Mechanism Type	Earthquake Magnitude (Mw)	Source-to-Site Distance (R_{rup} km)	Site Ground Condition (V_{S30} m/s)	Scale Factor
1	516	N. Palm Springs, USA	1986	Cranston Forest Station	Reverse Oblique	6.06	28	425	1.11
2	530	N. Palm Springs, USA	1986	Palm Springs Airport	Reverse Oblique	6.06	11	312	0.95
3	1833	Hector Mine, USA	1999	Snow Creek	Strike Slip	7.13	73	524	8.28
4	2927	Chi-Chi, Taiwan-04	1999	TTN040	Strike Slip	6.2	51	728	6.85
5	3185	Chi-Chi, Taiwan-05	1999	TCU060	Reverse	6.2	56	375	3.19
6	4347	Umbria Marche, Italy	1997	Borgo-Cerreto Torre	Normal	6	19	519	1.90
7	5618	Iwate, Japan	2008	IWT010	Reverse	6.9	16	826	0.59
8	5773	Iwate, Japan	2008	Miyagi Great Village	Reverse	6.9	41	531	0.80

Table 11: Suite of Selected EATHs Scaled for the Long Period Range (0.23 s to 2.3 s) at the Louvicourt TSF Site.

ID	Record Sequence Number	Earthquake Designation or Name	Year	Recording Station Name	Source Mechanism Type	Earthquake Magnitude (Mw)	Source-to-Site Distance (R_{rup} km)	Site Ground Condition (V_{S30} m/s)	Scale Factor
1	68	San Fernando, USA	1971	LA - Hollywood Stor FF	Reverse	6.61	23	316	0.64
2	746	Loma Prieta, USA	1989	Bear Valley #5 Callens Ranch	Reverse Oblique	6.93	54	391	1.51
3	774	Loma Prieta, USA	1989	Hayward City Hall - North	Reverse Oblique	6.93	55	735	2.67
4	869	Landers, USA	1992	LA - N Westmoreland	Strike Slip	7.28	159	315	2.33
5	923	Big Bear-01, USA	1992	Phelan - Wilson Ranch	Strike Slip	6.46	64	333	2.87
6	1474	Chi-Chi, Taiwan	1999	TCU025	Reverse Oblique	7.62	53	665	1.51
7	3471	Chi-Chi, Taiwan-06	1999	TCU075	Reverse	6.3	26	573	1.71
8	6060	Big Bear-01, USA	1992	North Palm Springs Fire Sta #36	Strike Slip	6.46	42	368	0.77

Table 12: Intensity Measures of the Selected Scaled EATHs for the Short Period Range (0.062 s to 0.62 s) at the Louvicourt TSF Site.

ID	Earthquake Designation or Name	Scale Factor	Recording Component	PGV (cm/s)	AI (m/s)	CAV (m/s)	D_{5-75} (s)	D_{5-95} (s)
1	516	1.11	225	8.24	0.14	2.03	5.04	7.45
			315	13.25	0.23	2.61	3.39	5.60
2	530	0.95	180	11.93	0.27	4.87	6.14	14.70
			270	11.61	0.29	5.25	5.87	17.21
3	1833	8.28	90	38.55	0.71	10.23	14.01	23.35
			180	24.14	0.62	10.04	15.43	26.78
4	2927	6.85	N	15.10	0.29	4.70	6.00	14.13
			E	26.50	0.27	4.62	6.75	14.12
5	3185	3.19	N	9.72	0.28	5.35	9.84	17.88
			E	10.19	0.37	6.09	10.24	16.72
6	4347	1.90	0	6.36	0.25	3.69	5.08	9.32
			90	8.49	0.24	3.52	4.37	8.74
7	5618	0.59	NS	12.92	0.44	8.26	9.28	19.85
			EW	15.57	0.44	8.44	7.87	24.62
8	5773	0.80	NS	9.21	0.34	6.18	10.02	17.85
			EW	11.57	0.47	6.9	7.96	16.86

Table 13: Intensity Measures of the Selected Scaled EATHs for the Long Period Range (0.23 s to 2.3 s) at the Louvicourt TSF Site.

