ERCB/AGS Open File Report 2011-15

Alberta Microseismicity Project, Phase I: Site Assessments for the ATSN Semipermanent Stations and the PSEIP Strachan Temporary Seismic Array

Energy Resources Conservation Board

Alberta Geological Survey

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Alberta Microseismicity Project, Phase I: Site Assessments for the ATSN Semipermanent Stations and the PSEIP Strachan Temporary Seismic Array

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Contents

Tables

Figures

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Abstract

In 2008, the University of Calgary's Passive Seismic Imaging of Earth Processes (PSIEP) research group in the Department of Geosciences approached the Alberta Geological Survey with a proposal to install eight or more telemetered seismic stations throughout Alberta, to be known as the Alberta Telemetered Seismograph Network (ATSN). This network would complement the federal government's telemetered Canadian National Seismograph Network (CNSN) and the University of Alberta's non-telemetered Canadian Rockies and Alberta Network (CRANE). This collaboration initiated the Energy Resources Conservation Board/Alberta Geological Survey (ERCB/AGS) Microseismicity Project (MSP).

The first phase of the project spanned 2009–2010 and 2010–2011, its goals being to support, encourage and enable the installation of new seismic stations and maintain existing networks within Alberta. The goals of the second phase of the MSP, spanning 2010–2011 and 2011–2012 are to 1) acquire the seismic software and computer hardware required to monitor the new ATSN and the existing CNSN stations; 2) configure and modify the system to suit research objectives in Alberta; and 3) analyze the waveforms from the ATSN, CRANE and CNSN networks to establish a database of Alberta earthquakes and their parameters. The goals of the third phase of the MSP, starting in 2011, are to 1) develop velocity models specific to Alberta; 2) improve the accuracy and precision of micro-earthquake locations; and 3) actively participate in studies of microseismicity using temporary arrays of portable seismographs.

This report documents Phase I of the Alberta Microseismicity Project. It details the preparations and fieldwork involved in 1) assessing potential sites in Alberta for the semipermanent ATSN stations; 2) assessing sites for the temporary portable array near the Strachan D3-A gas reservoir southwest of Rocky Mountain House; and 3) maintenance of several CRANE stations in central Alberta.

In the summers of 2009 and 2010, seven sites were selected for installation of ATSN seismic stations, consisting of seismometers and digital seismographs: one on the northern border of Alberta just south of Fort Smith, Northwest Territories, four in northwestern Alberta (Grande Prairie, Manning, High Level and Red Earth Creek) and two in southern Alberta (Raymond and Medicine Hat). An eighth site was selected by PSIEP at Priddis as an upgrade to a previous installation.

The Strachan field sites were part of a PSIEP project to revisit the Strachan D-3A gas reservoir, which had been the subject of previous studies in the mid-1980s and early 1990s by the Geological Survey of Canada (GSC) and the University of Alberta. The AGS field team assessed 47 sites within a 10 km radius of the Strachan reservoir. Ten of the sites, within a 5 km radius of the reservoir, were presented to PSIEP, which selected three of the assessed privately owned sites and added two privately owned sites for the installation of five portable seismic stations.

1 Introduction

The federal government has monitored earthquakes in Alberta with a subset of the Canadian National Seismograph Network (CNSN) since the mid-1960s. The up to 800 earthquakes detected, located and recorded in Alberta from 1918 to 2009 are concentrated in a northwesterly trend along the eastern edge of the Rocky Mountain Foothills (Figure 1).

The number of earthquakes located within Alberta increased in the mid-1970s. This increase was not solely due to an increase in the number of reporting seismic stations because the number of stations remained stable through the 1990s. It may, in part, have reflected a changing mandate of the federal government to locate all detectable earthquakes in its jurisdiction. Figure 2 shows the number of recorded earthquakes versus time. The earthquakes are separated into three groups: 1) minor earthquakes with local magnitude (ML) of 3 ML or more (orange line in Figure 2); 2) micro-earthquakes with local magnitude between 2.0 and 2.9 ML (yellow line); and 3) micro-earthquakes with local magnitudes of <1.9 ML and below (blue line).

The increase during the mid-1960s seen in all earthquake magnitudes, but most noticeable with those of magnitude 2, is contemporaneous with the installation of seismic stations in Edmonton (EDM) and Suffield (SES). The decade between 1965 and 1975 should, therefore, be considered the baseline period, with an average of five earthquakes per year, rather than the aseismic period prior to 1965. The fact that there is a small increase in minor earthquakes, as well as the large increase in micro-earthquakes, in the mid-1970s implies that the increase is not entirely an artifact of the increasing focus of the federal government on locating all detectable earthquakes. Minor earthquakes are rarely missed by the stations that have been in operation since the mid-1960s. An increase related to the increase in available personnel to locate earthquakes, therefore, would be expected for earthquakes smaller than 2.5 local magnitude but probably not for larger earthquakes.

The earthquakes that are located in several clusters (Figure 3) in southwestern Alberta are thought to be related to the onset and increase in hydrocarbon production in the province (Wetmillar, 1986). Several studies have sought to test the links between these clusters of earthquakes, notably the cluster south of Rocky Mountain House. These studies were constrained by either the density of the CNSN stations (e.g., Rebollar et al., 1982, 1984; Baranova et al., 1999), which limited the number and size of earthquakes detected, or the duration of the study (e.g., Wetmillar, 1986), which limited the ability of the researchers to link the earthquakes temporally with monthly volumetric reports of hydrocarbon production.

2 Alberta Seismic Stations

2.1 Canadian National Seismograph Network (CNSN)

The subset of CNSN seismic stations (indicated by red stars in Figure 4 and 'GSC' in 'Agency' column of Table 1) routinely used by the federal government for locating earthquakes in Alberta included several within the province: an early station in Banff (BAN, 1956–1966); one in Edmonton (EDM, 1963 onwards); and one in Suffield (SES, 1966–1993) that was later replaced by the station in Waterton (WALA, 1992 onwards). These stations were usually augmented by one or two stations from southeastern British Columbia: one in Penticton (PNT, 1960 onwards) and one in Mica Creek (MCC, 1966–1977 and MCE, 1977–1981). The spatial orientation of these stations has favoured detection in south-central Alberta, where they were generally able to detect earthquakes with local magnitudes as small as 2–2.5 on more than three stations. In north and northeastern Alberta, the detection limit was closer to 3–3.5 ML.

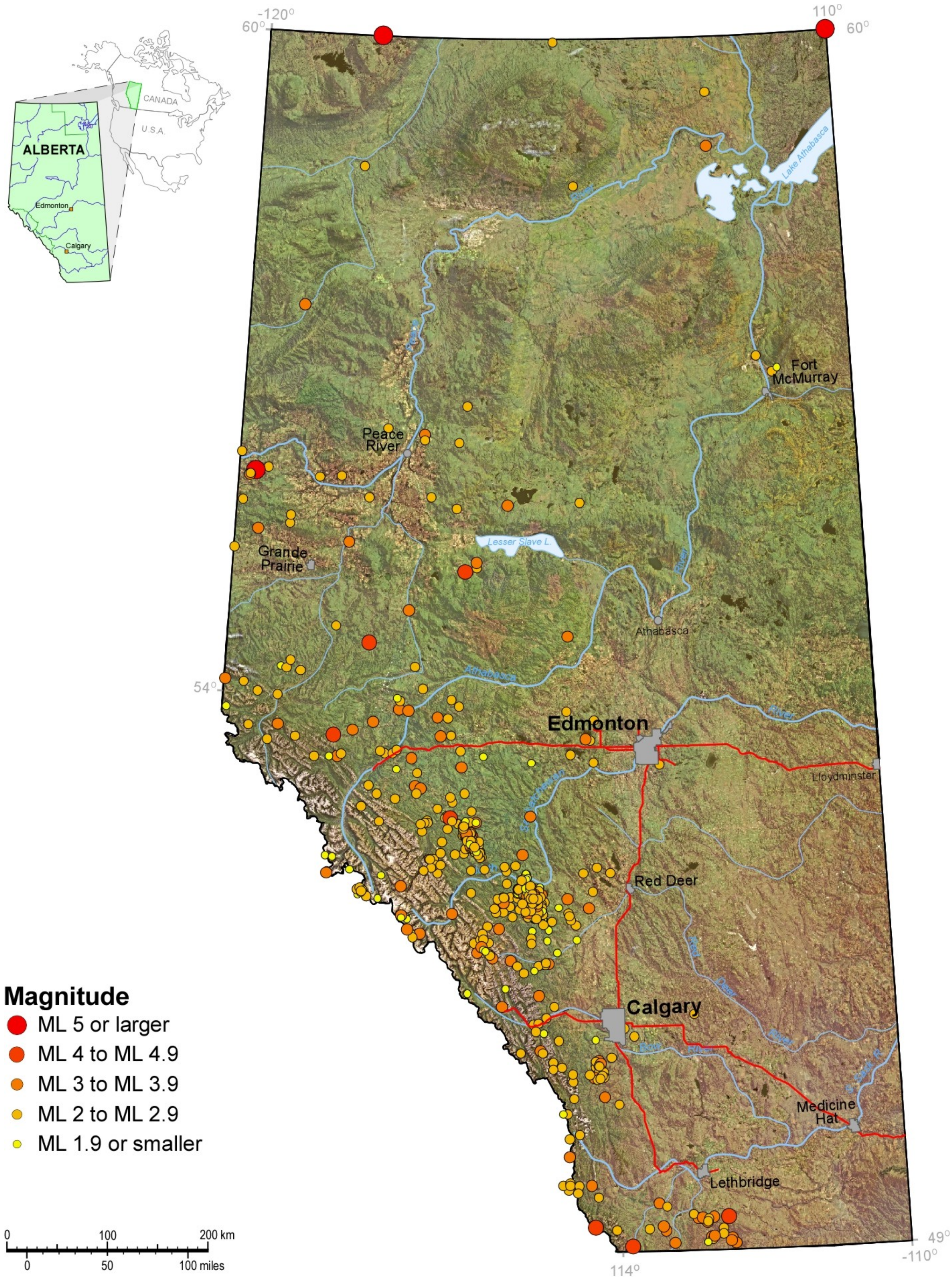

Figure 1. Locations of earthquakes in Alberta, 1918–2009. Data from Earthquakes Canada (2011).

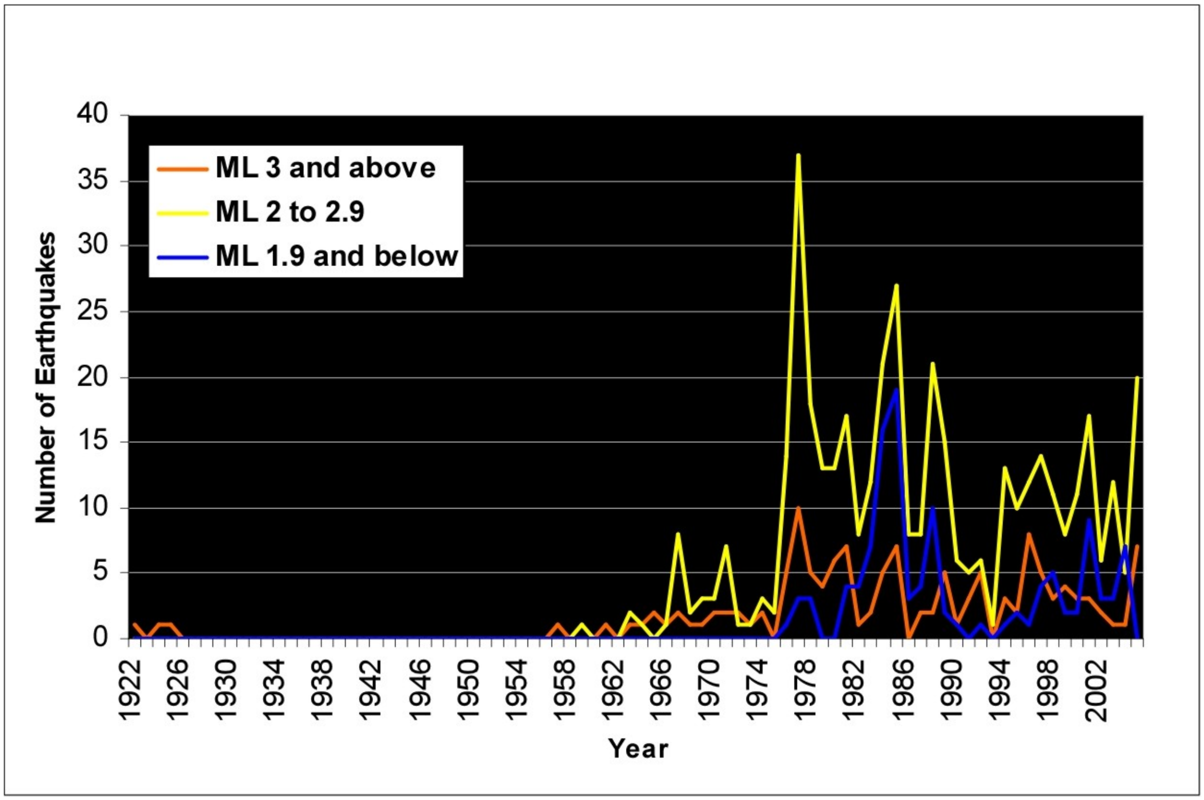

Figure 2. Number of recorded earthquakes in Alberta, plotted by year, 1922–2006. Data from Earthquakes Canada (2011).

2.2 Canadian Rockies and Alberta Network (CRANE)

Beginning in late 2005, the University of Alberta installed 11 non-telemetered seismic stations in a semi-uniform network in central and southern Alberta (indicated by green triangles in Figure 4 and 'U of A' in 'Agency' column of Table 1). This network, the Canadian Rockies and Alberta Network (CRANE), provides a relatively dense network of stations compared to similar low-seismicity regions, such as Saskatchewan and Manitoba. However, as the CRANE stations are not telemetered, their seismic data have not been available to the federal government in near–real time for detection, refinement or location of events. The main use of the CRANE data has been for research in anisotropy, conducted at the University of Alberta, using shear-wave splitting of large teleseismic events and studies of regional seismic structure using ambient noise fields between stations (e.g., Gu et al., 2009).

2.3 Alberta Telemetered Seismograph Network (ATSN)

The University of Calgary's Passive Seismic Imaging of Earth Processes (PSIEP) project increased station density, particularly in northwestern Alberta, with the installation of up to eight new telemetered ATSN seismic stations (indicated by blue squares in Figure 4 and 'U Of C' in 'Agency' column of Table 1). Five stations were installed in northern Alberta: near the Wapiti River close to Grande Prairie (WAPA), outside Manning (MANA), outside High Level (HILA), south of Fort Smith (FSMA) and in Red Earth Creek (RDEA). Three stations were installed in southern Alberta: south of Medicine Hat(MEDA), south of Raymond (RAYA) and near Priddis (PRDA; installed in a pre-existing vault to replace older decommissioned equipment). These telemetered stations are part of the Portable Observatories for Lithospheric Analysis and Research Investigating Seismicity (POLARIS) project and are available to the federal government in near–real time for detection and location of events within Canada.

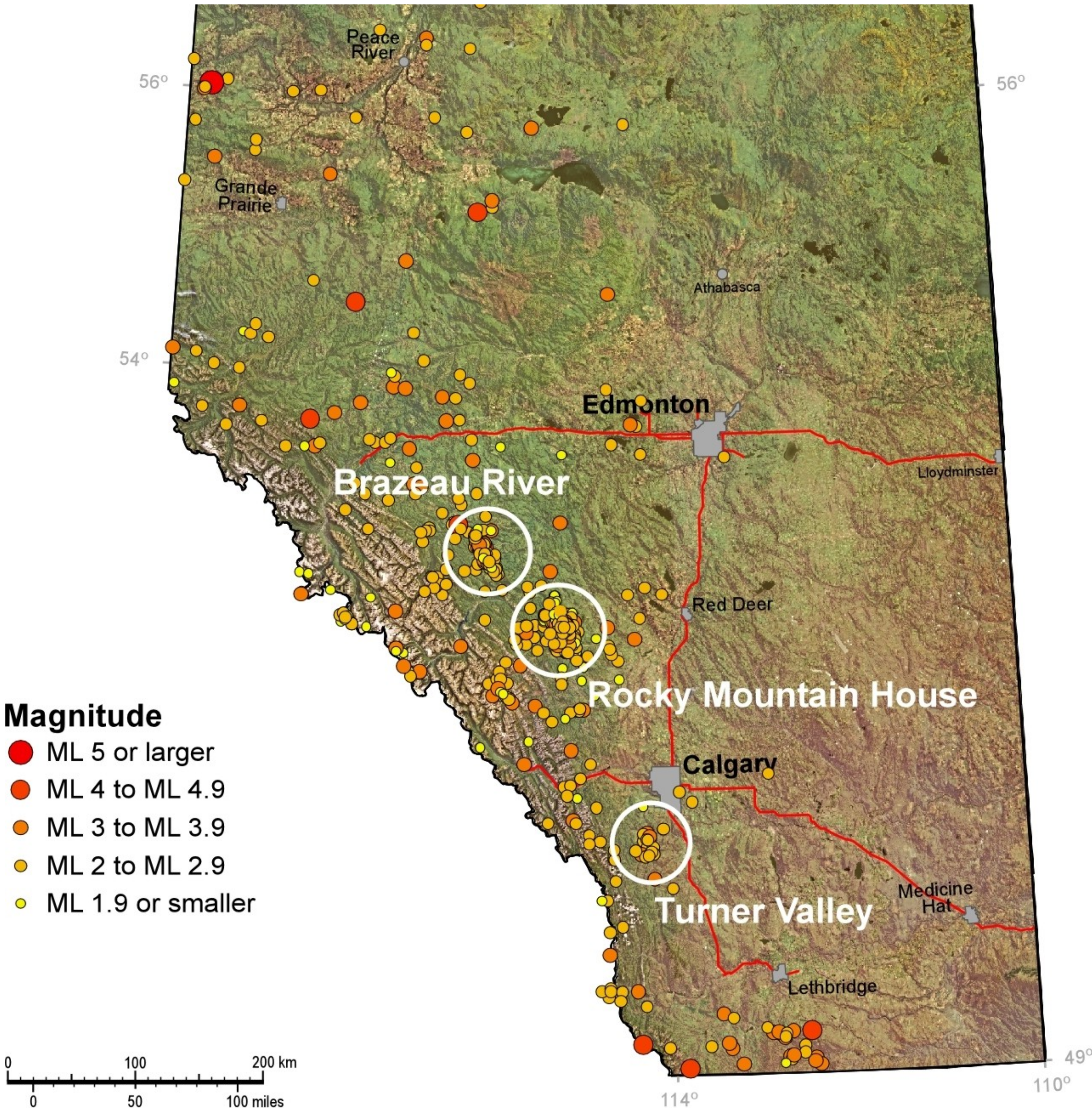

Figure 3. Clusters of earthquakes (white circles) in the Brazeau River, Rocky Mountain House and Turner Valley regions, 1918–2009. Data from Earthquakes Canada (2011).

