KLOHN LEONOFF
CONSULTING ENGINEERS

Our File: PB 2834 0301

April 19, 1984

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Mr. D.J. Wright, P.Eng.
Manager, Thermal Engineering Department

Seismic Observations at Hat Creek
January 1, 1983 to March 31, 1984

Dear Sirs:

We are pleased to present three (3) copies of our report on the micro-earthquake observations at Hat Creek during the period January 1, 1983 to March 31, 1984.

We have found this study very interesting and have enjoyed performing the work. Should there be any questions concerning this report, please call.

Yours very truly,

KLOHN LEONOFF LTD.

Robin G. Charlwood, Ph.D., P.Eng.
Project Manager

Encl.

RGC/tp

604H-G032

PB 2834-0301 April 19, 1984

SEISMIC OBSERVATIONS AT HAT CREEK JANUARY 1, 1983 TO MARCH 31, 1984

1. INTRODUCTION

In accordance with B.C. Hydro Purchase Order No. 359001, dated February 16, 1983, Klohn Leonoff Limited (KLL) operated a vertical component high gain seismograph at a site near the Hat Creek coal field during the period January 1, 1983 to March 31, 1984. The principal objectives of this experiment were:

1) to monitor earthquake activity within a 50 km radius of the site, and

2) to report epicentral distances and magnitudes of observed earthquakes.

Such data would be used in a seismic risk assessment of the area in general and the Hat Creek Thermal Project in particular.

This report summarizes and discusses the observations during the fifteen month period. Although the terms of reference in the B.C. Hydro Purchase Order refer only to the twelve month period February 1, 1983 to January 31, 1984, the observations of the other months are included for completeness (see next paragraph). The station was dismantled at the end of March 1984 and the equipment returned to B.C. Hydro. All seismograms recorded during the fifteen month period are kept in KLL offices.

The station was originally installed by the Department of Geophysics and Astronomy of the University of British Columbia. Operation began on October 2, 1982. In addition to two interim reports, a final report concerning the observations during the period October 2, 1981 to October 2, 1982 has been issued (Ellis and Meldrum, 1982a). A report on an

earthquake swarm which occurred in early October 1982 has also been issued (Ellis and Meldrum, 1982b). A report discussing observations during the months of October to December 1982 is still outstanding.

2. STATION CHARACTERISTICS

The station characteristics is as described in previous reports, but are presented here for completeness.

The recording system consists of a vertical component Mark Products L4-C 1 Hz seismometer, the output of which is recorded on a Sprengnether MLQ-800 chart recording system operated at a speed of 60 mm/min. Time calibration for this system is provided by WWV and WWVB radio time signals.

The seismometer is anchored on bedrock on the hill west of the B.C. Hydro field office at Hat Creek. A cable connects the seismometer to the chart recorder located in a heated pump-house at the base of the hill. The seismometer coordinates are 50° 47' 38" N, 121° 36' 47" W, elevation 930 m.

The magnification curve for the system is shown in Figure 1. (This curve gives the amount by which ground movement at a particular frequency is magnified before recording on the chart.) The amplifier gain is 90 db. A low cut filter is not used, but a 20 Hz high cut filter is.

3. MAGNITUDE AND DISTANCE DETERMINATION

The epicentral distance of an event was calculated by measuring the time difference, Δt, (measured in seconds) between the arrival times of the S (Shear) wave and the P (Primary or Compressional) wave. The P wave velocity of the upper layers of the earth is usually taken to be 6.1 km/sec. Assuming a Poisson's ratio of 0.25 for the earth, the S

wave velocity is then 3.52 km/sec. The epicentral distance, x, is derived as follows:

$$\Delta t = t_s - t_p$$

$$= \frac{x}{3.52} - \frac{x}{6.1}$$

$$\text{or} \quad x = 8.3\ \Delta t$$

where t_s and t_p are the arrival times of the S and P waves, respectively. Note that this only provides a distance from the station, not a direction. More stations would be required to give the epicentral location.