ID	Earthquake Designation or Name	Scale Factor	Recording Component	PGV (cm/s)	AI (m/s)	CAV (m/s)	D_{5-75} (s)	D_{5-95} (s)
1	68	0.64	90	13.86	0.27	4.84	5.25	13.19
			180	10.81	0.18	4.04	5.10	13.53
2	746	1.51	220	14.00	0.20	4.41	10.82	17.47
			310	15.43	0.20	4.36	10.97	17.79
3	774	2.67	64	14.98	0.28	5.45	7.53	19.55
			334	16.15	0.27	4.90	6.69	14.65
4	869	2.33	0	27.55	0.33	6.37	15.26	22.60
			270	10.91	0.26	5.81	16.48	24.05
5	923	2.87	90	9.16	0.41	8.19	14.66	30.70
			180	11.62	0.50	8.15	10.19	21.83
6	1474	1.51	W	26.12	0.24	4.64	12.71	18.15
			N	14.12	0.21	4.36	11.78	14.65
7	3471	1.71	N	7.98	0.17	4.66	10.97	24.72
			E	13.63	0.39	6.28	8.87	17.04
8	6060	0.77	90	10.33	0.24	4.36	8.54	12.89
			180	8.99	0.23	4.29	7.50	12.54

Figure 18: Acceleration Response Spectra for Horizontal Geometric Mean and Individual Selected Scaled EATHs Compared to the Target Spectrum (Short Period Range). Period Range of Interest Highlighted.

Figure 19: Acceleration Response Spectra for Horizontal Geometric Mean and Individual Selected Scaled EATHs Compared to the Target Spectrum (Long Period Range). Period Range of Interest Highlighted.

Figure 20: Cumulative Probability of Scaled (blue) and Conditional (black) AI, CAV, $D_{5\text{-}75}$, and $D_{5\text{-}95}$ Intensity Measures from the Selected Scaled EATHs (Short Period Range).

Figure 21: Cumulative Probability of Scaled (blue) and Conditional (black) AI, CAV, $D_{5\text{-}75}$, and $D_{5\text{-}95}$ Intensity Measures from the Selected Scaled EATHs (Long Period Range).

9.0 CONCLUSIONS

WSP evaluated the site-specific seismic hazard at the Louvicourt TSF site through probabilistic analysis for AEPs of 1/2,475, 1/5,000, and 1/10,000. We implemented the CanadaSHM6 seismic source models for southeastern Canada along with the 17 NGA-East GMMs, AA13 standard deviation model, and equally weighted site amplification models developed for the CENA region. Results are presented for the Louvicourt TSF site measured seismic ground condition with a V_{S30} = 1,853 m/s.

The results of the probabilistic analysis indicate that:

- The site is within a region of generally low historical earthquake activity in southwestern Québec, to the west of the more historically seismically active St. Lawrence and Ottawa-Gatineau areas (Figure 1).
- The seismic hazard at the Louvicourt TSF site is relatively low compared to other parts of southeast Canada. For example, the 1/10,000 AEP mean horizontal spectral accelerations (5%-damped) are 0.193 g, 0.350 g, and 0.122 g for PGA, 0.2 s, and 1.0 s spectral periods, respectively (Figure 14).
- The dominant contributors to the seismic hazard across all spectral periods evaluated are moderate- to large-magnitude earthquakes (~Mw 6.8 to Mw 7.4) at distances of about 100 km to 200 km from the Louvicourt TSF site (Figure 15, Figure 16, Figure 17, and Table 6).
- There are some smaller contributions to the seismic hazard from moderate-magnitude earthquakes (typically Mw <6.0) within about 40 km of the site, particularly at short spectral periods (PGA and 0.2 s), and from moderate- to large-magnitude earthquakes (Mw 6.8 to Mw 7.4) at greater source-to-site distances (about 360 km and greater).
- The seismic hazard estimate for the Louvicourt TSF site from this SSSHA is higher than indicated in the 2020 NBCC (at 1/2,475 AEP) by up to 43%. The primary reason for the higher estimate is our application of more recent GMMs and site amplification models than those used for the 2020 NBCC.

The uncertainties associated with the mean hazard values are relatively large. For example, the average ratio of 95th-fractile to 5th-fractile PGA is about 5 for this site for the AEPs analyzed. The major contributors to the uncertainty in the probabilistic seismic hazard analysis are the:

- Relatively low occurrence rates of historical and instrumental earthquakes in the region surrounding the site.
- Lack of recorded earthquakes near the site to constrain earthquake recurrence parameters.
- Epistemic uncertainties in the NGA-East GMM weighted logic-tree framework.
- Aleatory uncertainty in the AA13 standard deviation (sigma) models.