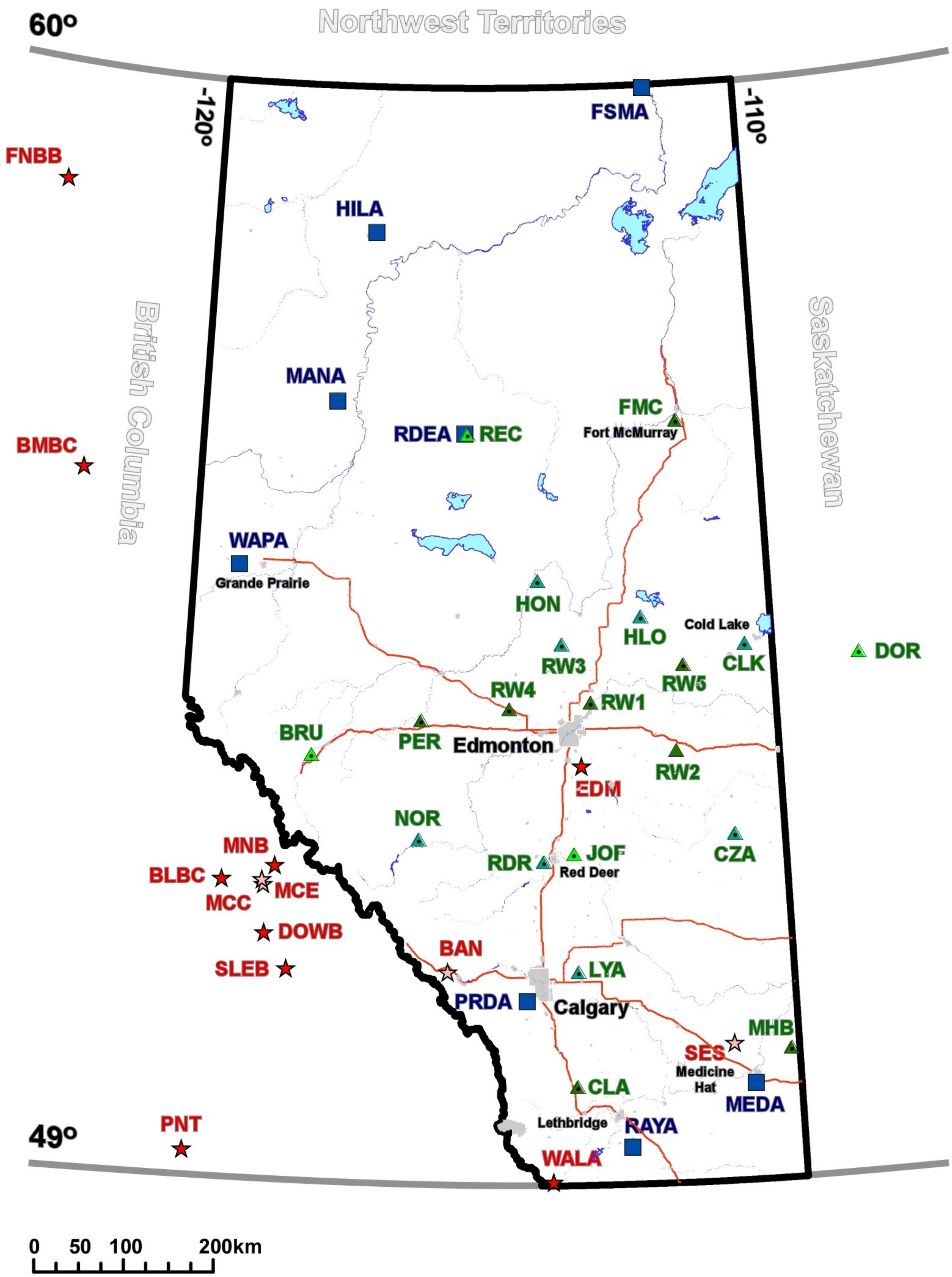

Figure 4. Locations of currently operating and decommissioned seismic stations in Alberta, British Columbia, and Saskatchewan: Canadian National Seismograph Network (CNSN, red stars)); Canadian Rockies and Alberta Network (CRANE, green triangles); Alberta Telemetered Seismograph Network (ATSN, blue squares).

Table 1. Seismic stations in and around Alberta.

Station Code	Latitude (°)	Longitude (°)	Elevation (m)	Location	Date Opened	Date Closed	Agency
BAN	51.1717	-115.5583	1500	Banff, Alta.	Aug-1956	22-Sep-1966	GSC
BLBC	52.0434	-119.2411	2362	Blue River, B.C.	17-Jun-1997		GSC
BMBC	56.045	-122.131	1100	Bull Mountain, B.C.	30-Jan-1998		GSC
BRU	53.32	-117.87	1005	Hinton, Alta.	02-Oct-2006	11-Jun-2010	U of A
CLA	50.01	-113.52	1039	Claresholm, Alta.	02-Oct-2006		U of A
CLK	54.3848	-110.507	536	Cold Lake, Alta.	23-Sep-2011		U of A
CZA	52.49	-110.86	701	Wainwright, Alta.	31-Aug-2007		U of A
DOR	54.22	-108.57	483	Dorintosh, Sask.	26-Oct-2007	04-Apr-2010	U of A
DOWB	51.5183	-118.5162	594	Downie Slide, B.C.	13-Jun-1997		GSC
EDM	53.2217	-113.35	730	Edmonton, Alta.	19-Apr-1963		GSC
FMC	56.65	-111.5	360	Fort McMurray, Alta.	16-Nov-2007		U of A
FNBB	58.8904	-123.0097	618	Fort Nelson, B.C.	24-Oct-1999		GSC
FSMA	59.9862	-111.8218	220	Fort Smith, Alta.	12-Sep-2010		U of C
HILA	58.55608	-117.02029	329	High Level, Alta.	19-Oct-2009		U of C
HLO/HYO	54.7	-112.28	581	Hylo, Alta.	05-May-2009		U of A
HON	55.08	-114.05	605	Hondo, Alta.	14-Oct-2006		U of A
JOF	52.34	-113.51	929	Joffre, Alta.	18-Sep-2006	24-May-2007	U of A
LYA	51.16	-113.47	943	Strathmore, Alta.	02-Oct-2006		U of A
MANA	56.85538	-117.63672	480	Manning, Alta.	17-Oct-2009		U of C
MCC	52.0517	-118.5853	578	Mica Creek, B.C.	05-Jul-1966	03-Jun-1977	GSC
MCE	52.0033	-118.5617	625	Mica Creek, B.C.	04-Jun-1977	12-Aug-1981	GSC
MEDA	49.98148	-110.74244	721.7	Medicine Hat, Alta.	09-Oct-2009		U of C
MHB/MHT	50.32	-110.16	719	Medicine Hat, Alta.	10-May-2009		U of A
MNB	52.1983	-118.3833	2271	Mount Dainard, B.C.	29-Oct-1981		GSC
NOR	52.49	-116.05	943	Nordegg, Alta.	18-Sep-2006		U of A
PER	53.68	-116.04	860	Peers, Alta.	28-Sep-2006		U of A
PNT	49.3167	-119.6167	550	Penticton, B.C.	01-Jan-1960		GSC
PRDA	50.8674	-114.29185	1252	Priddis, Alta.	13-Nov-2009		U of C
RAYA	49.386271	-112.687403	1019	Raymond, Alta.			U of C
RDEA	56.53006	-115.27918	534	Red Earth Creek, Alta.	21-Sep-2010		U of C
RDR	52.2658	-114.00	934	Red Deer, Alta.	14-Sep-2011		U of A
REC	56.55	-115.28	534	Red Earth Creek, Alta.	13-Oct-2006	28-May-2007	U of A
RW1	53.8529	-113.1759	643	Coronado, Alta.	15-Oct-2010		U of A
RW2	53.3493	-111.7463	691	Ranfurly, Alta.	17-Sep-2010		U of A
RW3	54.4415	-113.6513	683	Meadowbrook, Alta.	15-Oct-2010		U of A
RW4	53.8006	-114.5519	746	Glenevis, Alta.	13-Oct-2010		U of A
RW5	54.2043	-111.5781	625	Ashmount, Alta.	01-Oct-2010		U of A
SES	50.396	-111.042	770	Suffield, Alta.	1966	31-Mar-1993	GSC
SLEB	51.1672	-118.1336	2075	Sale Mountain, B.C.	01-Oct-1985		GSC
WALA	49.0586	-113.9115	1400	Waterton Lake, Alta.	01-Jun-1992		GSC
WAPA	55.18333	-119.25361	784	Grande Prairie, Alta.	15-Oct-2009		U of C
YKB3	62.4486	-114.6052	187.6	Yellowknife, N.W.T.	25-Jan-1989		GSC
YKB6	62.5165	-114.605	202.6	Yellowknife, N.W.T.	25-Jan-1989		GSC
YKR1	62.49322	-114.60528	197	Yellowknife, N.W.T.	25-Jan-1989		GSC
YKR2	62.4928	-114.8964	175	Yellowknife, N.W.T.	25-Jan-1989		GSC
YKR4	62.4928	-114.7995	173.4	Yellowknife, N.W.T.	25-Jan-1989		GSC
YKR9	62.4932	-114.5557	201.1	Yellowknife, N.W.T.	25-Jan-1989		GSC
YKW3	62.5608	-114.6164	198	Yellowknife, N.W.T.	25-Jan-1989		GSC

Geological Survey of Canada's Canadian National Seismograph Network (CNSN) station data from Munro et al. (1990) and Earthquakes Canada (2010)
University of Alberta Canadian Rockies and Alberta Network (CRANE) station data courtesy J. Gu
University of Calgary Alberta Telemetered Seismograph Network (ATSN) station data courtesy of D. Eaton
Agency abbreviations: GSC, Geological Survey of Canada; U of A, University of Alberta; U of C, University of Calgary
Latitude and longitude in decimal degrees in the WGS 1984 Geographic Co-ordinate System

3 Site Selection

Sites for the ATSN stations were selected exclusively on privately owned land. The sites assessed for the Strachan temporary deployment were largely on leased Crown land, except for three on privately owned land north and northeast of the Strachan D-3A gas field. Site-selection preparations for new sites for both the ATSN and the Strachan temporary array were similar, although installation of sites on leased Crown land requires involvement of Ministry of Sustainable Resource Development (SRD) staff.

3.1 Preparation

Preparations for field excursions to identify potential sites for seismic-station installations on private or Crown land include the following:

- collecting the most recent ownership maps and provincial base maps for each area;
- identifying potential ground conditions from surficial geology maps and SPOT imagery photos;
- assessing hazards and risks; and
- contacting the nearest regional Energy Resources Conservation Board (ERCB) field office to notify of the dates that an Alberta Geological Survey (AGS) field party will be in their region.

Abandoned well sites with security fencing were the most suitable sites on leased Crown land. Once these sites were identified, leaseholders could be contacted. Although contact information for private landowners can be extracted from ownership maps, driving door to door and speaking personally with the landowners was more effective than making phone calls.

3.1.1 Private Property

Privately owned properties are the most secure sites for installation. The ATSN semipermanent seismic-station sites required connection to the electrical grid for power and Internet access for sending telemetry. The University of Calgary chose to submit a legal land-use agreement to the landowner (Appendix 2) that describes the equipment and terms of installation. An additional requirement is for an Albert One-Call for any installation that requires digging deeper than 15 cm.

3.1.2 Crown or Public Land

Crown land is federally or provincially owned land. Crown land administered by the Public Lands Act is termed *public land* by the Alberta Government. Although it is the least secure option, Crown or public land is often all that is available in a given area. The land may or may not be leased. The original study of the Strachan D-3A gas field by Wetmillar (1986) used seismic stations installed on Crown land. Seven of the 10 sites with the best potential for the current Strachan temporary array were on Crown land. The procedure for acquiring permission to install equipment on Crown land is determined by the length or duration of the activity.

3.1.2.1 Short-Term Installations

Alberta Sustainable Resource Development will issue a Temporary Field Authorization (TFA) permit for one-time-only, passive-seismic–GPS installations with an occupation duration of less than one year (Alberta Sustainable Resource Development, 2011). This TFA has conditions that must be met, such as

- set-backs from natural water bodies;
- use of pre-existing natural clearings and avoidance of vehicle tire ruts while accessing the site;
- notifications and approval from existing leaseholder, if any;
- sketch plan drawn to scale (a legal survey is not required);

- GPS co-ordinates of the site;
- brief description of the equipment to be installed; and
- installation timelines and statement of purpose.

It usually takes 3–4 days to get a TFA issued and to meet all of the permit conditions after SRD receives the application. Two additional days are required to contact Alberta One-Call to mark buried lines if installation will require any digging deeper than 15 cm below the surface. Ground-disturbance concerns are covered within the licence or permit issued.

3.1.2.2 Long-Term Installations

Alberta Sustainable Resource Development requires that any site for long-term installation (more than one year) be legally surveyed. The licence or permit issued will depend upon whether the applicant is a government department, private industry or a research institute.

Typically, a Licence of Occupation (LOC) is issued to private industry and research institutes, and a Disposition Reservation (DRS) is issued to other government agencies requiring long-term access to public lands.

The expensive and time-consuming requirement for a long-term LOC or DRS is the surveyed site plan that must be submitted with the application. Survey costs run about $4000–$6000 per site, depending on the availability of legal-survey-company personnel and location of the site. It could take up to a month to meet the conditions of the application before a licence is granted.

As with the short-term sites, a call must be made to Alberta One-Call if installations require any digging deeper than 15 cm. Ground disturbance concerns are covered in the licence or permit issued.

3.1.2.3 Leased Sites

Leased sites are Crown land temporarily leased to an individual or company. Authorization and agreements must be obtained from the leaseholder. Locating a passive seismic station on leased Crown land is quicker than on non-leased land, as the land has already been surveyed by the leaseholder. A note from the leaseholder with a sketch plan, study description and timeline is sufficient to obtain approval from SRD for the installation.

3.2 General Assessment Criteria

Alberta Telemetered Seismograph Network (ATSN) sites require access to AC electrical power and the Internet, whereas the portable equipment used for the temporary array near Strachan is self-contained, running off solar panels and batteries. The criteria for a good site, documented in Bormann (2002), can be summarized as follows:

- Array layout and station density: AGS's operational purpose for the composite (CNSN, ATSN, CRANE) array requires good azimuth coverage for the location of micro-earthquakes. Poor azimuth coverage can result in inaccurate locations or systematically biased results.
- Quiet locations: The presence of noise and excessive signal spikes will produce poor-quality data. Seismic-noise sources, common in Alberta, are pump jacks, compressor stations, wind and wave action from nearby lakes.
- Security from vandalism and animal destruction.
- Positive landowner or leaseholder attitude.

- Ground conditions: The type of sediment or rock underlying the site affects drainage, vegetation and ease of access. The monitors are best located in clearings, with the distance from tall structures such as towers or trees equal to the height of the structure to avoid wind-generated noise. Additionally, if the power source is a solar panel, there needs to be a clear line of sight southwards.

3.3 Alberta Telemetered Seismograph Network (ATSN) Semipermanent Stations

3.3.1 FSMA

Alberta Geological Survey staff scouted the site for seismic station FSMA (Figure 5) on July 13, 2009, just south of the Alberta–Northwest Territories border and 4 km southwest of Fort Smith, N.W.T. It is 200 m west of the Slave River, between the Pelican Rapids and Mountain Rapids, at the Pelican Rapids Golf Club (Figure 6). The surficial sediments on which the golf course was built are eolian sands (Bayrock, 1972) of variable thickness (0–100 m), most likely towards the latter value. The site has good drainage and is approximately 100–200 m above river level. The station was installed by U of C staff and commissioned on September 12, 2010. Figure 7 shows a seismogram recorded at FSMA.

3.3.2 HILA

The site for seismic station HILA was scouted by AGS staff on June 19, 2009, 8.5 km northwest of High Level (Figure 8). It is on privately owned land 100 m west of the Bushe River. The installation is in a clearing that measures approximately 100 by 100 m, with a drainage pond on the west perimeter (Figure 9). The surficial sediments are hummocky glaciolacustrine fine sand, silt and clay more than 1 m thick (Plouffe et al., 2006, Map 414). The station was installed by U of C staff and commissioned on October 19, 2009. Figure 10 shows a seismogram recorded at HILA.

3.3.3 MANA

Alberta Geological Survey staff scouted the site for seismic station MANA on June 17, 2009, 7 km south of Manning (Figure 11). The site is on private land, owned by the North Peace Applied Research Association, and consists of a large utility building (Figure 12). The surficial sediments are fine-grained glaciolacustrine sand, silt and clay more than 2 m thick (Paulen, 2004). The surrounding area is agricultural with seasonal farming activity. University of Calgary staff installed the station, and it was commissioned on October 19, 2009. Figure 13 shows a seismogram recorded at MANA.

3.3.4 MEDA

University of Calgary and AGS staff scouted the site for seismic station MEDA on July 21, 2009, 8 km southwest of Medicine Hat, on a private rural property (Figure 14). The surrounding area is primarily agricultural land on Pleistocene and Holocene lacustrine deposits of coarse sand and silt up to 40 m thick (Shetsen, 1987). University of Calgary staff installed the station, and it was commissioned on October 9, 2010. It was the first of the seven new sites to be installed and commissioned. Figure 15 shows a seismogram recorded at MEDA.