Knowing the magnification of the seismograph system and the epicentral distance, the local magnitude, M_L, of an event was determined by measuring the amplitude, in millimetres, of the largest wave motion on the seismogram of the event. The nomogram in Figure 2 was then used to determine the magnitude.

The magnitude was also determined by measuring the coda length, T, which is the time interval between the arrival of the S wave and the time that the signal to noise ratio returns to 1. Given T, the coda length magnitude, M_T, is given by:

$$M_T = -3.2 = 2.7 \log_{10} T$$

For most earthquakes of small magnitude in British Columbia, M_L should be roughly equal to M_T.

4. OBSERVED SEISMICITY

A major difficulty in detecting natural events is distinguishing them from blasts in local mines. This can usually be done by noting the time of day or week of the occurrence of the event or from blast records obtained from the mines. Also the "signature" of most blast events is quite different from that of natural events; the latter usually have a prominent S wave arrival.

During the fifteen month period, four earthquakes were recorded with an epicentral distance less than 50 km. (See Table 1) Another earthquake, Event 4, whose epicentral distance was approximately 90 km from Hat Creek, is also included. This event, whose local magnitude is 1.8, occurred near Nicola Lake and was observed at other seismograph stations in southern British Columbia. Its epicentre was located by the Pacific Geoscience Centre at 50° 16' 48" N, 120° 36' 36" (D. Weichert, pers. comm., April 12, 1984).

The other events, except Event 3, are very small earthquakes within 20 km of the station. Their local magnitudes are less than or equal to 1.0. Event 3 is possibly a blast, but occurred late at night (local time).

TABLE 1

OBSERVED SEISMICITY
January 1, 1983 to March 31, 1984

Event	Date y	m	d	Time (GMT) h	m	s	M_L	M_T	Distance (km)
1	83	2	18	9	41	01	0.5	0	14
2	83	2	22	7	47	34	1.0	1.0	17
3	83	4	18	6	06	55	1.3	0.7	40
4	83	5	30	11	03	46	1.8	1.7	90
5	83	10	6	4	25	17	0.9	0.4	17

REFERENCES

Klohn Leonoff Limited, 1982. Seismicity Assessment and Seismic Design Criteria. Report to B.C. Hydro, August 16, 1982.

Ellis, R.M. and Meldrum, R.D., 1982a. Seismic Observations at Hat Creek, October 2, 1981 to October 2, 1982. Report to Klohn Leonoff Limited, October 19, 1982.

Ellis, R.M. and Meldrum R.D., 1982b. The Hat Creek Earthquake Sequence of October 1982. Report to Klohn Leonoff Limited, November 17, 1982.

5. CONCLUSIONS

The level of activity observed during the fifteen month period, January 1, 1983 to March 31, 1984 is similar to that observed in this region by Ellis and Meldrum, (1982a). With one station, it is not possible to determine epicentral locations and thereby attempt to associate the activity with any of the local faults at or near the Hat Creek site. However, Events 1, 2 and 5 are located 14 to 17 km from the station, which is the approximate distance to the Fraser fault (KLL, 1982).

It must be noted that, by themselves, the results of this experiment should be used with caution in that

1) magnitudes of small events are not reliable since usually only one measurement is possible; and

2) significant short term increases in activity, such as the swarm of events in October, 1982, (Ellis and Meldrum, 1982b) are possible.

KLOHN LEONOFF LTD.