The sources of uncertainty listed above cannot be reduced because they rely upon the occurrence of more earthquakes in a region of relatively low activity.

Two suites of eight, two-horizontal-component earthquake acceleration time histories (EATHs) are amplitude-scaled to match the 1/10,000 AEP mean UHS for one short fundamental period, T_S = 0.25 to 0.37 s, and one long fundamental period, T_L = 1.15 s, respectively. The EATHs were selected using causal parameters indicated by the disaggregation analysis, with additional consideration of secondary IMs. Candidate records were selected from the NGA-West2 database, due to a lack of records with the required causal parameters in other databases (i.e., NGA-East).

The results of the earthquake acceleration time history development indicate that:

- The geometric mean spectrum of the eight selected EATHs for each period range is generally within about 90% to 130% of the 1/10,000 AEP mean UHS.
- The secondary IMs of selected EATHs generally provide a good fit to conditional secondary IMs calculated using an earthquake scenario based on causal parameters indicated by the disaggregation analysis.
- Several of the selected EATHs have shorter source-to-site distances than indicated by the disaggregation analysis. Records with shorter source-to-site distances are required to capture the high-frequency (short-period) ground motions indicated by the 1/10,000 AEP UHS at the Louvicourt TSF site. These shorter distance records provide a good match to the target spectrum and secondary IMs and are, therefore, considered acceptable for geotechnical analysis.

10.0 CLOSING

Thank you for the opportunity to undertake this site-specific seismic hazard assessment. This report provides the seismic hazard information required to undertake further geotechnical analyses at the Louvicourt TSF site. If Teck has any questions about the content of the report, please contact the undersigned.

Signature Page

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APPENDIX A

Selected Earthquake Acceleration Time Histories - Short Period Range

CLIENT
TECK RESOURCES LTD

PROJECT
SITE-SPECIFIC SEISMIC HAZARD ASSESSMENT
LOUVICOURT MINE TAILINGS MANAGEMENT FACILITY

CONSULTANT

YYYY-MM-DD	2024-01-15
DESIGNED	NC
PREPARED	NC
REVIEWED	AH
APPROVED	AH

TITLE
SELECTED EARTHQUAKE ACCELERATION TIME HISTORIES
SHORT PERIOD RANGE (T* = 0.31 S)
N. PALM SPRINGS USA, RSN516, 225
SCALE FACTOR = 1.113

PROJECT NO.	PHASE	REV.	FIGURE
21494974	5000	0	**A1**

CLIENT

TECK RESOURCES LTD

PROJECT

SITE-SPECIFIC SEISMIC HAZARD ASSESSMENT
LOUVICOURT MINE TAILINGS MANAGEMENT FACILITY

CONSULTANT

YYYY-MM-DD	2024-01-15
DESIGNED	NC
PREPARED	NC
REVIEWED	AH
APPROVED	AH

TITLE

SELECTED EARTHQUAKE ACCELERATION TIME HISTORIES
SHORT PERIOD RANGE (T* = 0.31 S)
N. PALM SPRINGS USA, RSN516, 315
SCALE FACTOR = 1.113

PROJECT NO.	PHASE	REV.	FIGURE
21494974	5000	0	**A2**

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CLIENT
TECK RESOURCES LTD

PROJECT
SITE-SPECIFIC SEISMIC HAZARD ASSESSMENT
LOUVICOURT MINE TAILINGS MANAGEMENT FACILITY

CONSULTANT

YYYY-MM-DD	2024-01-15
DESIGNED	NC
PREPARED	NC
REVIEWED	AH
APPROVED	AH

TITLE
SELECTED EARTHQUAKE ACCELERATION TIME HISTORIES
SHORT PERIOD RANGE (T* = 0.31 S)
N. PALM SPRINGS USA, RSN530, 180
SCALE FACTOR = 0.952