3.3.5 RAYA

University of Calgary and AGS staff scouted the site for seismic station RAYA on July 21, 2009, 9 km south-southwest of Raymond, near the Milk River Ridge Reservoir (Figure 16). The surficial sediments are Pleistocene and Holocene fluvial deposits up to 20 m thick, including fine sand, silt and clay with minor gravel lenses (Shetsen, 1987). The property, owned and operated by Alberta Environment, includes a concrete utility shed (Figure 17). The station was installed by U of C staff and commissioned in July 2010. Figure 18 shows a seismogram recorded at RAYA

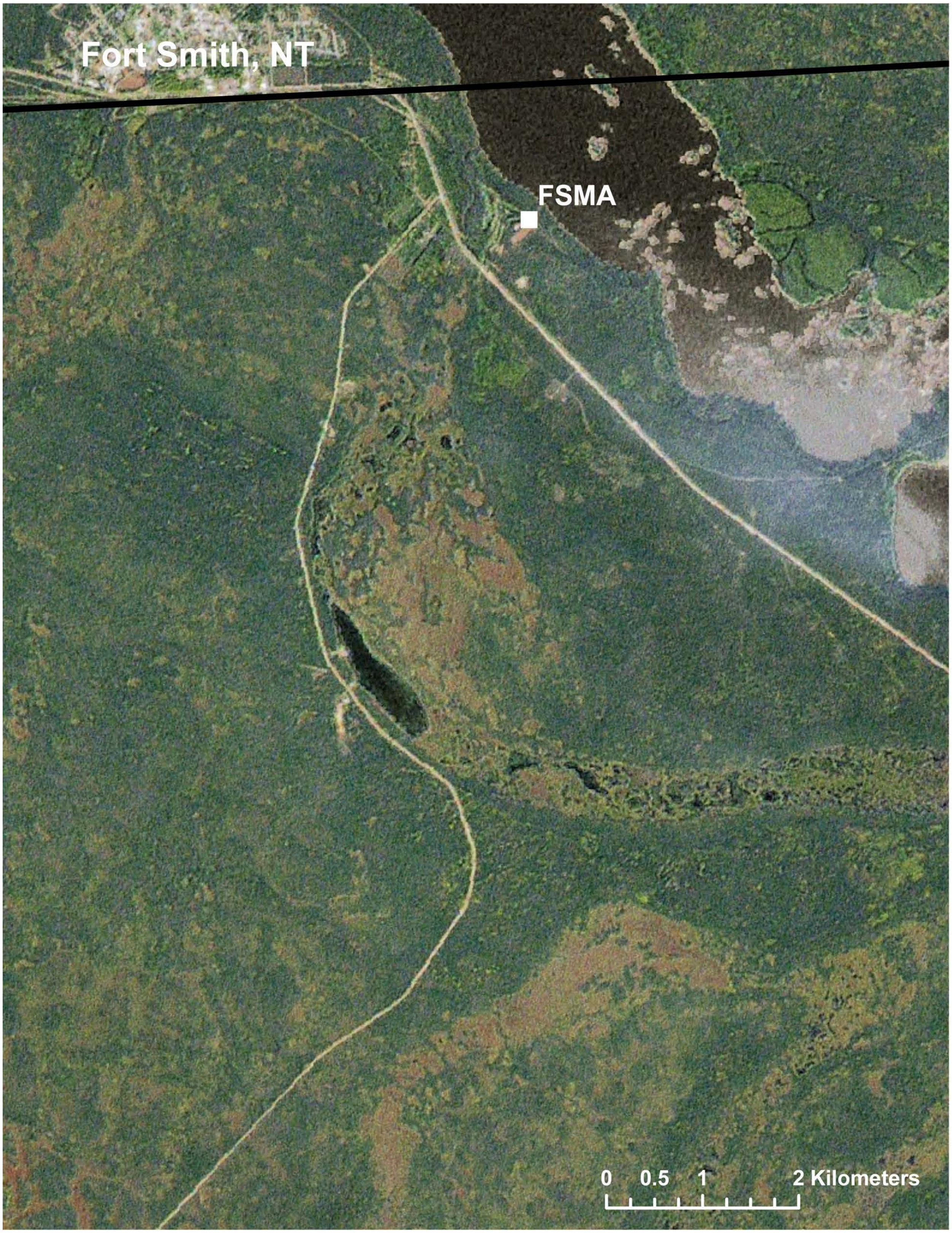

Figure 5. Location of seismic station FSMA (white square), just south of the Alberta–Northwest Territories border and 4 km southwest of Fort Smith, Northwest Territories. Image from Alberta Sustainable Resource Development (2002).

Figure 6. Site of seismic station FSMA, at the Pelican Rapids Golf Club, prior to installation, looking east.

3.3.6 RDEA

The site for seismic station RDEA is on graded public-school grounds within the town of Red Earth Creek, 90 km north-northwest of Slave Lake (Figure 19). The surficial sediments are described as Pleistocene till deposited in fluted moraines consisting of clay, silt, sand and minor pebbles, cobbles and boulders (Paulen et al., 2006). The site is on the west edge of a 200 m square clearing near a fire-access lane (Figure 20). The surrounding area to the north is forested. The site was assessed by AGS staff on June 8, 2010 and the seismic station installed by U of C staff and commissioned on September 21, 2010. Telemetry of data began June 24, 2011. Figure 21 shows a seismogram recorded at RDEA.

3.3.7 WAPA

The site for seismic station WAPA was scouted by AGS staff on June 19, 2009. It is located 30 km west of Grande Prairie and north of the Wapiti River (Figure 22) on private rural property (Figure 23). The surficial deposits are glaciolacustrine silt and clay with few coarse clasts (Liverman, 1989). The station was installed by U of C staff and commissioned on October 15, 2009. Figure 24 shows a seismogram recorded at WAPA.

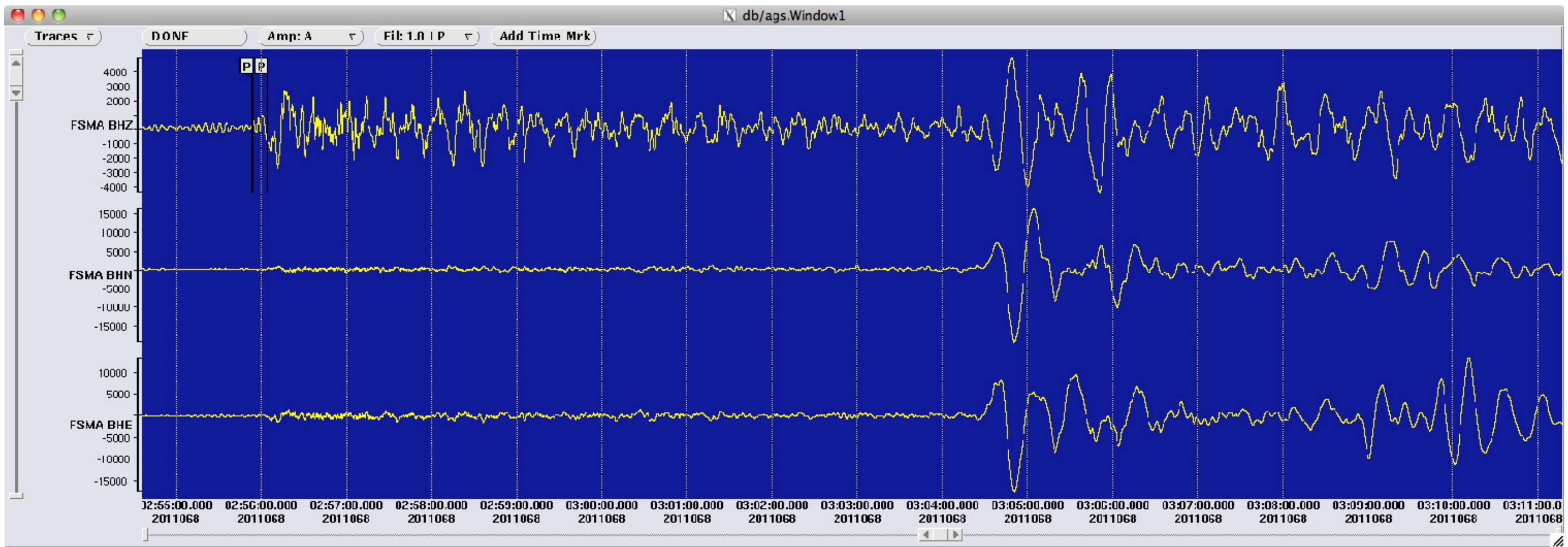

Figure 7. Seismogram from seismic station FSMA, showing the 7.2 Mw event near the east coast of Honshu, Japan on March 9, 2011 at 02:45:18 Co-ordinated Universal Time (UTC).

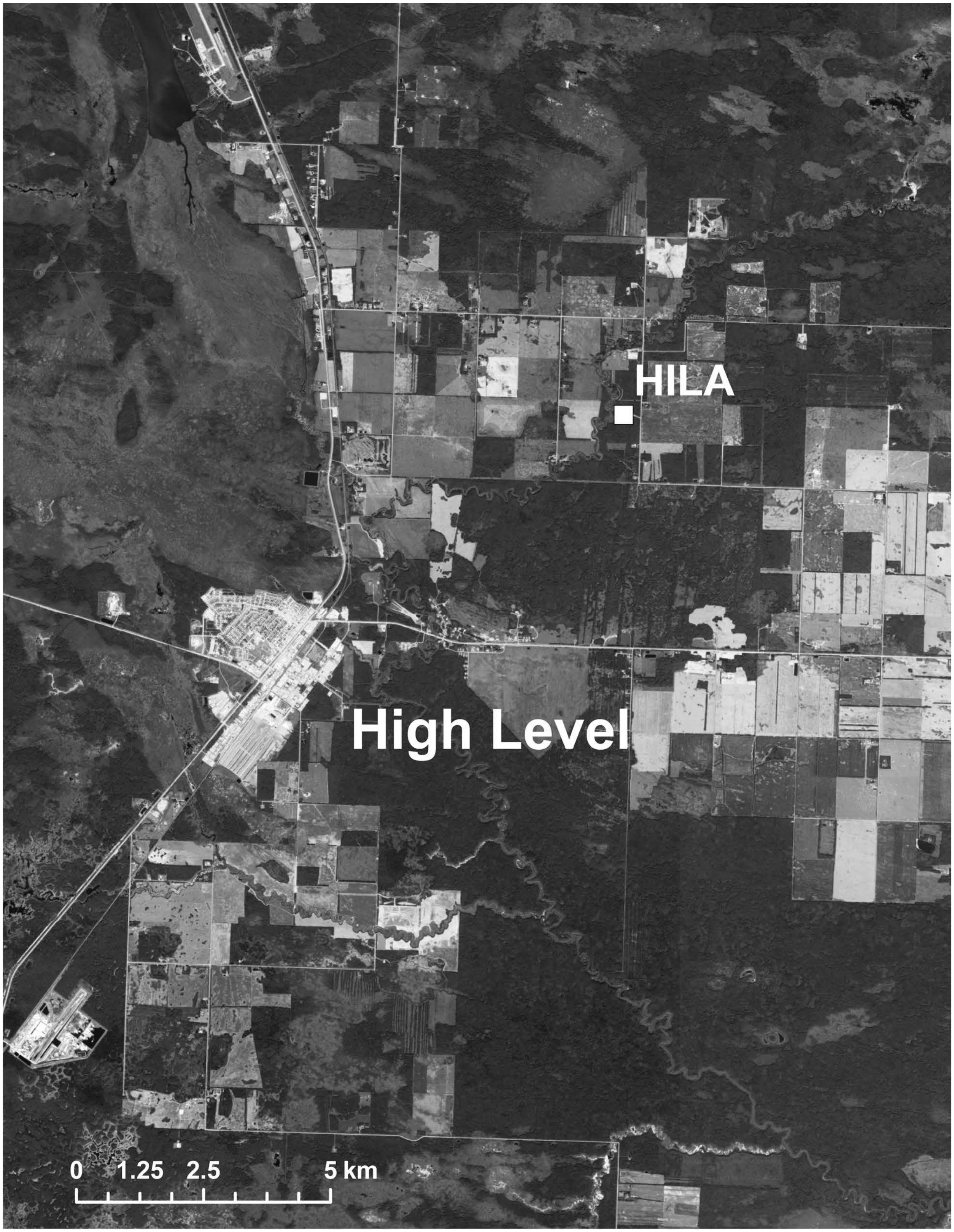

Figure 8. Location of seismic station HILA, 8.5 km northwest of High Level. Image from Iunctus Geomatics Corp. (2008).

Figure 9. Site of seismic station HILA prior to installation, looking west.

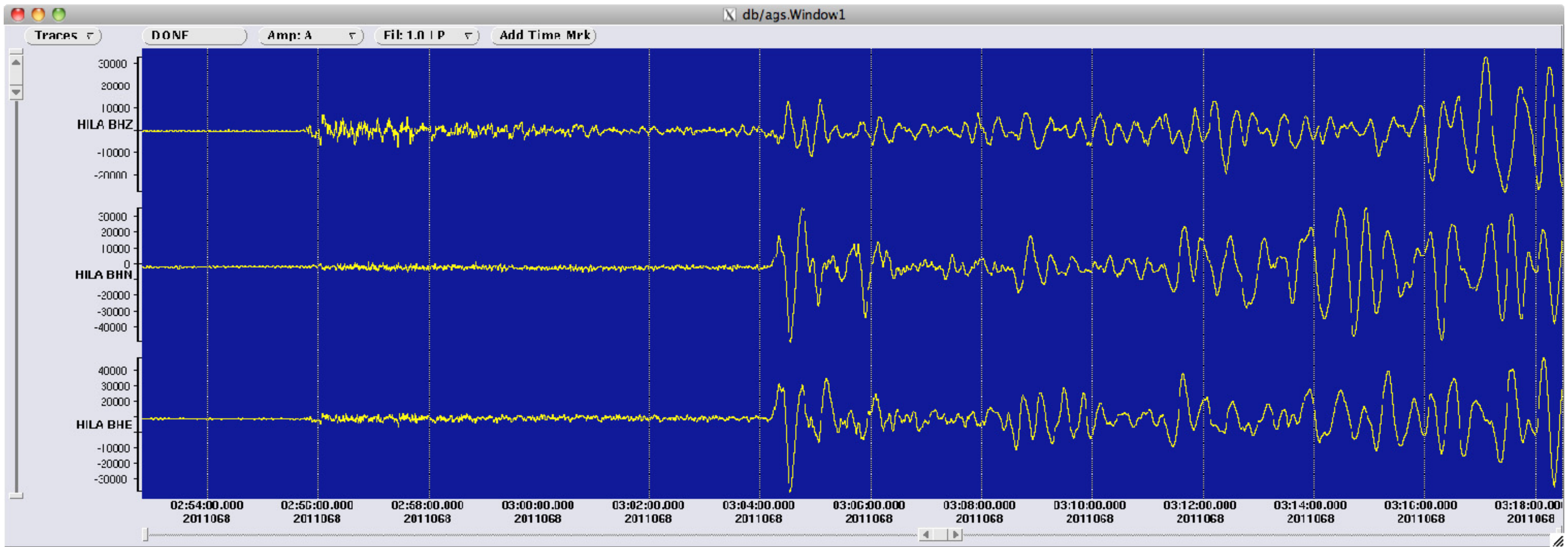

Figure 10. Seismogram from seismic station HILA, showing the 7.2 Mw event near the east coast of Honshu, Japan on March 9, 2011 at 02:45:18 Co-ordinated Universal Time (UTC).

Figure 11. Location of seismic station MANA, 7 km south of Manning. Orthophoto image from Alberta Sustainable Resource Development (2001a).

Figure 12. Site of seismic station MANA prior to installation, looking east.

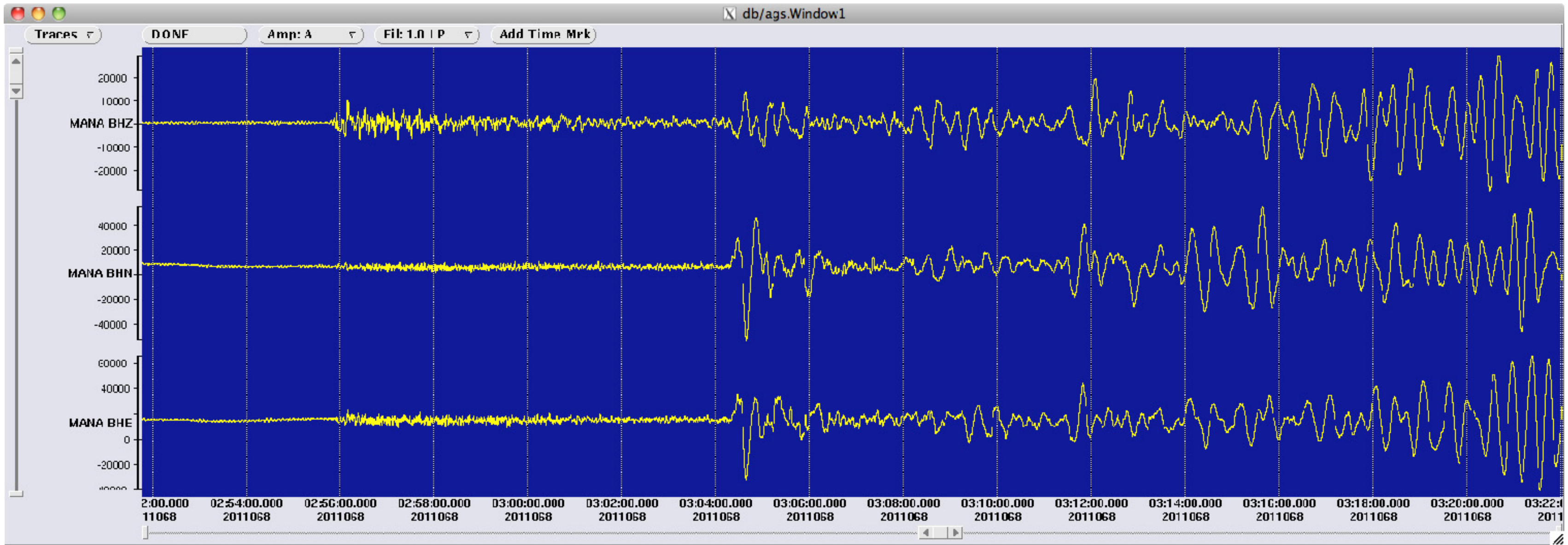

Figure 13. Seismogram from seismic station MANA, showing the 7.2 Mw event near the east coast of Honshu, Japan on March 9, 2011 at 02:45:18 Co-ordinated Universal Time (UTC).