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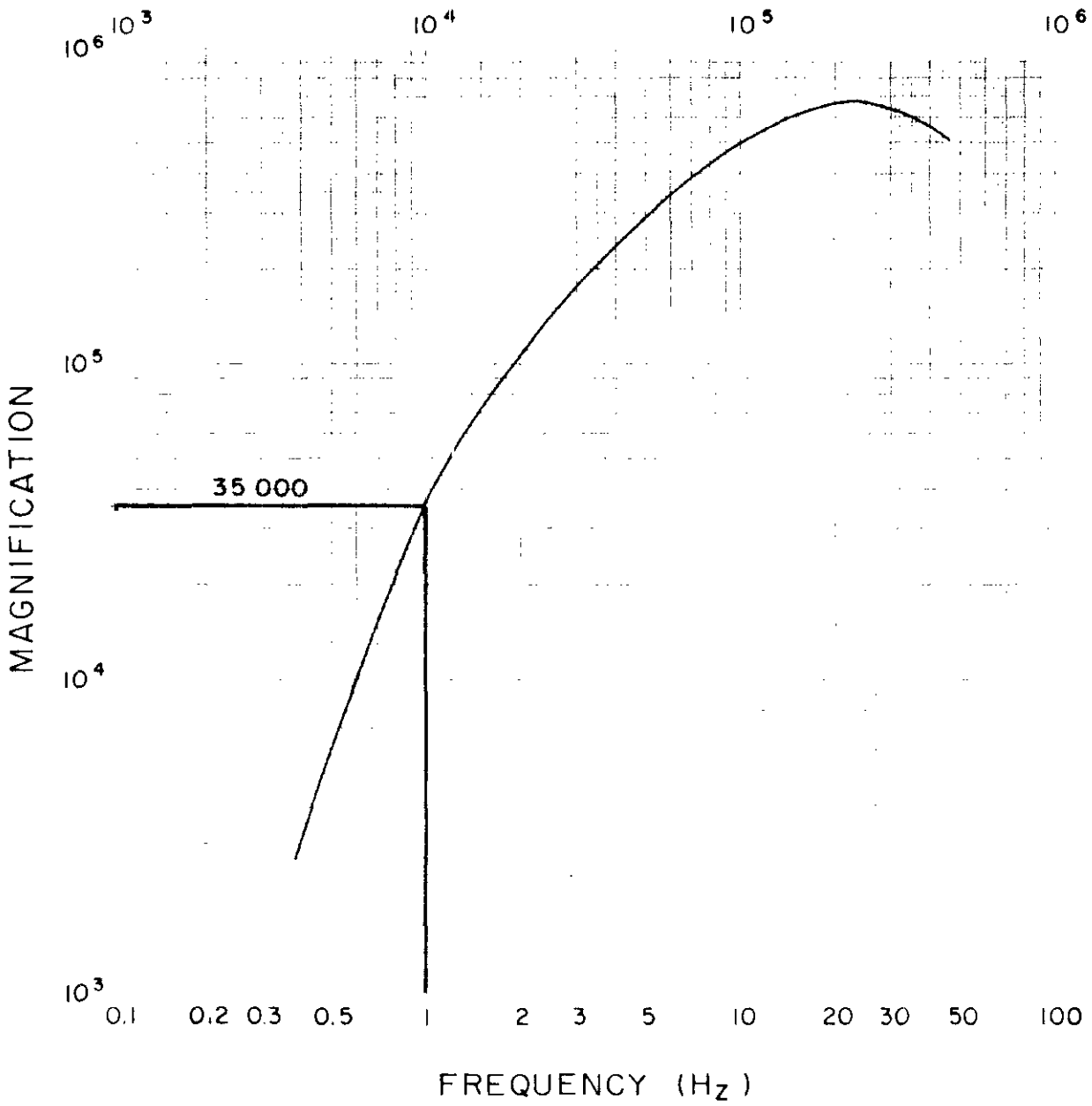
DRAWINGS

Figure 1	Magnification Curve of Hat Creek Seismograph
Figure 2	Nomogram for Magnitude Determination



SCALE

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

PROJECT: HAT CREEK SEISMICITY

TITLE: MAGNIFICATION CURVE OF HAT CREEK SEISMOGRAPH

CLIENT: BC. HYDRO & POWER AUTHORITY

DATE OF ISSUE: APR. 19, 1984

APPROVED:

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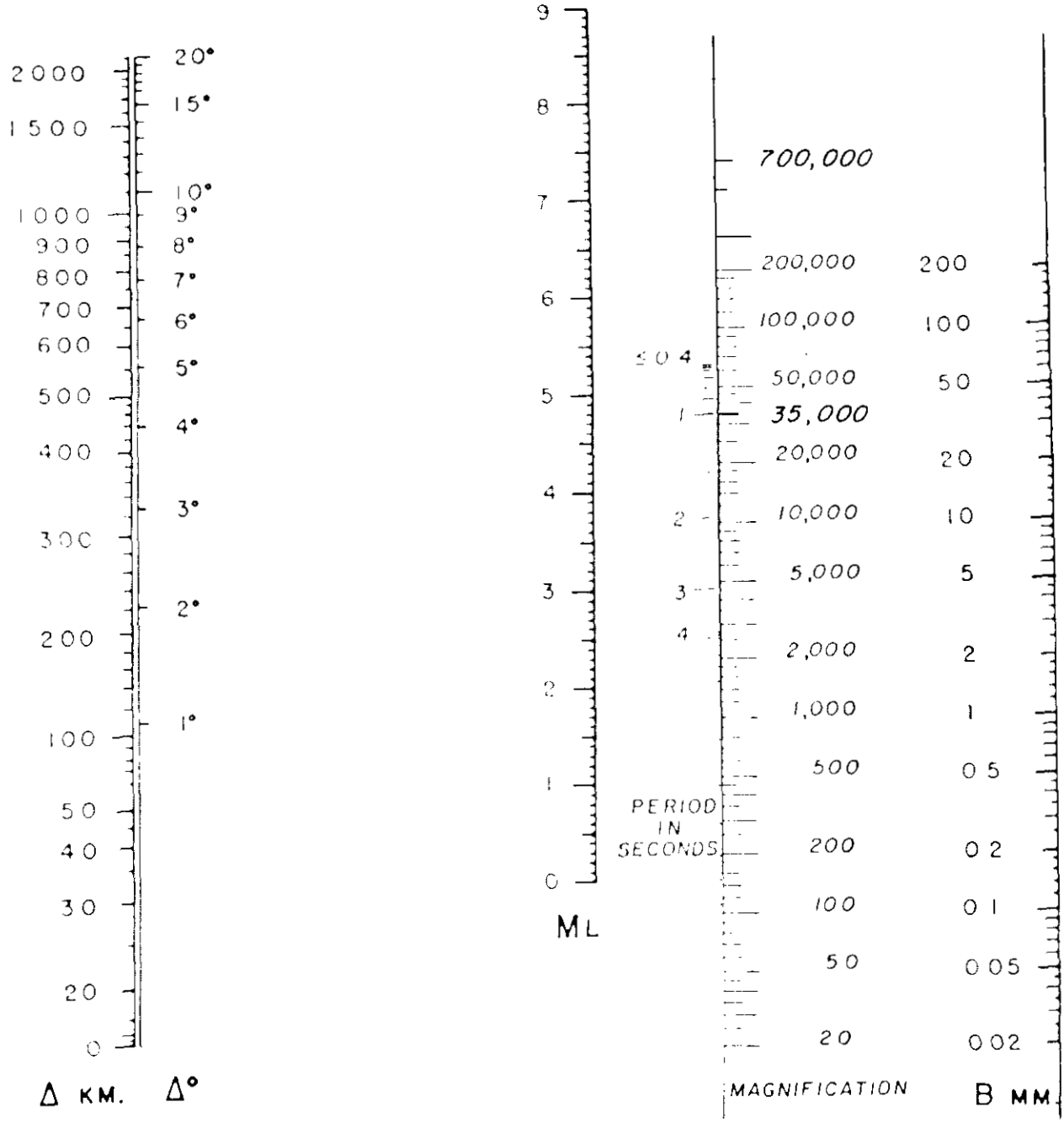
DWG No: FIGURE - 1

REV:



B = Maximum Trace Amplitude

Δ = Epicentral Distance

SCALE

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

PROJECT: HAT CREEK SEISMICITY

TITLE: NOMOGRAM FOR MAGNITUDE DETERMINATION

CLIENT: B.C. HYDRO & POWER AUTHORITY

DATE OF ISSUE	PROJECT No	DWG No	REV
APR. 19, 1984	PB2834-03	FIGURE - 2	

APPROVED