PROJECT NO.	PHASE	REV.	FIGURE
21494974	5000	0	**A3**

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CLIENT	TECK RESOURCES LTD
PROJECT	SITE-SPECIFIC SEISMIC HAZARD ASSESSMENT LOUVICOURT MINE TAILINGS MANAGEMENT FACILITY
CONSULTANT	
YYYY-MM-DD	2024-01-15
DESIGNED	NC
PREPARED	NC
REVIEWED	AH
APPROVED	AH

TITLE

SELECTED EARTHQUAKE ACCELERATION TIME HISTORIES
SHORT PERIOD RANGE (T* = 0.31 S)
N. PALM SPRINGS USA, RSN530, 270
SCALE FACTOR = 0.952

PROJECT NO.	PHASE	REV.	FIGURE
21494974	5000	0	**A4**

CLIENT
TECK RESOURCES LTD

PROJECT
SITE-SPECIFIC SEISMIC HAZARD ASSESSMENT
LOUVICOURT MINE TAILINGS MANAGEMENT FACILITY

CONSULTANT

YYYY-MM-DD	2024-01-15
DESIGNED	NC
PREPARED	NC
REVIEWED	AH
APPROVED	AH

TITLE
SELECTED EARTHQUAKE ACCELERATION TIME HISTORIES
SHORT PERIOD RANGE (T* = 0.31 S)
HECTOR MINE USA, RSN1833, 90
SCALE FACTOR = 8.275

PROJECT NO.	PHASE	REV.	FIGURE
21494974	5000	0	**A5**

CLIENT
TECK RESOURCES LTD

PROJECT
SITE-SPECIFIC SEISMIC HAZARD ASSESSMENT
LOUVICOURT MINE TAILINGS MANAGEMENT FACILITY

CONSULTANT

YYYY-MM-DD	2024-01-15
DESIGNED	NC
PREPARED	NC
REVIEWED	AH
APPROVED	AH

TITLE
SELECTED EARTHQUAKE ACCELERATION TIME HISTORIES
SHORT PERIOD RANGE (T* = 0.31 S)
HECTOR MINE USA, RSN1833, 180
SCALE FACTOR = 8.275

PROJECT NO.	PHASE	REV.	FIGURE
21494974	5000	0	**A6**

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PROJECT
SITE-SPECIFIC SEISMIC HAZARD ASSESSMENT
LOUVICOURT MINE TAILINGS MANAGEMENT FACILITY

CONSULTANT

YYYY-MM-DD	2024-01-15
DESIGNED	NC
PREPARED	NC
REVIEWED	AH
APPROVED	AH

TITLE
SELECTED EARTHQUAKE ACCELERATION TIME HISTORIES
SHORT PERIOD RANGE (T* = 0.31 S)
CHI-CHI TAIWAN-04, RSN2927, E
SCALE FACTOR = 6.846

PROJECT NO.	PHASE	REV.	FIGURE
21494974	5000	0	**A7**

CLIENT	TECK RESOURCES LTD
PROJECT	SITE-SPECIFIC SEISMIC HAZARD ASSESSMENT LOUVICOURT MINE TAILINGS MANAGEMENT FACILITY
CONSULTANT	

YYYY-MM-DD	2024-01-15
DESIGNED	NC
PREPARED	NC
REVIEWED	AH
APPROVED	AH

TITLE

SELECTED EARTHQUAKE ACCELERATION TIME HISTORIES
SHORT PERIOD RANGE (T* = 0.31 S)
CHI-CHI TAIWAN-04, RSN2927, N
SCALE FACTOR = 6.846

PROJECT NO.	PHASE	REV.	FIGURE
21494974	5000	0	**A8**

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CLIENT
TECK RESOURCES LTD

PROJECT
SITE-SPECIFIC SEISMIC HAZARD ASSESSMENT
LOUVICOURT MINE TAILINGS MANAGEMENT FACILITY

CONSULTANT

YYYY-MM-DD	2024-01-15
DESIGNED	NC
PREPARED	NC
REVIEWED	AH
APPROVED	AH

TITLE
SELECTED EARTHQUAKE ACCELERATION TIME HISTORIES
SHORT PERIOD RANGE (T* = 0.31 S)
CHI-CHI TAIWAN-05, RSN3185, E
SCALE FACTOR = 3.191