Figure 14. Location of seismic station MEDA, 8 km southwest of Medicine Hat. Orthophoto image from Alberta Sustainable Resource Development (2001b)

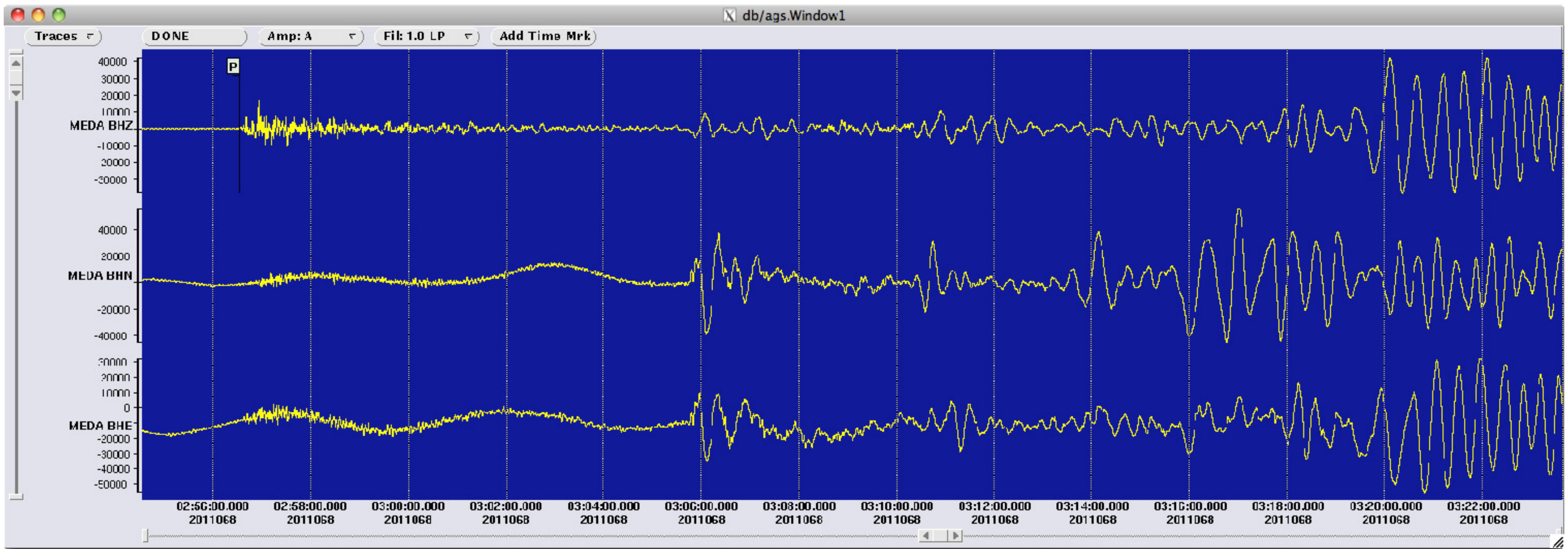

Figure 15. Seismogram from seismic station MEDA, showing the 7.2 Mw event near the east coast of Honshu, Japan on March 9, 2011 at 02:45:18 Co-ordinated Universal Time (UTC). The flag marked ‘P’ is the p-arrival pick from an automated detection and association algorithm.

Figure 16. Location of seismic station RAYA, 9 km south-southwest of Raymond. Orthophoto image from Alberta Sustainable Resource Development (2001b).

Figure 17. Facility at site of seismic station RAYA prior to installation, looking east.

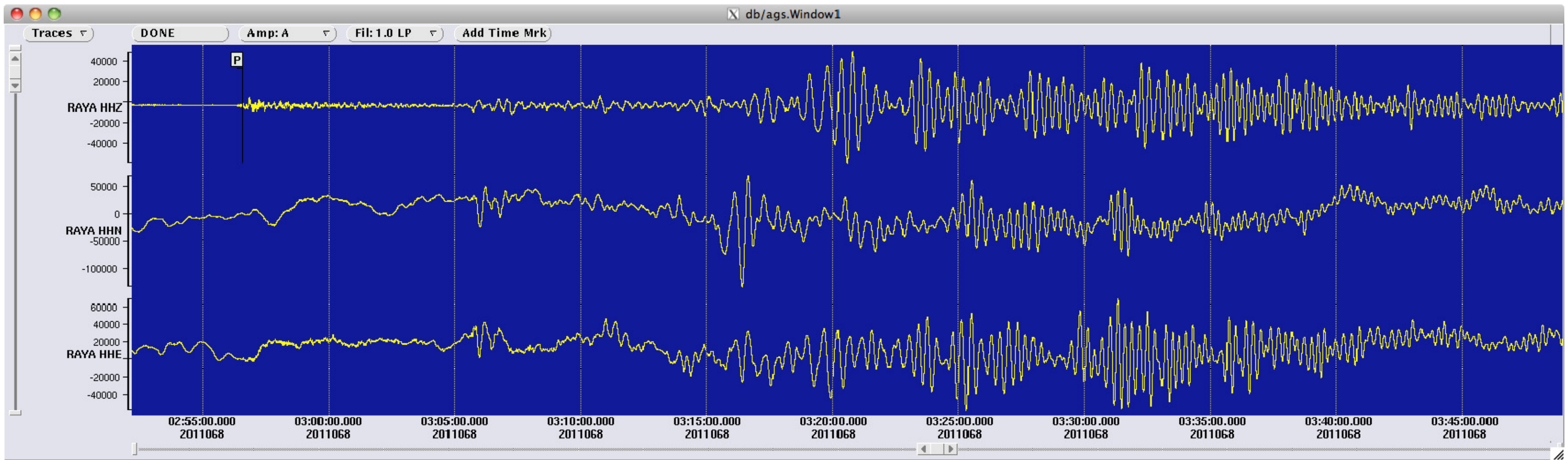

Figure 18. Seismogram from seismic station RAYA, showing the 7.2 Mw event near the east coast of Honshu, Japan on March 9, 2011 at 02:45:18 Co-ordinated Universal Time (UTC). The flag marked 'P' is the p-arrival pick from an automated detection and association algorithm.

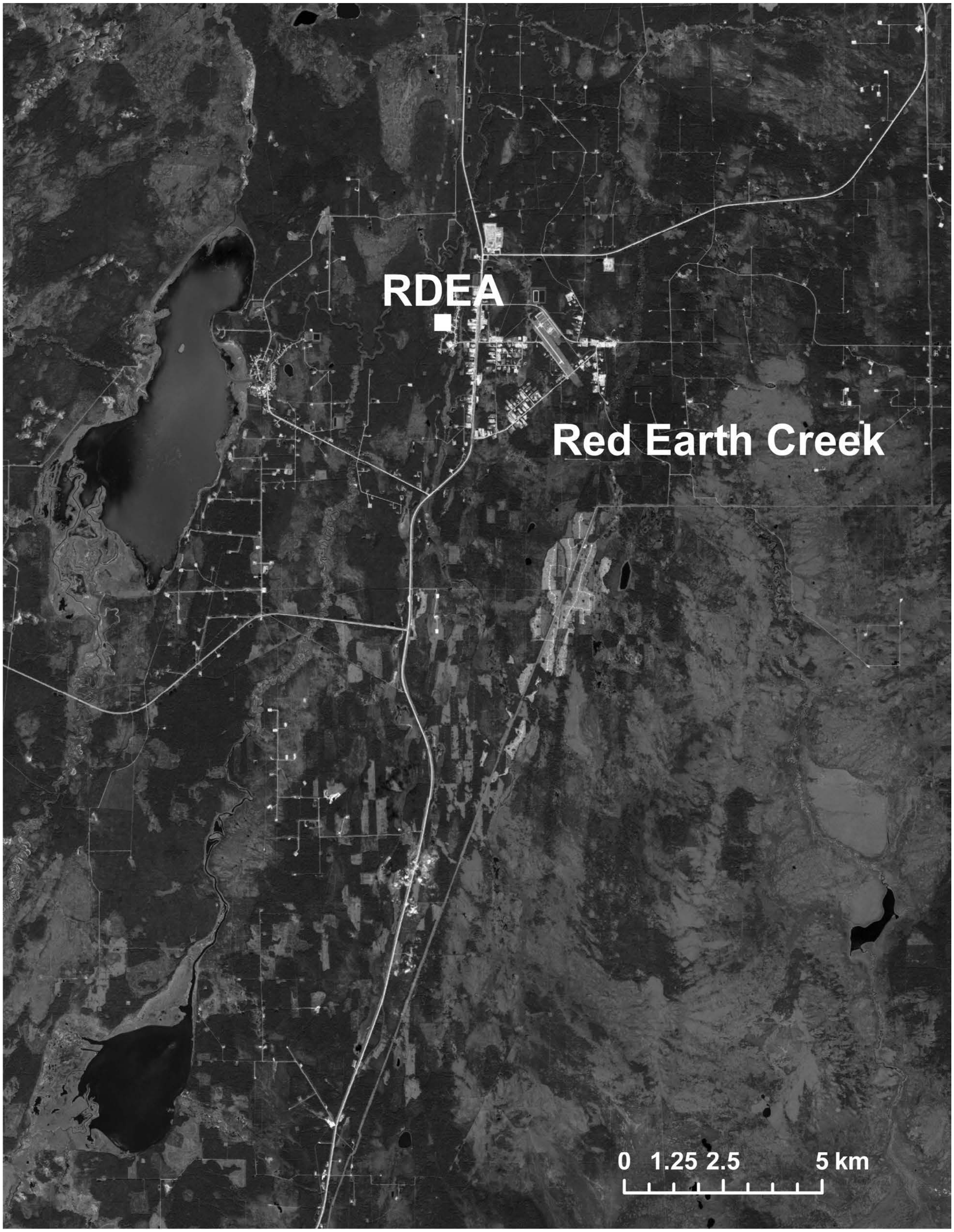

Figure 19. Location of seismic station RDEA, within the town of Red Earth Creek, 90 km north-northwest of Slave Lake. SPOT image from Iunctus Geomatics Corp. (2008).

Figure 20. Site of seismic station RDEA before installation, looking northeast.

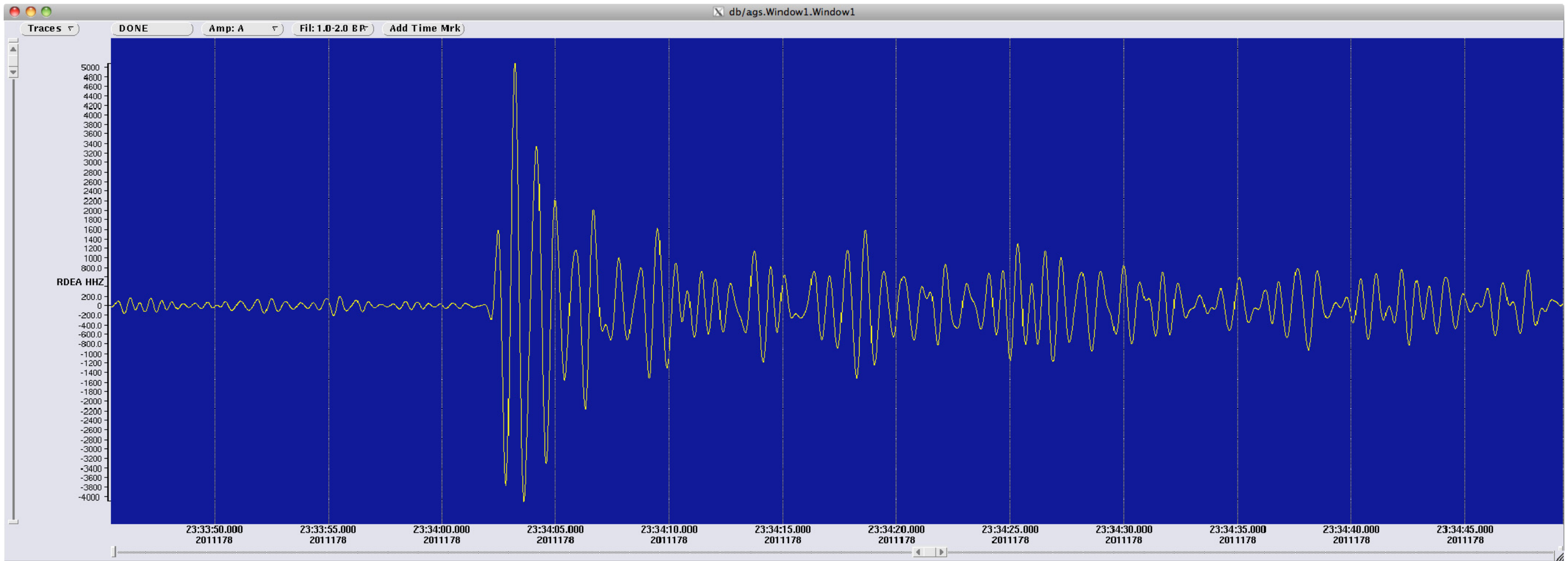

Figure 21. Seismogram from seismic station RDEA, showing a 5.8 event near the Aleutian Islands on June 27, 2011 at 23:27:33 Co-ordinated Universal Time (UTC).

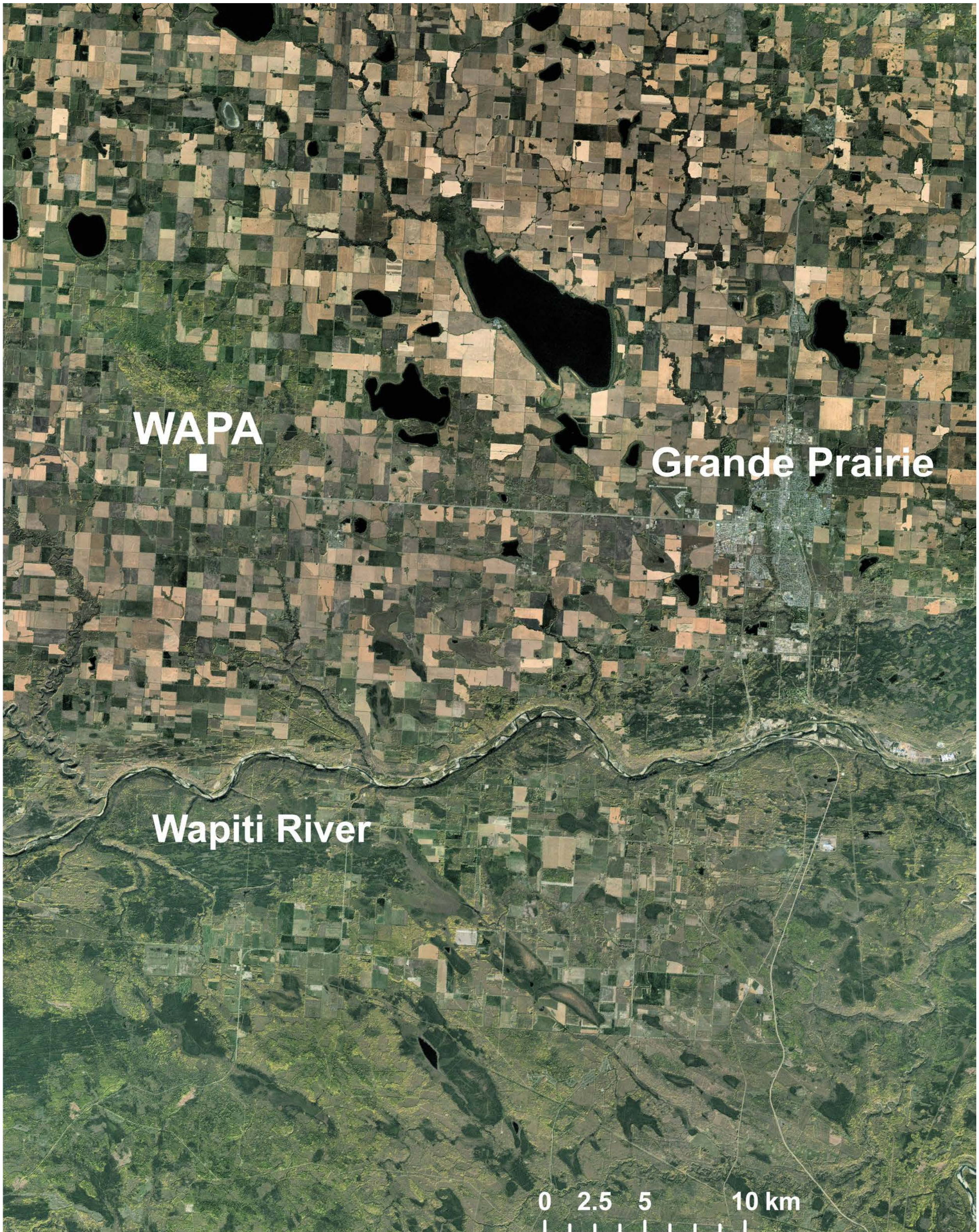

Figure 22. Location of seismic station WAPA, 30 km west of Grande Prairie. Landsat image from Alberta Sustainable Resource Development (2002).


Figure 23. Site of seismic station WAPA before installation, looking north.

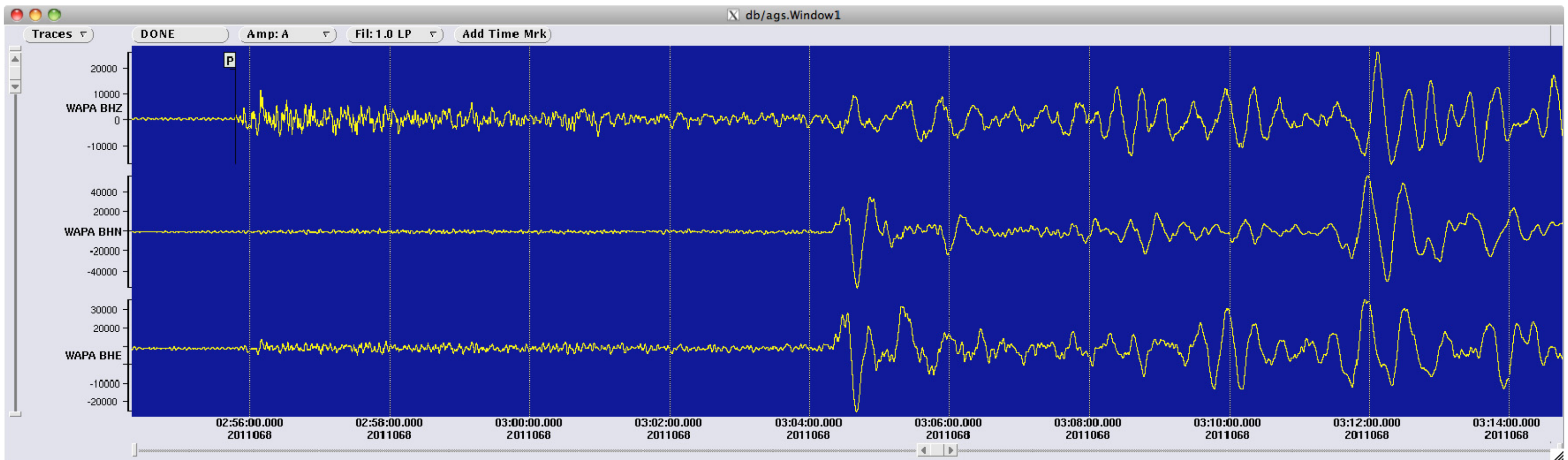

Figure 24. Seismogram from WAPA, showing the 7.2 Mw event near the east coast of Honshu, Japan on March 9, 2011 at 02:45:18 Co-ordinated Universal Time (UTC). The flag marked 'P' is the p-arrival pick from an automated detection and association algorithm.