PROJECT NO.	PHASE	REV.	FIGURE
21494974	5000	0	**A9**

CLIENT
TECK RESOURCES LTD

PROJECT
SITE-SPECIFIC SEISMIC HAZARD ASSESSMENT
LOUVICOURT MINE TAILINGS MANAGEMENT FACILITY

CONSULTANT

YYYY-MM-DD	2024-01-15
DESIGNED	NC
PREPARED	NC
REVIEWED	AH
APPROVED	AH

TITLE
SELECTED EARTHQUAKE ACCELERATION TIME HISTORIES
SHORT PERIOD RANGE (T* = 0.31 S)
CHI-CHI TAIWAN-05, RSN3185, N
SCALE FACTOR = 3.191

PROJECT NO.	PHASE	REV.	FIGURE
21494974	5000	0	**A10**

CLIENT

TECK RESOURCES LTD

PROJECT

SITE-SPECIFIC SEISMIC HAZARD ASSESSMENT
LOUVICOURT MINE TAILINGS MANAGEMENT FACILITY

CONSULTANT

YYYY-MM-DD	2024-01-15
DESIGNED	NC
PREPARED	NC
REVIEWED	AH
APPROVED	AH

TITLE

SELECTED EARTHQUAKE ACCELERATION TIME HISTORIES
SHORT PERIOD RANGE (T* = 0.31 S)
UMBRIA MARCHE ITALY, RSN4347, 0
SCALE FACTOR = 1.895

PROJECT NO.	PHASE	REV.	FIGURE
21494974	5000	0	**A11**

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CLIENT
TECK RESOURCES LTD

PROJECT
SITE-SPECIFIC SEISMIC HAZARD ASSESSMENT
LOUVICOURT MINE TAILINGS MANAGEMENT FACILITY

CONSULTANT

YYYY-MM-DD	2024-01-15
DESIGNED	NC
PREPARED	NC
REVIEWED	AH
APPROVED	AH

TITLE
SELECTED EARTHQUAKE ACCELERATION TIME HISTORIES
SHORT PERIOD RANGE (T* = 0.31 S)
UMBRIA MARCHE ITALY, RSN4347, 90
SCALE FACTOR = 1.895

PROJECT NO.	PHASE	REV.	FIGURE
21494974	5000	0	**A12**

CLIENT
TECK RESOURCES LTD

PROJECT
SITE-SPECIFIC SEISMIC HAZARD ASSESSMENT
LOUVICOURT MINE TAILINGS MANAGEMENT FACILITY

CONSULTANT

YYYY-MM-DD	2024-01-15
DESIGNED	NC
PREPARED	NC
REVIEWED	AH
APPROVED	AH

TITLE
SELECTED EARTHQUAKE ACCELERATION TIME HISTORIES
SHORT PERIOD RANGE (T* = 0.31 S)
IWATE JAPAN, RSN5618, EW
SCALE FACTOR = 0.593

PROJECT NO.	PHASE	REV.	FIGURE
21494974	5000	0	**A13**

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TECK RESOURCES LTD

PROJECT

SITE-SPECIFIC SEISMIC HAZARD ASSESSMENT
LOUVICOURT MINE TAILINGS MANAGEMENT FACILITY

CONSULTANT

YYYY-MM-DD	2024-01-15
DESIGNED	NC
PREPARED	NC
REVIEWED	AH
APPROVED	AH

TITLE

SELECTED EARTHQUAKE ACCELERATION TIME HISTORIES
SHORT PERIOD RANGE (T* = 0.31 S)
IWATE JAPAN, RSN5618, NS
SCALE FACTOR = 0.593

PROJECT NO.	PHASE	REV.	FIGURE
21494974	5000	0	**A14**

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TECK RESOURCES LTD

PROJECT

SITE-SPECIFIC SEISMIC HAZARD ASSESSMENT
LOUVICOURT MINE TAILINGS MANAGEMENT FACILITY

CONSULTANT

YYYY-MM-DD	2024-01-15
DESIGNED	NC
PREPARED	NC
REVIEWED	AH
APPROVED	AH

TITLE

**SELECTED EARTHQUAKE ACCELERATION TIME HISTORIES
SHORT PERIOD RANGE (T* = 0.31 S)
IWATE JAPAN, RSN5773, EW
SCALE FACTOR = 0.799**

PROJECT NO.	PHASE	REV.	FIGURE
21494974	5000	0	**A15**

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CLIENT
TECK RESOURCES LTD

PROJECT
SITE-SPECIFIC SEISMIC HAZARD ASSESSMENT
LOUVICOURT MINE TAILINGS MANAGEMENT FACILITY

CONSULTANT

YYYY-MM-DD	2024-01-15
DESIGNED	NC
PREPARED	NC
REVIEWED	AH
APPROVED	AH

TITLE
SELECTED EARTHQUAKE ACCELERATION TIME HISTORIES
SHORT PERIOD RANGE (T* = 0.31 S)
IWATE JAPAN, RSN5773, NS
SCALE FACTOR = 0.799

PROJECT NO.	PHASE	REV.	FIGURE
21494974	5000	0	**A16**

APPENDIX B

Selected Earthquake Acceleration Time Histories - Long Period Range

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CLIENT
TECK RESOURCES LTD

PROJECT
SITE-SPECIFIC SEISMIC HAZARD ASSESSMENT
LOUVICOURT MINE TAILINGS MANAGEMENT FACILITY

CONSULTANT

YYYY-MM-DD	2024-01-15
DESIGNED	NC
PREPARED	NC
REVIEWED	AH
APPROVED	AH

TITLE
SELECTED EARTHQUAKE ACCELERATION TIME HISTORIES
LONG PERIOD RANGE (T* = 1.15 S)
SAN FERNANDO USA, RSN68, 90
SCALE FACTOR = 0.638

PROJECT NO.	PHASE	REV.	FIGURE
21494974	5000	0	**B1**

PATH: C:\Users\CANC079442\Golder Associates\21494974, Teck Dams1D and 4B Stability Louvicourt - 5000 - SSSHA update\final_report

CLIENT
TECK RESOURCES LTD

PROJECT
SITE-SPECIFIC SEISMIC HAZARD ASSESSMENT
LOUVICOURT MINE TAILINGS MANAGEMENT FACILITY

CONSULTANT

YYYY-MM-DD	2024-01-15
DESIGNED	NC
PREPARED	NC
REVIEWED	AH
APPROVED	AH

TITLE
SELECTED EARTHQUAKE ACCELERATION TIME HISTORIES
LONG PERIOD RANGE (T* = 1.15 S)
SAN FERNANDO USA, RSN68, 180
SCALE FACTOR = 0.638

PROJECT NO.	PHASE	REV.	FIGURE
21494974	5000	0	**B2**

PATH: C:\Users\CANC079442\Golder Associates\21494974, Teck Dams1D and 4B Stability Louvicourt - 5000 - SSSHA update\final_report

CLIENT
TECK RESOURCES LTD

PROJECT
SITE-SPECIFIC SEISMIC HAZARD ASSESSMENT
LOUVICOURT MINE TAILINGS MANAGEMENT FACILITY

CONSULTANT

YYYY-MM-DD	2024-01-15
DESIGNED	NC
PREPARED	NC
REVIEWED	AH
APPROVED	AH

TITLE
SELECTED EARTHQUAKE ACCELERATION TIME HISTORIES
LONG PERIOD RANGE (T* = 1.15 S)
LOMA PRIETA USA, RSN746, 220
SCALE FACTOR = 1.514

PROJECT NO.	PHASE	REV.	FIGURE
21494974	5000	0	**B3**

CLIENT
TECK RESOURCES LTD

PROJECT
SITE-SPECIFIC SEISMIC HAZARD ASSESSMENT
LOUVICOURT MINE TAILINGS MANAGEMENT FACILITY

CONSULTANT

YYYY-MM-DD	2024-01-15
DESIGNED	NC
PREPARED	NC
REVIEWED	AH
APPROVED	AH

TITLE
SELECTED EARTHQUAKE ACCELERATION TIME HISTORIES
LONG PERIOD RANGE (T* = 1.15 S)
LOMA PRIETA USA, RSN746, 310
SCALE FACTOR = 1.514