3.4 Passive Seismic Imaging of Earth Processes (PSIEP) Portable Stations

Between July 12 and 17, 2010, AGS staff assessed 47 sites (Table 2) near the Strachan D3-A gas field; U of A staff joined the field party on July 13. Most of the assessed sites were on leased Crown land, except for six sites that were on four separate, privately owned, rural properties. The criteria for selection were the same as those used for semipermanent installations. The limiting criterion for sites on the leased Crown land was security. Seven sites (SODAR, 90, 103, 125, 126, 128 and 129) of the 41 on leased land were selected, as were three (105, 109 and 121) of the privately owned sites. These 10 sites were presented to a U of C PSIEP group as representing the best sites to install the temporary seismic array.

3.4.1 Sites on Crown Land Leased to the Energy Industry

3.4.1.1 Sonic Detection and Ranging (SODAR)

The SODAR site is on leased Crown land in a clearing with a 15.2 by 24.4 m (50 by 80 ft.) fenced area and a 3.0 by 6.1 m (10 ft. by 20 ft.) shed on a concrete pad (Figure 25). Figure 26 shows a map of the site with the Dominion Land Survey (DLS) location. The site is accessible by gravel road. Security, ground conditions and logistics considerations make this an excellent site. The potential for noise is high, as the site has an active SODAR instrument for detecting atmospheric turbulence. Frequency of noise (between 1000 and 4000 Hz) is in the audible range, with a cyclicity of 10 seconds.

3.4.1.2 Site 90

Site 90, on leased Crown land (Figure 27), is an abandoned well site with fenced enclosure (Figure 28). Security and ground conditions, as well as logistical considerations, make this an excellent choice. The site is accessed via a rarely used gravel road.

3.4.1.3 Site 103

Site 103, on leased Crown land (Figure 29), has a fenced enclosure with a metal shed on a concrete pad (Figure 30). Although rated as excellent based on security and logistics considerations, standing water after several days of rain may indicate a high or perched water table.

3.4.1.4 Site 129

Site 129 is an abandoned well site without a fenced enclosure (Figure 31) on Crown land. Its location is shown in Figure 32. The security rating makes it a poor choice, whereas site conditions and logistics considerations make it a good site. It is situated 600 m from a seldom-used service road, behind trees and hidden from view.

3.4.2 Sites on Forestry Leases

3.4.2.1 Site 125

Site 125, on leased Crown land 100 m from a service road (Figure 33), is characterized by recently clear-cut brush piles on very rough terrain. The clearing is roughly 200 by 200 m (Figure 34); surrounding trees are approximately 80 m high. Although site conditions and logistics make this a good to excellent site, security is nonexistent.

3.4.2.2 Site 126

Site 126 is on leased Crown land (Figure 35) that has been clear cut and replanted (Figure 36). The site is 150 m from a service road and can be seen from the road. Although site conditions and logistics make this a good to excellent site, security is nonexistent.

Table 2. Sites assessed to install Passive Seismic Imaging of Earth Processes (PSIEP) Strachan temporary seismic array.

Site Name	Location (WGS 1984)		Elevation (m asl)	Land Owner	Ranking Values		
	Latitude (°)	Longitude (°)			Security	Site Conditions	Logistics
SODAR	**52.17768**	**-115.29427**	**1358**	**Crown**	**2.0**	**2.0**	**3.0**
84	52.12554	-115.35320	1388	Crown	2.0	3.0	3.0
85	52.10955	-115.31715	1221	Crown	2.0	2.0	3.0
86	52.13420	-115.36578	1446	Crown	1.0	2.0	3.0
87	52.18229	-115.36641	1376	Crown	1.0	2.0	3.0
88	52.17799	-115.25520	1292	Crown	1.0	2.0	3.0
89	52.16675	-115.23869	1303	Crown	0.0	0.5	1.0
90	**52.17138**	**-115.25846**	**1259**	**Crown**	**3.0**	**2.5**	**2.0**
91	52.16969	-115.27311	1284	Crown	0.0	0.0	0.0
92	52.19625	-115.32092	1337	Crown	0.5	2.5	2.0
93	52.19033	-115.35030	1393	Crown	0.5	2.0	0.5
94	52.21257	-115.31818	1324	Crown	0.0	0.5	1.0
95	52.22598	-115.31985	1296	Crown	0.5	1.5	1.5
96	52.21062	-115.29331	1398	Crown	2.0	2.5	2.5
97	52.24083	-115.25401	1256	Crown	1.0	1.0	1.5
98	52.23585	-115.24843	1290	Crown	1.0	2.0	2.0
99	52.21267	-115.27058	1307	Crown	0.0	1.0	1.0
100	52.21238	-115.24634	1274	Crown	0.5	1.5	1.5
101	52.21045	-115.23165	1219	Crown	3.0	1.0	3.0
102	52.21105	-115.22277	1219	Crown	3.0	1.0	3.0
103	**52.19792**	**-115.22299**	**1225**	**Crown**	**3.0**	**3.0**	**3.0**
104	52.20919	-115.18575	1169	Crown	3.0	1.0	3.0
105	**52.27312**	**-115.17778**	**1106**	**Private**	**3.0**	**3.0**	**3.0**
107	52.27693	-115.19763	1106	Private	3.0	3.0	2.5
108	52.26449	-115.25903	1171	Crown	0.0	1.0	1.0
109	**52.25831**	**-115.26929**	**1143**	**Private**	**3.0**	**2.0**	**3.0**
110	52.23557	-115.30219	1228	Crown	3.0	1.0	3.0
111	52.13132	-115.26630	1154	Crown	0.0	2.0	1.0
112	52.13197	-115.23340	1294	Crown	0.0	1.0	2.0
113	52.12284	-115.23299	1248	Crown	1.0	2.0	2.0
114	52.12537	-115.23460	1260	Crown	0.0	2.0	2.0
115	52.12362	-115.20259	1270	Crown	0.0	1.0	2.0
116	52.12703	-115.20739	1257	Crown	1.0	1.0	2.0
117	52.13344	-115.21173	1316	Crown	1.0	1.0	2.0
118	52.13890	-115.16154	1282	Crown	0.0	1.0	1.0
119	52.12769	-115.17168	1269	Crown	0.0	2.0	2.0
120	52.21511	-115.19299	1298	Private	3.0	2.0	3.0
121	**52.21965**	**-115.20093**	**1192**	**Private**	**3.0**	**2.0**	**3.0**
122	52.21691	-115.19969	1162	Private	3.0	2.0	3.0
123	52.21532	-115.32544	1337	Crown	0.0	3.0	0.5
124	52.21598	-115.30544	1333	Crown	0.0	3.0	0.5
125	**52.21600**	**-115.30144**	**1322**	**Crown**	**0.0**	**3.0**	**2.0**
126	**52.23672**	**-115.26257**	**1300**	**Crown**	**0.0**	**2.5**	**2.0**
127	52.15377	-115.17296	1287	Crown	0.0	0.0	0.0
128	**52.14629**	**-115.19336**	**1297**	**Crown**	**0.0**	**2.0**	**2.0**
129	**52.16378**	**-115.29896**	**1333**	**Crown**	**0.5**	**2.0**	**1.5**
130	52.15960	-115.31264	1371	Crown	0.5	2.0	2.0

Security, site conditions, and logistics are rated on a scale from 0 (unacceptable) to 3 (excellent); sites in bold are those judged to be the ten best sites, based on these criteria.

Figure 25. SODAR fenced enclosure, looking north-northeast.

3.4.2.3 Site 128

Site 128 is on leased Crown land (Figure 37) that has been clear cut (Figure 38), 200 metres from a service road. Site conditions and logistics make this a good site, but security is nonexistent.

3.4.3 Sites on Private Land

3.4.3.1 Site 105

Site 105, on privately owned land (Figure 39), is approximately 250 m from a paved road and 150 m from a slow-moving creek. Security, ground conditions and logistics considerations make this an excellent site (Figure 40), but disturbance by domestic animals is a possibility.

3.4.3.2 Site 109

Site 109, on privately owned land (Figure 41), is located 50 m south of Prairie Creek. Security, ground conditions (Figure 42) and logistics considerations make this an excellent site.

3.4.3.3 Site 121

Site 121 is on privately owned land (Figure 43). Security, ground conditions (Figure 44) and logistics considerations make this an excellent site. Access requires the use of an all-terrain vehicle.

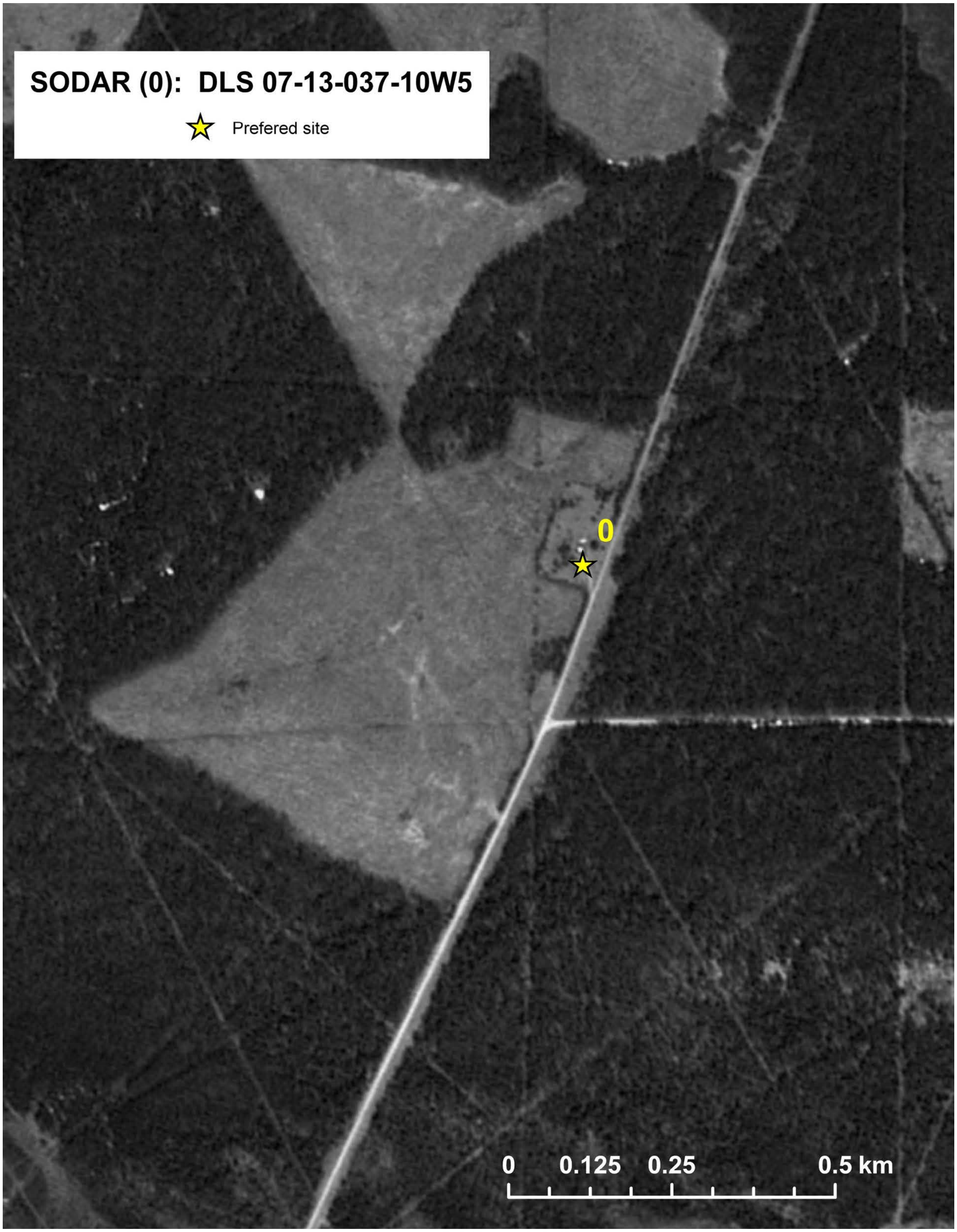

Figure 26. Location of preferred site SODAR (yellow star). Location is given in the Dominion Land Survey (DLS) system. The first number (07) is the legal subdivision (LSD); the second number (13) is the section; the third number (037) is the township, and the last sequence represents the range (10) and meridian (5). SPOT image from Iunctus Geomatics Corp. (2008).

Figure 27. Location of site 90 (yellow star), in the Dominion Land Survey (DLS) system. The first number (13) is the legal subdivision (LSD); the second number (08) is the section; the third number (037) is the township; and the last sequence represents the range (09) and meridian (5). Other assessed sites (88, 89 and 91) are shown as red circles. SPOT image from Iunctus Geomatics Corp. (2008).

Figure 28. Site 90, looking south-southeast.

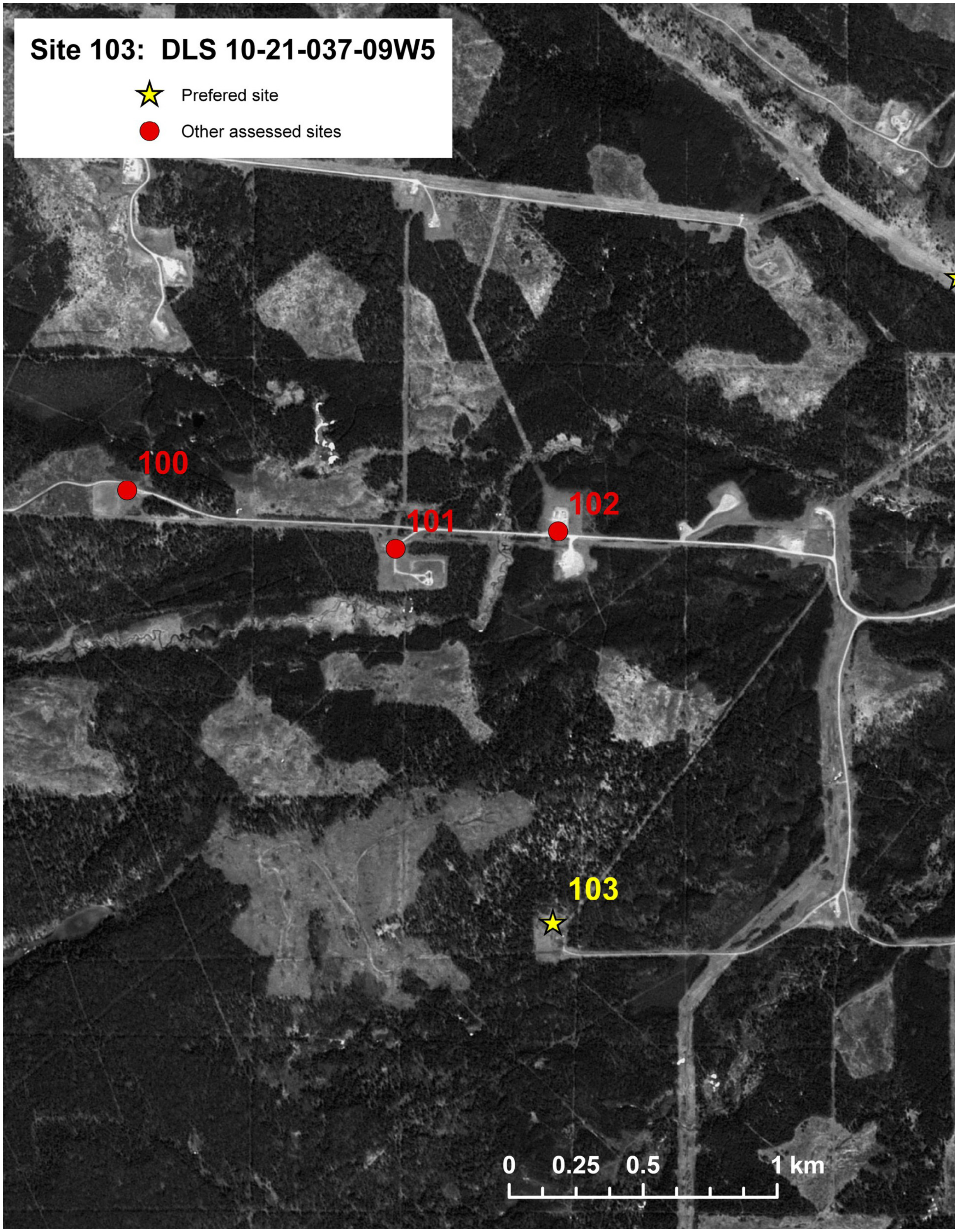

Figure 29. Location of site 103 (yellow star), in the Dominion Land Survey (DLS) system. The first number (10) is the legal subdivision (LSD); the second number (21) is the section; the third number (037) is the township; and the last sequence represents the range (09) and meridian (5). Other assessed sites (100, 101, 102 and 122) are shown as red circles. SPOT image from Iunctus Geomatics Corp. (2008).

Figure 30. Site 103, looking north.

Figure 31. Site 129, looking west.

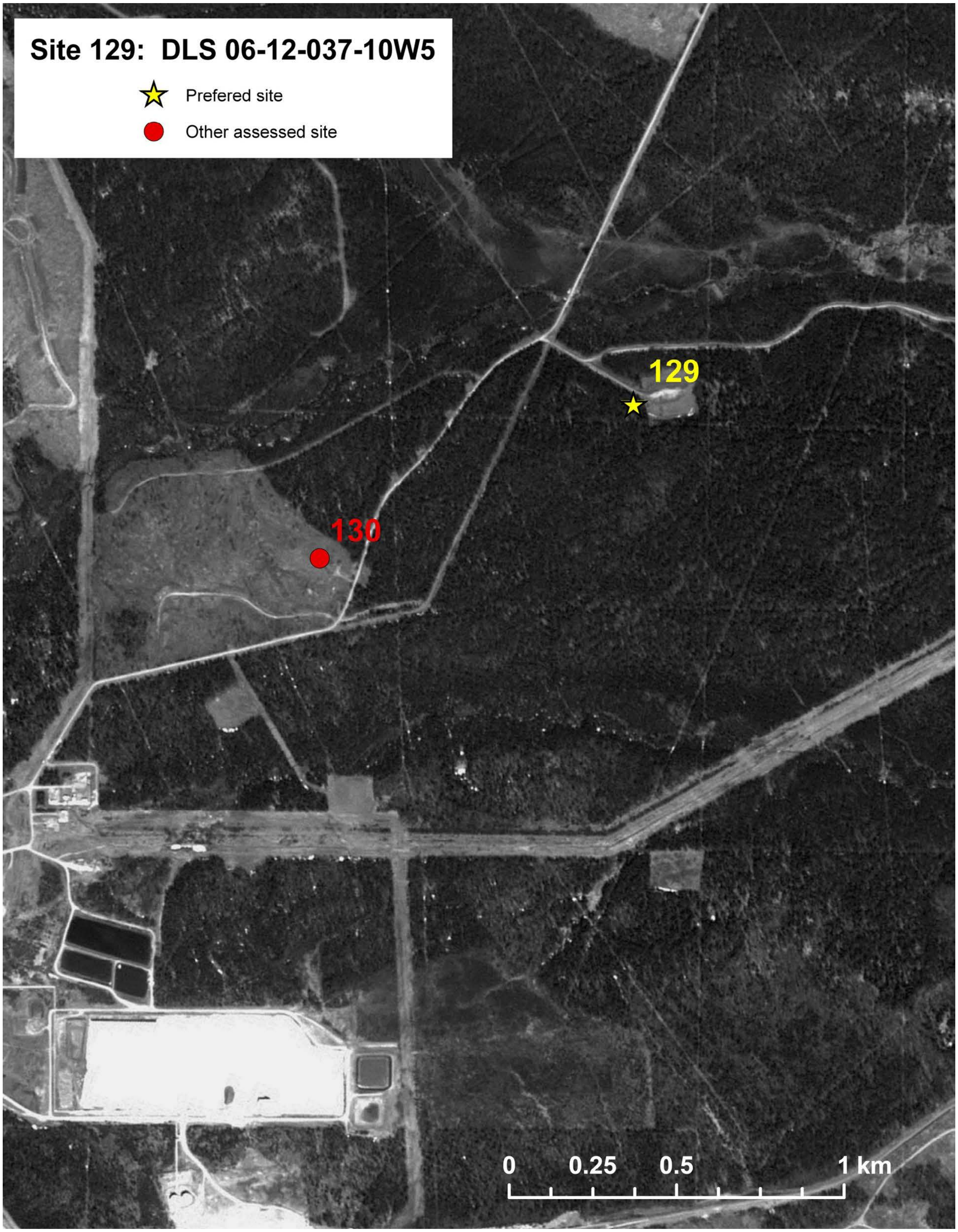

Figure 32. Location of site 129 (yellow star), in the Dominion Land Survey (DLS) system. The first number (06) is the legal subdivision (LSD); the second number (12) is the section; the third number (037) is the township; and the last sequence represents the range (10) and meridian (5). Another assessed site (130) is shown as a red circle. SPOT image from Iunctus Geomatics Corp. (2008).

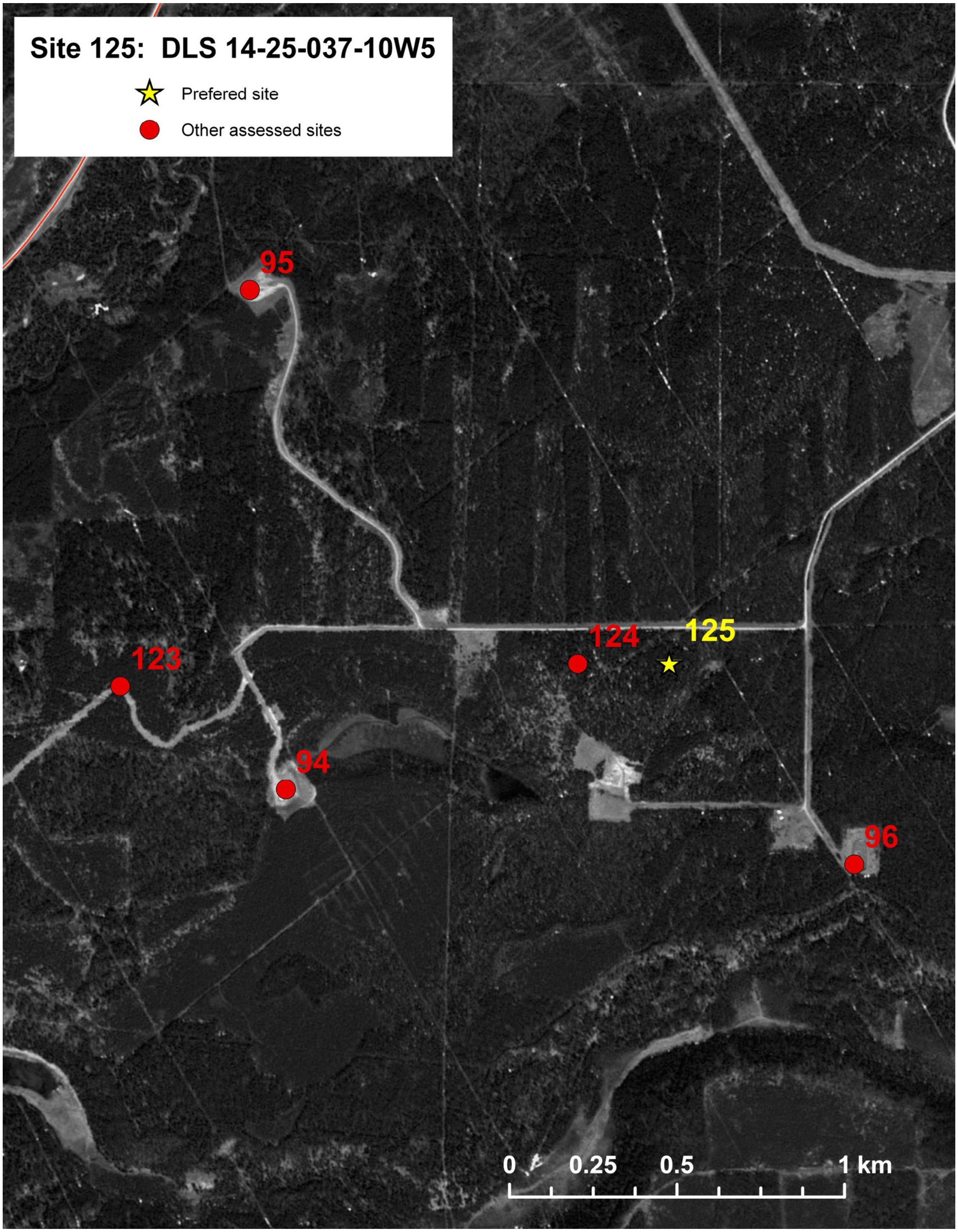

Figure 33. Location of site 125 (yellow star), in the Dominion Land Survey (DLS) system. The first number (14) is the legal subdivision (LSD); the second number (25) is the section; the third number (037) is the township; and the last sequence represents the range (10) and meridian (5). Other assessed sites (94, 95, 96, 123 and 124) are shown as red circles. SPOT image from Iunctus Geomatics Corp. (2008).

Figure 34. Site 125, looking south.

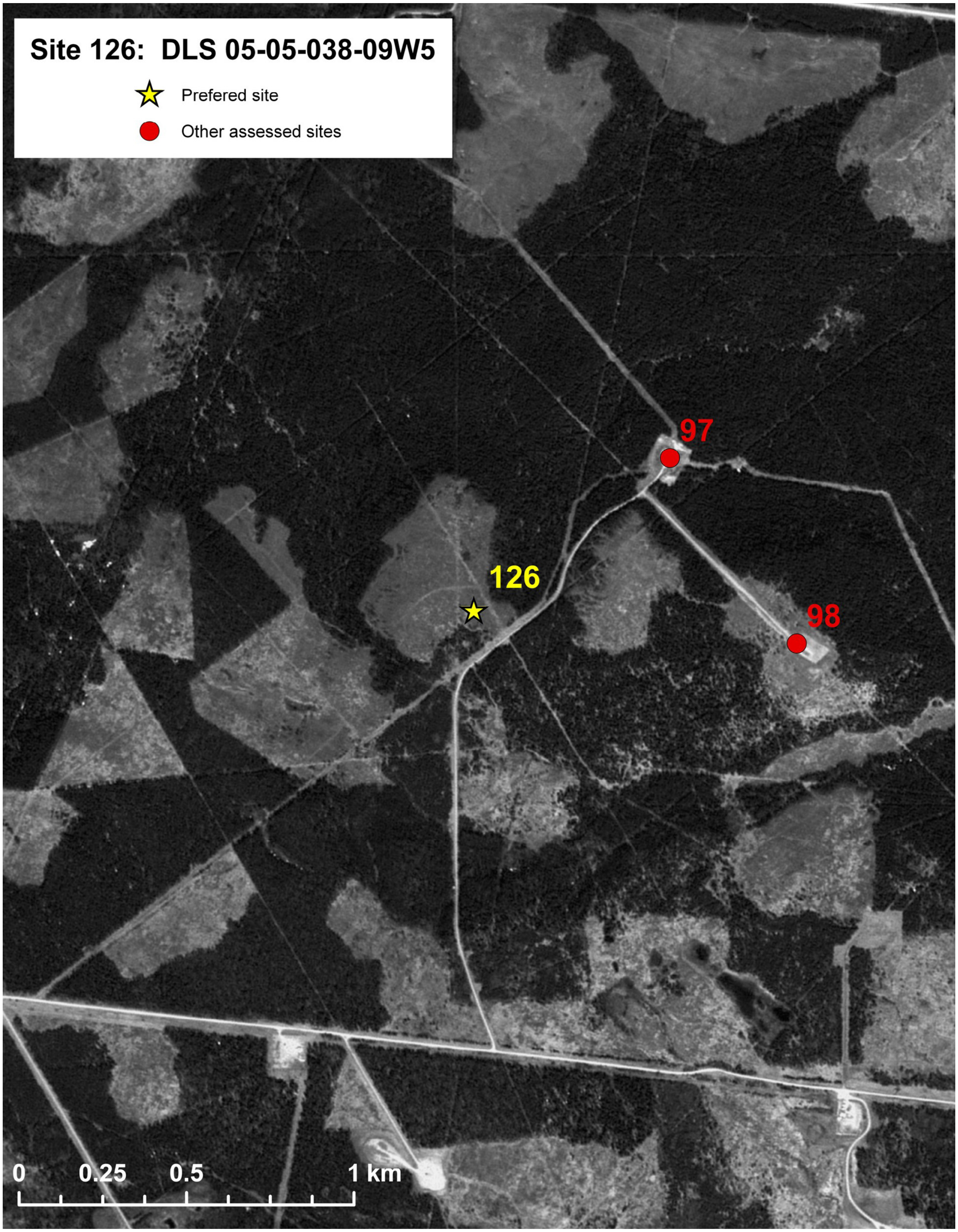

Figure 35. Location of site 126 (yellow star), in the Dominion Land Survey (DLS) system. The first number (05) is the legal subdivision (LSD); the second number (05) is the section; the third number (038) is the township; and the last sequence represents the range (09) and meridian (5). Other assessed sites (97 and 98) are shown as red circles. SPOT image from Iunctus Geomatics Corp. (2008).

Figure 36. Site 126, looking southeast.

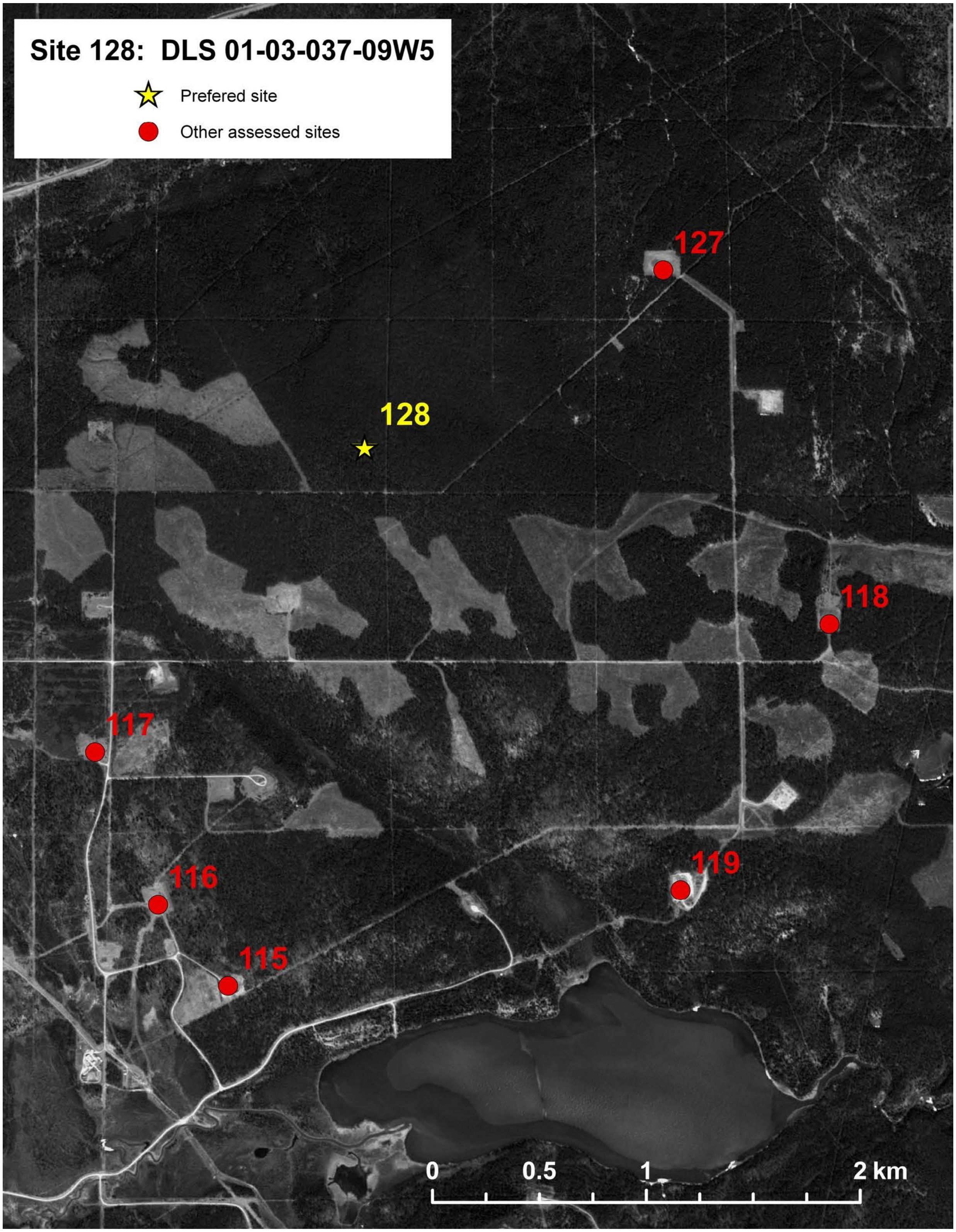

Figure 37. Location of site 128 (yellow star), in the Dominion Land Survey (DLS) system. The first number (01) is the legal subdivision (LSD); the second number (03) is the section; the third number (037) is the township; and the last sequence represents the range (09) and meridian (5). Other assessed sites (115, 116, 117, 118, 119 and 127) are shown as red circles. SPOT image from Iunctus Geomatics Corp. (2008).

Figure 38. Site 128, looking north.

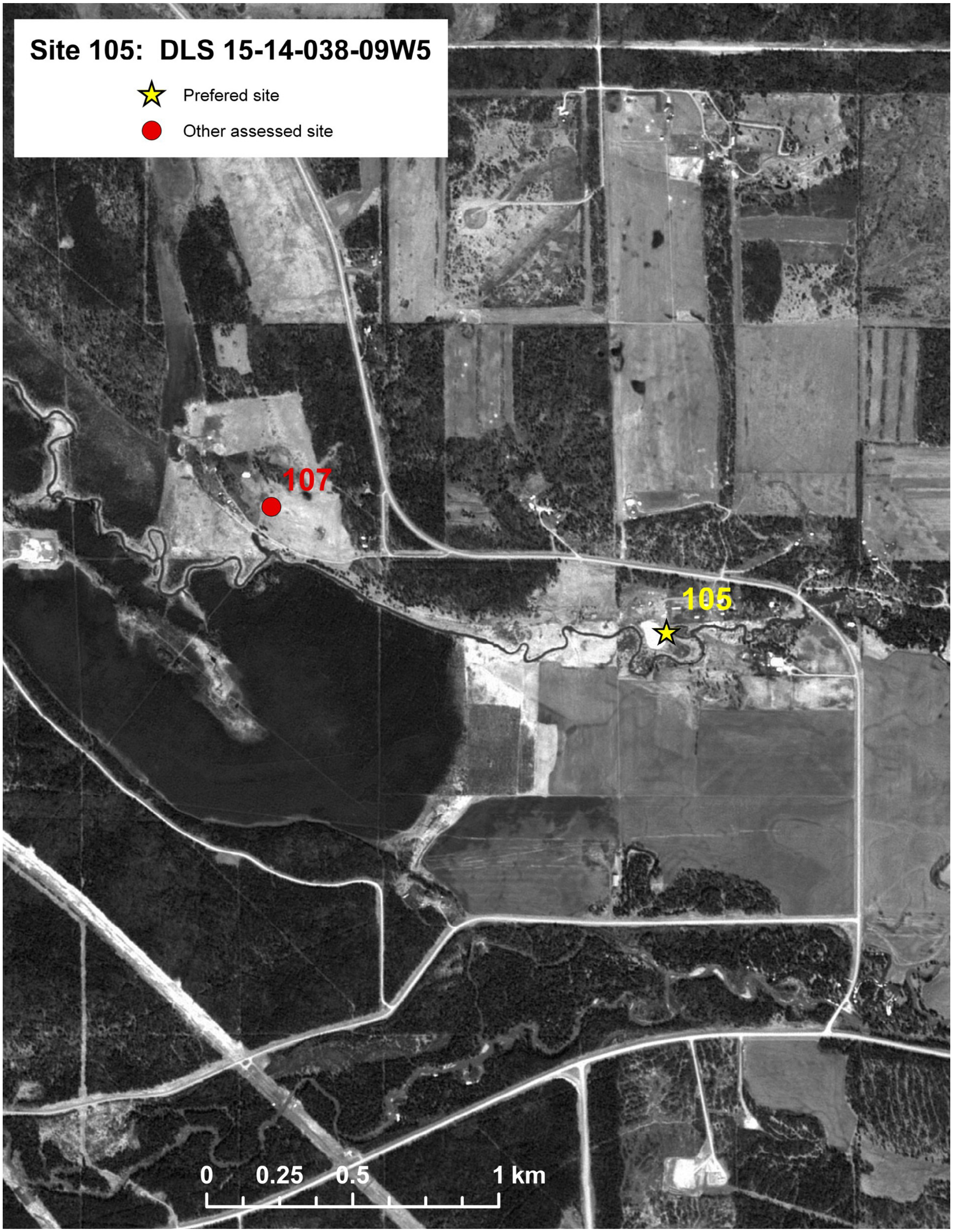

Figure 39. Location of site 105 (yellow star), in the Dominion Land Survey (DLS) system. The first number (15) is the legal subdivision (LSD); the second number (14) is the section; the third number (038) is the township; and the last sequence represents the range (09) and meridian (5). Another assessed site (107) is shown as a red circle. SPOT image from Iunctus Geomatics Corp. (2008)

Figure 40. Site 105, looking west-northwest.