PROJECT NO.	PHASE	REV.	FIGURE
21494974	5000	0	**B4**

CLIENT
TECK RESOURCES LTD

PROJECT
SITE-SPECIFIC SEISMIC HAZARD ASSESSMENT
LOUVICOURT MINE TAILINGS MANAGEMENT FACILITY

CONSULTANT

YYYY-MM-DD	2024-01-15
DESIGNED	NC
PREPARED	NC
REVIEWED	AH
APPROVED	AH

TITLE
SELECTED EARTHQUAKE ACCELERATION TIME HISTORIES
LONG PERIOD RANGE (T* = 1.15 S)
LOMA PRIETA USA, RSN774, 64
SCALE FACTOR = 2.668

PROJECT NO.	PHASE	REV.	FIGURE
21494974	5000	0	**B5**

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CLIENT
TECK RESOURCES LTD

PROJECT
SITE-SPECIFIC SEISMIC HAZARD ASSESSMENT
LOUVICOURT MINE TAILINGS MANAGEMENT FACILITY

CONSULTANT

YYYY-MM-DD	2024-01-15
DESIGNED	NC
PREPARED	NC
REVIEWED	AH
APPROVED	AH

TITLE
SELECTED EARTHQUAKE ACCELERATION TIME HISTORIES
LONG PERIOD RANGE (T* = 1.15 S)
LOMA PRIETA USA, RSN774, 334
SCALE FACTOR = 2.668

PROJECT NO.	PHASE	REV.	FIGURE
21494974	5000	0	**B6**

CLIENT
TECK RESOURCES LTD

PROJECT
SITE-SPECIFIC SEISMIC HAZARD ASSESSMENT
LOUVICOURT MINE TAILINGS MANAGEMENT FACILITY

CONSULTANT

YYYY-MM-DD	2024-01-15
DESIGNED	NC
PREPARED	NC
REVIEWED	AH
APPROVED	AH

TITLE
SELECTED EARTHQUAKE ACCELERATION TIME HISTORIES
LONG PERIOD RANGE (T* = 1.15 S)
LANDERS USA, RSN869, 0
SCALE FACTOR = 2.330

PROJECT NO.	PHASE	REV.	FIGURE
21494974	5000	0	**B7**

PATH: C:\Users\CANC079442\Golder Associates\21494974, Teck Dams1D and 4B Stability Louvicourt - 5000 - SSSHA update\final_report

CLIENT
TECK RESOURCES LTD

PROJECT
SITE-SPECIFIC SEISMIC HAZARD ASSESSMENT
LOUVICOURT MINE TAILINGS MANAGEMENT FACILITY

CONSULTANT

YYYY-MM-DD	2024-01-15
DESIGNED	NC
PREPARED	NC
REVIEWED	AH
APPROVED	AH

TITLE
SELECTED EARTHQUAKE ACCELERATION TIME HISTORIES
LONG PERIOD RANGE (T* = 1.15 S)
LANDERS USA, RSN869, 270
SCALE FACTOR = 2.330

PROJECT NO.	PHASE	REV.	FIGURE
21494974	5000	0	**B8**

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CLIENT

TECK RESOURCES LTD

PROJECT

SITE-SPECIFIC SEISMIC HAZARD ASSESSMENT
LOUVICOURT MINE TAILINGS MANAGEMENT FACILITY

CONSULTANT

YYYY-MM-DD	2024-01-15
DESIGNED	NC
PREPARED	NC
REVIEWED	AH
APPROVED	AH

TITLE

SELECTED EARTHQUAKE ACCELERATION TIME HISTORIES
LONG PERIOD RANGE (T* = 1.15 S)
BIG BEAR-01 USA, RSN923, 90
SCALE FACTOR = 2.866

PROJECT NO.	PHASE	REV.	FIGURE
21494974	5000	0	**B9**

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CLIENT
TECK RESOURCES LTD

PROJECT
SITE-SPECIFIC SEISMIC HAZARD ASSESSMENT
LOUVICOURT MINE TAILINGS MANAGEMENT FACILITY

CONSULTANT

YYYY-MM-DD	2024-01-15
DESIGNED	NC
PREPARED	NC
REVIEWED	AH
APPROVED	AH

TITLE
SELECTED EARTHQUAKE ACCELERATION TIME HISTORIES
LONG PERIOD RANGE (T* = 1.15 S)
BIG BEAR-01 USA, RSN923, 180
SCALE FACTOR = 2.866