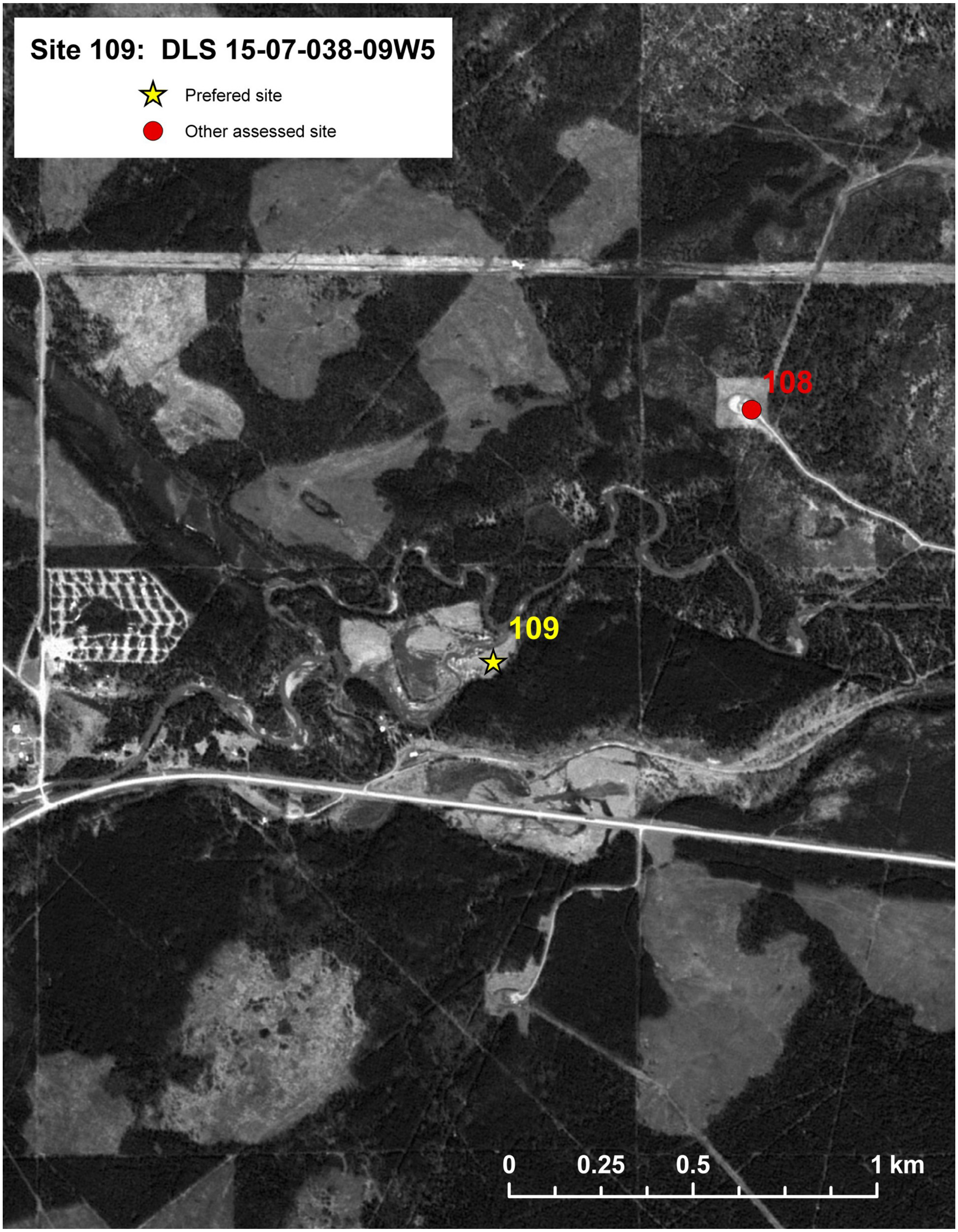

Figure 41. Location of site 109 (yellow star), in the Dominion Land Survey (DLS) system. The first number (15) is the legal subdivision (LSD); the second number (07) is the section; the third number (038) is the township; and the last sequence represents the range (09) and meridian (5). Another assessed site (108) is shown as a red circle. SPOT image from Iunctus Geomatics Corp. (2008).

Figure 42. Site 105, looking southwest.

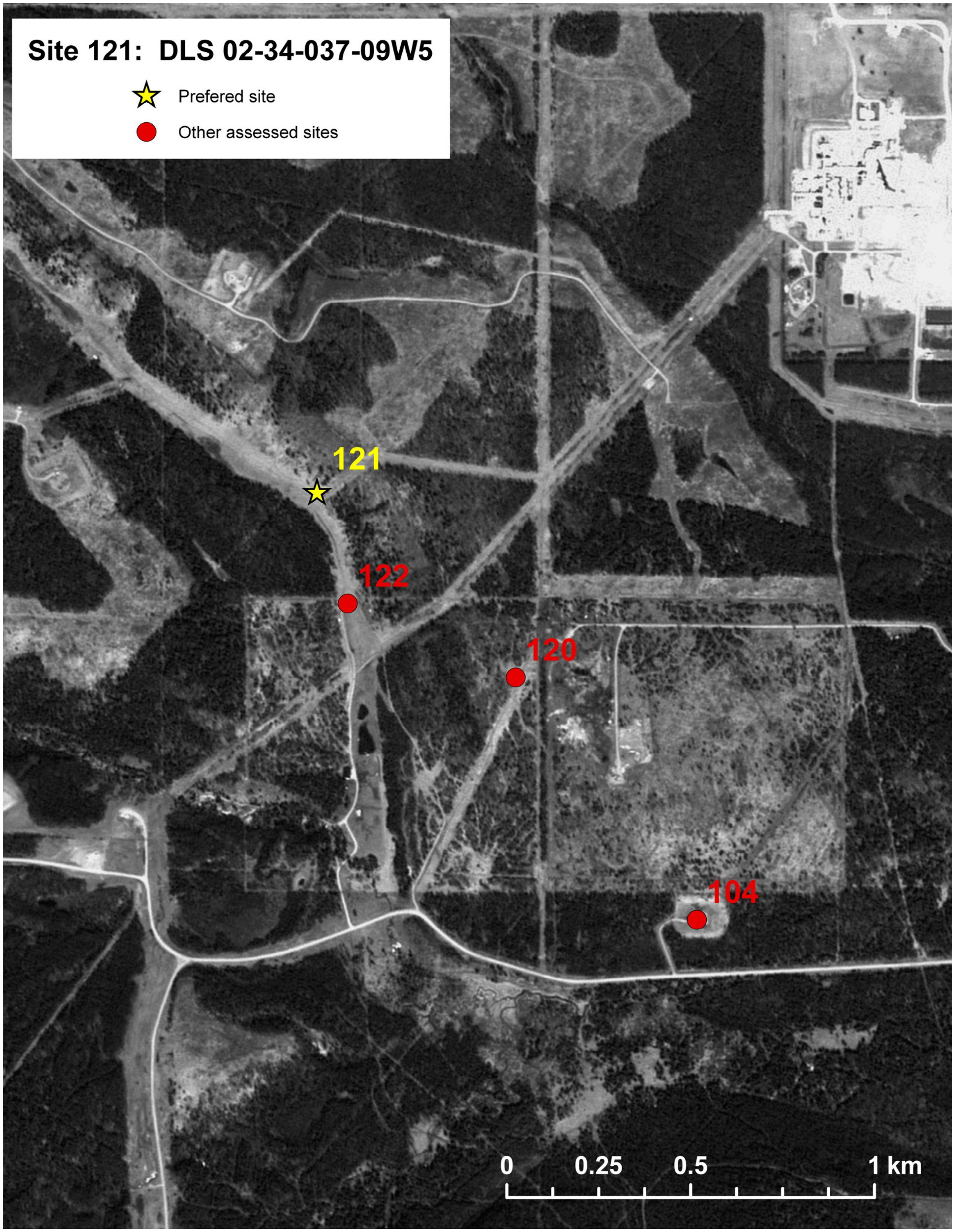

Figure 43. Location of site 121 (yellow star), in the Dominion Land Survey (DLS) system. The first number (02) is the legal subdivision (LSD); the second number (34) is the section; the third number (037) is the township; and the last sequence represents the range (09) and meridian (5). Other assessed sites (104, 120, 122) are shown as red circles. SPOT image from Iunctus Geomatics Corp. (2008).

Figure 44. Site 121, looking north.

4 Site and Equipment Maintenance

4.1 Canadian Rockies and Alberta Network (CRANE) Stations

The Canadian Rockies and Alberta Network (CRANE) stations (see Figure 4 for locations) store continuous seismic data on CompactFlash® cards that need to be exchanged twice yearly. During the exchange visits, the equipment is checked and replaced as necessary. AGS staff participated in the spring maintenance visits to four stations: Hondo (HON), Hylo (HLO/HYO), Peers (PER) and Brûlé Mines (BRU).

4.1.1 Hondo (HON)

Seismic station HON is near Hondo, 50 km southeast of Lesser Slave Lake. The site is on private property in a stand of saplings facing south towards a fenced clearing containing commercial bison and elk (see Figure 4). The station was installed by U of A staff on October 14, 2006; the instruments are buried approximately l m deep in unconsolidated surficial sediments comprising Holocene, eolian, medium- to fine-grained sand and minor silt (Pawley, 2010). The weather during the site visit was sunny with clear skies. The operating conditions of this station were within normal values and the battery was operating normally. The Trillium 240 seismometer was recentred using automatic centring. The CompactFlash card was exchanged and the vault was sealed and covered.

4.1.2 Hylo (HLO/HYO)

Seismic station HLO (also known as HYO) is in a vacant field on privately owned rural land, 25 km from Hylo (see Figure 4). The station was installed by U of A staff on May 5, 2009. The surficial sediment is a 2–30 m thick deposit of Late Wisconsin till described as containing minor sand, gravel, and silt; unsorted pebbles, cobbles and boulders in a matrix of clay, sand and silt (Richards, 1986). The weather during the site visit was sunny with clear skies. This station required extensive maintenance. Condensation was observed on the walls when the vault was opened, so AGS staff removed the insulation and dried the interior of the vault. The battery had a low charge and was therefore replaced. The Trillium 120P seismometer required manual recentring and the CompactFlash card was exchanged. The insulation was reinstalled and the vault sealed.

4.1.3 Peers (PER)

Seismic station PER is 3 km southeast of Peers. The station was installed by U of A staff on September 28, 2006 in a clearing near the top of high ground (Figure 45). The site is on privately owned rural property (see Figure 4). The surficial sediments are Quaternary eolian deposits of fine-grained sand, commonly as inactive dunes (Roed, 1970). The weather during the site visit was overcast with light rain. The sandy soil and buried vaults (see Appendix 1 for configuration) were inundated with ants, although the operating conditions of this station were found to be within normal limits. The CompactFlash card was exchanged and the vault sealed.

Figure 45. University of Alberta graduate students L. Shen and R. Schultz inspecting equipment at the PER station.

4.1.4 Brûlé Mines (BRU)

Seismic station BRU is 4 km southeast of Brûlé Mines (see Figure 4). The surficial deposits comprise Pleistocene glaciofluvial sand and gravel outwash (Roed, 1970). This station was installed by U of A staff on October 2, 2006 and removed June 11–13, 2010 for redeployment.

5 Summary

Seven sites were successfully located and assessed for the installation of U of C's semipermanent ATSN seismic stations. Five sites were located in northern and northwestern Alberta and two sites in southern Alberta. Ten of forty-seven sites that were assessed in southwestern Alberta, during the summer of 2010 near the Strachan oil and gas field, were determined to be suitable for the installation of U of C's PSEIP temporary seismic array. Four of the U of A's CRANE stations were visited during the spring of 2010, three for their twice yearly maintenance and one for decommissioning. The fieldwork documented in this report represents the first phase of the Alberta Microseismicity Project initiated by ERCB/AGS to enable research on seismicity within Alberta through partnerships with Alberta universities.

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Appendix 1 – Station Configuration

Alberta Telemetered Seismograph Network (ATSN) Stations

The ATSN stations, with the exception of Priddis (PRDA), house three-component broadband seismometers in bottomless metal cylindrical vaults with plastic, insulative, inner vaults (Figure 46). Cement floors and piers were manufactured on site to provide a stable contact between the seismometers and the sediment. The elevated piers are designed to protect the seismometers from flooding. The digitizers (dataloggers), virtual private networks (VPN) and GPS antennas are housed above ground in insulated metal electrical boxes along with a backup battery, heating element and electrical connections. The site selection process included such considerations as the ease with which connection could be made to an AC power source and wireless Internet for telemetry of seismic data.

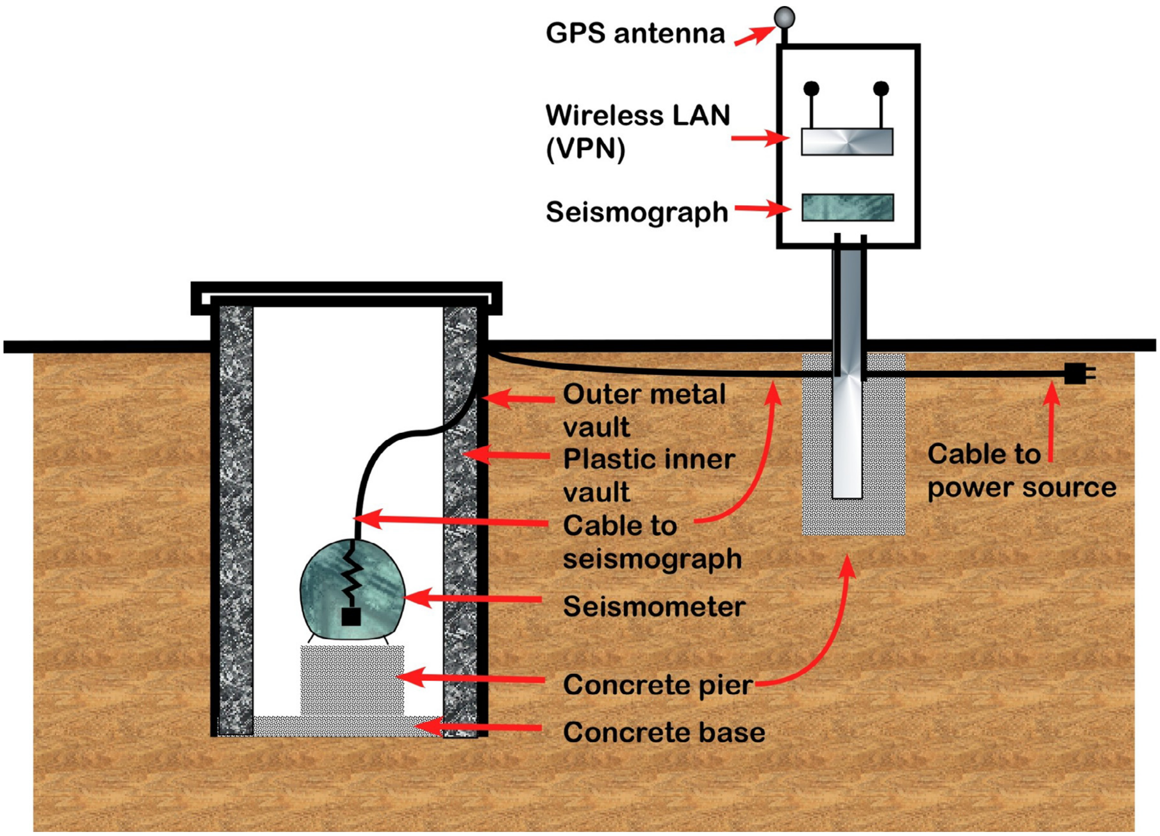


Figure 46. Schematic cross-section of an Alberta Telemetered Seismograph Network (ATSN) station installation. Abbreviations: LAN, local area network; VPN, virtual private network.

Canadian Rockies and Alberta Network (CRANE) Stations

The installation design of the Canadian Rockies and Alberta Network (CRANE) stations differed from the ATSN stations in that the power source is solar panels and the seismic data are stored on CompactFlash cards in the digitizer (datalogger) rather than being telemetered. The seismometers are housed in an insulated plastic cylindrical vault. The datalogger and rechargeable battery are housed in a separate but identical vault (Figure 47). Solar panels are mounted on wooden posts facing south.

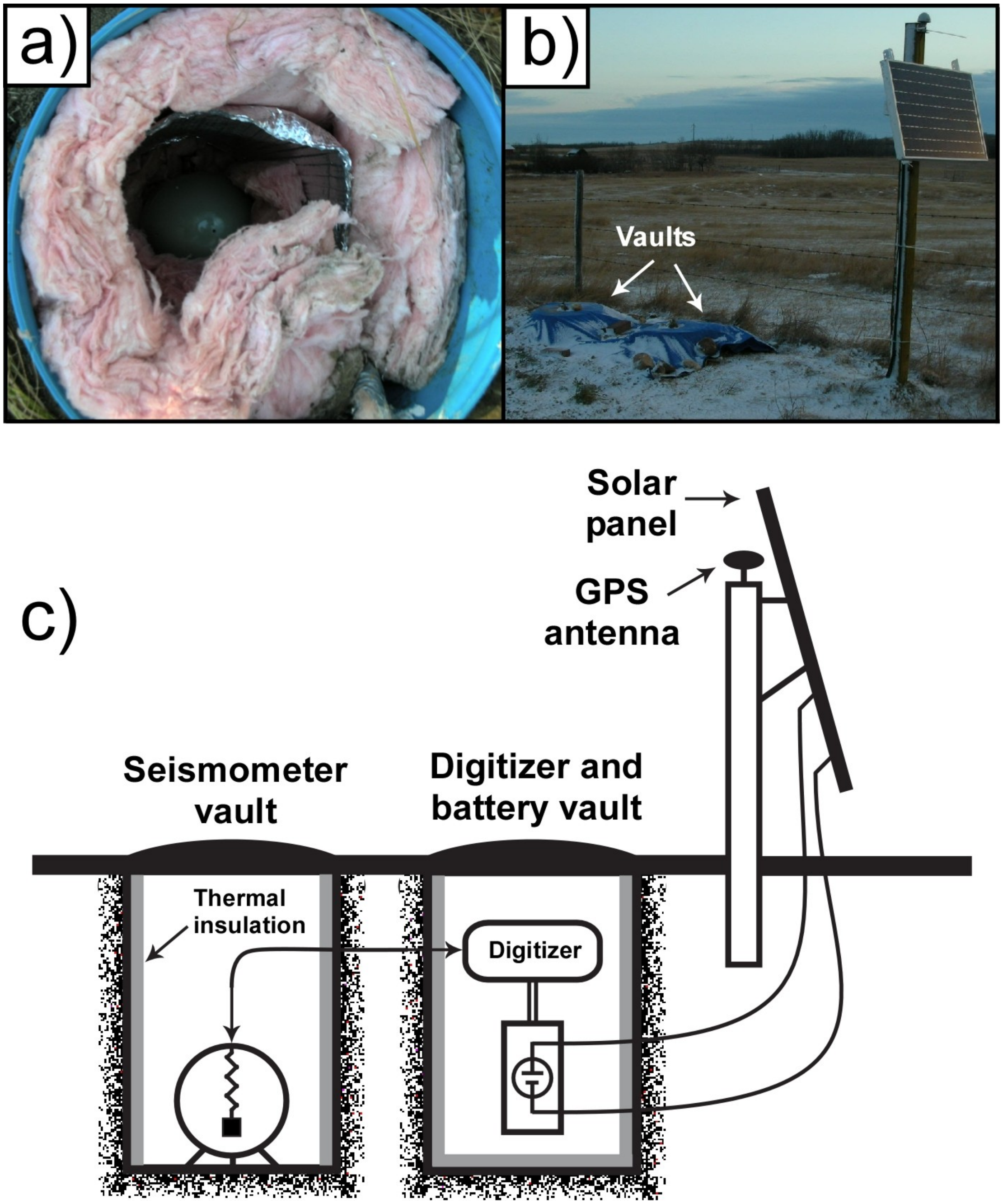


Figure 47. Configuration of Canadian Rockies and Alberta Network (CRANE) stations: a) view looking into vault from above, b) surface view of installed vaults and solar panel, and c) schematic cross-section of buried vaults (photo courtesy of J. Gu).

Strachan temporary array

The portable temporary stations are deployed with compact three-component broadband seismometers that are buried 0.3 m (1 ft.) beneath the surface (Figure 48). The digitizer and a rechargeable lithium-polymer battery are housed within a rugged case, which rests on the surface above the seismometer. The battery is connected to a small solar panel, which has attachments to secure it to the lid of the instrument case (Figure 49).

Figure 48. Compact seismometer and digitizer similar to the equipment deployed in the Strachan temporary array.

Figure 49. Transport and deployment case for temporary seismic stations. The battery shown on the left is normally inside the protective case.

Appendix 2 – Sample Land-Use Agreements

Sample of Alberta Telemetered Seismograph Network (ATSN) Land-Use Agreement between the University of Calgary and Landowners

LAND USE AGREEMENT
BETWEEN
THE UNIVERSITY OF CALGARY (the "University")
and

(the "*Landholder*")

Description of the property: ____________________________ *(the "Lands")*

____

____

____

____

This agreement, made effective as of the ___ day of ______ 2009, permits the University to locate and operate an earthquake seismic monitoring station at a mutually agreeable location the Lands on the terms set out herein.

In consideration of the mutual covenants between the parties and consideration as set out below, the receipt and sufficiency of which is acknowledged, the parties agree as follows:

1. The Landholder grants use of the Lands to the University to permit the University to install, maintain, service, and retrieve results from earthquake seismic monitoring equipment on the Lands. The exact location of the equipment will be agreed upon by both parties acting reasonably, having regard to the requirements of each party. The equipment will consist mainly of a 1m high x 60cm diameter cylindrical enclosure containing a seismograph, and a 30x20x20 cm steel box containing batteries and electronics. Both enclosures will be locked. If possible, the seismograph enclosure will be located at a shallow depth in soil and may be up to approximately 20-m from the battery box. The battery box contains a CSA-approved universal power supply (UPS) system, which must be plugged into a standard 120-volt AC power outlet provided by the Landholder. A buried (or semi-buried, as conditions permit) conduit will be used to connect the two enclosures. The installation will also require the installation of a small (less than 10 cm in all direction) antenna in a suitable outdoor location, such as the side of a building or on a steel post mounted in the ground. Where required the equipment will be installed by a licensed electrician.

2. The University may only access the Land for the purposes set out in Section 1. The University's rights of access shall extend to the Researcher, as well as University staff and students, consultants or contractors, as deemed appropriate by the Researcher.

3. The University agrees to have the area of the site returned substantially to its existing condition after the installation is complete and agrees to notify the Landholder of any visits to the site to service the instruments and equipment.

4. Subject to the minimum term under paragraph 4, this agreement may be terminated by either party at any time provided at least three (3) months notice is given. With such notice, the University shall remove all equipment from the Lands.

5. The term of the agreement is three (3) years, from the effective date. After the initial 3 year term, this Agreement may be renewed by written notice from the University for a total period not to exceed 20 years.

6. The University will pay to the Landholder ONE THOUSAND DOLLARS ($1000) per year the use of the land. Payment for the first THREE (3) years will be paid in advance within 60 days of the execution of this Agreement.

7. The University acknowledges that the Landholder shall not be responsible for any damage or theft to any

Page 1 of 3

of the equipment of the University, unless such damage or theft is caused by an employee of the Landholder or someone for whom it is in law responsible. The University agrees to maintain insurance in reasonable amounts to protect against property damage or injury to persons arising from the installation, operation or removal of the equipment from the Lands.

8. The Landholder will provide 120-volt AC power and high-speed Internet service for the equipment.

The Landholder represents and warrants to and covenants with the University as follows, which representations, warranties and covenants shall continue during the Term:

(a) The Landholder has full rights and authority to execute, deliver and perform its obligations under this Agreement; and

(b) The Landholder shall comply with all applicable laws and regulations in respect of the performance of this Agreement.

9. NOTICES

Any written communication from one Party to the other must be mailed, personally delivered, faxed, or electronically transmitted as follows:

If to Landholder, to:

If to the U of C, for contract and administrative matters, to:

University of Calgary
2500 University Drive, N.W.
Calgary, Alberta
T2N 1N4

Attention: Senior Executive Director, Research Services and Research Accounting

If to the U of C, for scientific and technical matters, to:

Department of Geoscience, Faculty of Science
University of Calgary
2500 University Drive, N.W.
Calgary, Alberta
T2N 1N4

10. This agreement constitutes the entire agreement among the parties as to its subject matter and may be amended only by agreement in writing executed by all of the parties.

11. Nothing in this agreement shall be construed as constituting either Party as the agent, employee or representative of the other Party; or creating a partnership or as imposing upon either Party any partnership duty, obligation or liability to the other Party.

12. The Landowner will not use the University's name, logos or trade-marks or trade names in any publicity, advertising, or similar activity, without the prior written consent of the University, which consent if granted, may be withdrawn at any time in the sole discretion of the University.

13. This agreement shall be governed by the laws of the Province of Alberta.

14. This agreement will bind the parties' successors and assigns.

THE UNIVERSITY OF CALGARY I have authority to bind the University.	Date
Landowner	Date

Page 3 of 3

Sample of Strachan Temporary Seismic Array Land-Use Agreement Between the University of Calgary and Landowners

LAND USE AGREEMENT

BETWEEN

THE UNIVERSITY OF CALGARY (the "University")

and

____

(the "Landholder")

Description of the property: ______________________________ *(the "Lands")*

This agreement, made effective as of the ___ day of ______ 2010, permits the University to locate and operate a portable microearthquake seismic monitoring station at a mutually agreeable location the Lands on the terms set out herein.

In consideration of the mutual covenants between the parties and consideration as set out below, the receipt and sufficiency of which is acknowledged, the parties agree as follows:

1. The Landholder grants use of the Lands to the University to permit the University to install, maintain, service, and retrieve results from portable microearthquake seismic monitoring station equipment on the Lands. The exact location of the equipment will be agreed upon by both parties acting reasonably, having regard to the requirements of each party. The equipment will consist mainly of a small seismograph unit (approximately 20 cm high and 8 cm in diameter), which will be buried at a shallow depth in the group, as well as a suitcase-style electronics enclosure, a solar panel (approximately 25 cm x 25 cm) and a fist-sized GPS antenna.

2. The University may only access the Land for the purposes set out in Section 1. The University's rights of access shall extend to the Researcher, as well as University staff and students as deemed appropriate by the Researcher.

3. The University agrees to have the area of the site returned substantially to its existing condition after the installation is complete and agrees to notify the Landholder of any visits to the site to service the instruments and equipment.

4. Subject to the minimum term under paragraph 5, this agreement may be terminated by either party at any time provided at least one (1) month notice is given. With such notice, the University shall remove all equipment from the Lands.

5. The term of the agreement is four (4) months, from the effective date. After the initial 4-month term, this Agreement may be renewed by written notice from the University for a total period not to exceed 1 year.

6. The University will pay to the Landholder FOUR HUNDRED DOLLARS ($400) per year the use of the land within 60 days of the execution of this Agreement.

7. The University acknowledges that the Landholder shall not be responsible for any damage or theft to any of the equipment of the University, unless such damage or theft is caused by an employee of the Landholder or someone for whom it is in law responsible. The University agrees to maintain insurance in reasonable amounts to protect against property damage or injury to persons arising from the installation, operation or removal of the equipment from the Lands.

8. The Landholder represents and warrants to and covenants with the University as follows, which representations, warranties and covenants shall continue during the Term:

(a) The Landholder has full rights and authority to execute, deliver and perform its obligations under this Agreement; and

(b) The Landholder shall comply with all applicable laws and regulations in respect of the performance of this Agreement.

9. **NOTICES**

Any written communication from one Party to the other must be mailed, personally delivered, faxed, or electronically transmitted as follows:

If to Landholder, to:

If to the U of C, for contract and administrative matters, to:

University of Calgary

2500 University Drive, N.W.

Calgary, Alberta

T2N 1N4

Fax:

Phone:

Attention: Senior Executive Director, Research Services and Research Accounting

If to the U of C, for scientific and technical matters, to:

Department of Geoscience, Faculty of Science

University of Calgary

2500 University Drive, N.W.

Calgary, Alberta

T2N 1N4

Phone:

Email:

10. This agreement constitutes the entire agreement among the parties as to its subject matter and may be amended only by agreement in writing executed by all of the parties.

Appendix 3 – Information Brochures

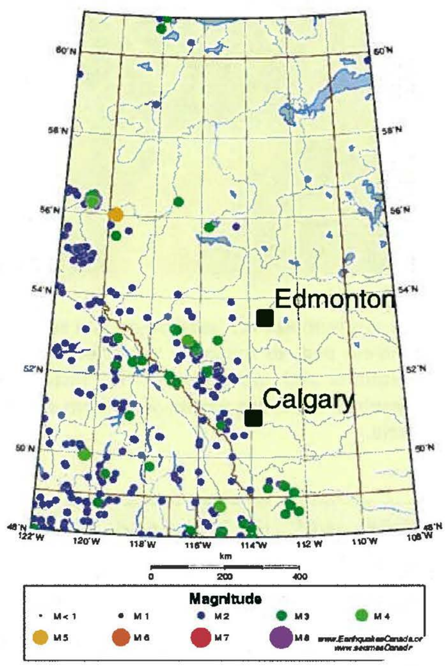
Alberta Telemetered Seismograph Network Station Sites

W.B. Merdhah created this brochure in the summer of 2009. The photo of the Taurus seismograph and Trillium 120P seismometer is courtesy of Nanometrics, Inc.

UNIVERSITY OF CALGARY

Earthquake Monitoring Research
University of Calgary

This research project by the University of Calgary, in co-operation with the ERCB/Alberta Geological Survey, is intended to monitor seismic activity caused by tiny earthquakes and human-induced vibrations in Alberta. A set of 9 seismographs will be installed at different locations across the province. The duration of this project is intended to last a minimum of 3 years. Earthquakes are currently monitored by the Geological Survey of Canada, but numerous small events are missed due to the sparse seismograph station coverage. Although large events are rare, it is important to have an accurate earthquake hazard model to help guide current and future development of critical infrastructure.



Earthquakes in Alberta for the past ten years, Source: *Earthquakes Canada.* Many small earthquakes have likely been missed, due to sparse current station coverage.

Components of a seismograph station: seismometer (right); digital seismograph (left). The seismometer is about the same size as a bowling ball.

What does seismograph equipment look like?

Each station consists of a buried seismometer (which measures ground motion), a digital seismograph (which converts data to a format understood by a computer), internet communication and power subsystems. This equipment operates passively to record background vibrations.

The seismometer is placed below the surface on a concrete pad, to minimize the effects of surface vibrations and wind noise. The instrument is capable of detecting earthquakes from around the world.

The equipment is housed within protective containers and insulated from cold conditions. At the end of the project, the site will be restored to its original condition (to the extent possible).

What will be learned from this project?

This research project will improve our knowledge about earthquake hazard in Alberta, and help to understand the potential role of human activity in induced seismicity. It will also help to unravel the deep geology (up to 100's of kilometres) beneath the surface, which can help to guide diamond exploration.

How can I participate?

We are looking for landowners (individuals or organizations) willing to give permission to install equipment owned by the University of Calgary for a minimum period of three years. Participants will receive an annual payment as well as a yearly newsletter summarizing the data recorded at their locations.

The above photos of the CRANE seismic stations, operated by the University of Alberta, are courtesy of J. Gu.

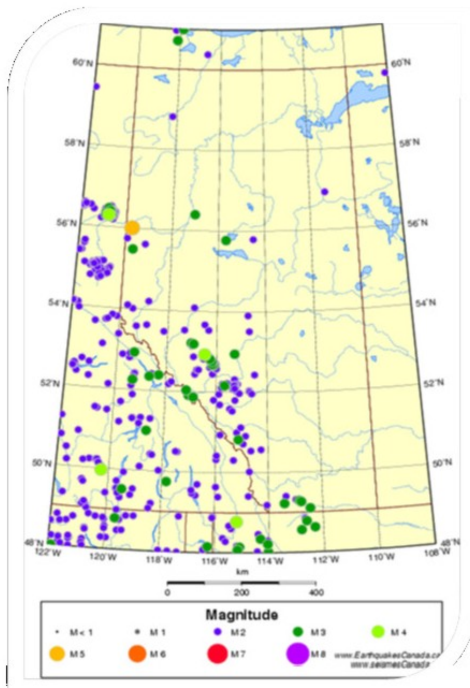
Strachan Temporary Seismic Array Station Sites

This brochure was modified from the ATSN brochure (Appendix 2.1) created by W. B. Merdhah. The equipment photos are courtesy of Nanometrics Inc.

UNIVERSITY OF CALGARY

Earthquake Monitoring Research
University of Calgary

This research project by the University of Calgary, in co-operation with the ERCB/Alberta Geological Survey, is intended to monitor seismic activity caused by tiny earthquakes and human-induced vibrations in Alberta. A set of 8 semi-permanent seismographs have been and are in the process of being installed at different locations across the province. The duration of that project is intended to last a minimum of 3 years. The Strachan Study will install 5 temporary seismographs for a duration of 3 to 4 months. Earthquakes are currently monitored by the Geological Survey of Canada, but numerous small events are missed due to the sparse seismograph station coverage. Although large events are rare, it is important to have an accurate earthquake hazard model to help guide current and future development.



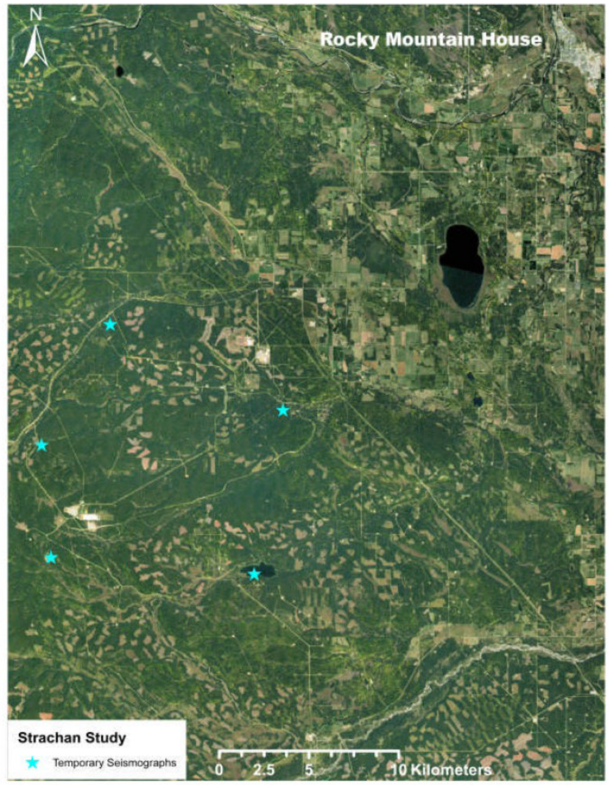
Earthquakes in Alberta for the past ten years, Source: *Earthquakes Canada.* Many small earthquakes have likely been missed, due to the sparse current station coverage.

Components of a temporary seismograph station. Seismometer (right); electronics and solar panel (left) which remains above ground.

What does seismograph equipment look like?

Each station consists of a buried seismometer (which measures ground motion), a digital seismograph (which converts data to a format understood by a computer), internet communication and power subsystems. Net power consumption is less than 20 Watts.

The temporary seismometer is about the size of an oil filter. It is placed 30 cm below the surface on a patio stone, to minimize the effects of surface vibrations and wind noise. The instrument is covered with a protective insulated housing and covered with soil.



What will be learned from this project?

This research project will improve our knowledge about earthquake hazard in Alberta, and help to understand the potential role of human activity in induced seismicity. It will also help to unravel the deep geology (up to 100's of kilometres) beneath the surface.

How can I participate?

We are looking for landowners (individuals or organizations) willing to give permission to install temporary equipment owned by the University of Calgary for its Strachan Study for 3 to 4 months. Participants will receive a one time payment as well as a newsletter summarizing the data recorded in your location.