PROJECT NO.	PHASE	REV.	FIGURE
21494974	5000	0	**B10**

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CLIENT
TECK RESOURCES LTD

PROJECT
SITE-SPECIFIC SEISMIC HAZARD ASSESSMENT
LOUVICOURT MINE TAILINGS MANAGEMENT FACILITY

CONSULTANT

YYYY-MM-DD	2024-01-15
DESIGNED	NC
PREPARED	NC
REVIEWED	AH
APPROVED	AH

TITLE
SELECTED EARTHQUAKE ACCELERATION TIME HISTORIES
LONG PERIOD RANGE (T* = 1.15 S)
CHI-CHI TAIWAN, RSN1474, N
SCALE FACTOR = 1.512

PROJECT NO.	PHASE	REV.	FIGURE
21494974	5000	0	**B11**

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TECK RESOURCES LTD

PROJECT
SITE-SPECIFIC SEISMIC HAZARD ASSESSMENT
LOUVICOURT MINE TAILINGS MANAGEMENT FACILITY

CONSULTANT

YYYY-MM-DD	2024-01-15
DESIGNED	NC
PREPARED	NC
REVIEWED	AH
APPROVED	AH

TITLE
SELECTED EARTHQUAKE ACCELERATION TIME HISTORIES
LONG PERIOD RANGE (T* = 1.15 S)
CHI-CHI TAIWAN, RSN1474, W
SCALE FACTOR = 1.512

PROJECT NO.	PHASE	REV.	FIGURE
21494974	5000	0	**B12**

CLIENT
TECK RESOURCES LTD

PROJECT
SITE-SPECIFIC SEISMIC HAZARD ASSESSMENT
LOUVICOURT MINE TAILINGS MANAGEMENT FACILITY

CONSULTANT

YYYY-MM-DD	2024-01-15
DESIGNED	NC
PREPARED	NC
REVIEWED	AH
APPROVED	AH

TITLE
SELECTED EARTHQUAKE ACCELERATION TIME HISTORIES
LONG PERIOD RANGE (T* = 1.15 S)
CHI-CHI TAIWAN-06, RSN3471, E
SCALE FACTOR = 1.713

PROJECT NO.	PHASE	REV.	FIGURE
21494974	5000	0	**B13**

CLIENT
TECK RESOURCES LTD

PROJECT
SITE-SPECIFIC SEISMIC HAZARD ASSESSMENT
LOUVICOURT MINE TAILINGS MANAGEMENT FACILITY

CONSULTANT

YYYY-MM-DD	2024-01-15
DESIGNED	NC
PREPARED	NC
REVIEWED	AH
APPROVED	AH

TITLE
SELECTED EARTHQUAKE ACCELERATION TIME HISTORIES
LONG PERIOD RANGE (T* = 1.15 S)
CHI-CHI TAIWAN-06, RSN3471, N
SCALE FACTOR = 1.713

PROJECT NO.	PHASE	REV.	FIGURE
21494974	5000	0	**B14**

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TECK RESOURCES LTD

PROJECT
SITE-SPECIFIC SEISMIC HAZARD ASSESSMENT
LOUVICOURT MINE TAILINGS MANAGEMENT FACILITY

CONSULTANT

YYYY-MM-DD	2024-01-15
DESIGNED	NC
PREPARED	NC
REVIEWED	AH
APPROVED	AH

TITLE
SELECTED EARTHQUAKE ACCELERATION TIME HISTORIES
LONG PERIOD RANGE (T* = 1.15 S)
BIG BEAR-01 USA, RSN6060, 90
SCALE FACTOR = 0.769

PROJECT NO.	PHASE	REV.	FIGURE
21494974	5000	0	**B15**

CLIENT
TECK RESOURCES LTD

PROJECT
SITE-SPECIFIC SEISMIC HAZARD ASSESSMENT
LOUVICOURT MINE TAILINGS MANAGEMENT FACILITY

CONSULTANT

YYYY-MM-DD	2024-01-15
DESIGNED	NC
PREPARED	NC
REVIEWED	AH
APPROVED	AH

TITLE
SELECTED EARTHQUAKE ACCELERATION TIME HISTORIES
LONG PERIOD RANGE (T* = 1.15 S)
BIG BEAR-01 USA, RSN6060, 180
SCALE FACTOR = 0.769

PROJECT NO.	PHASE	REV.	FIGURE
21494974	5000	0	**B16**

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