DESIGN BASIS SEISMIC GROUND MOTION FOR DARLINGTON NUCLEAR GENERATING STATION A

by

P.W. Basham

Seismological Service of Canada

Internal Report 75-16

Division of Seismology and Geothermal Studies

Earth Physics Branch

Department of Energy, Mines and Resources

December 1975

INTRODUCTION

At a meeting of representatives of AECB, AECL, Ontario Hydro and EMR on 24 September 1975 at AECB offices, it was agreed that EMR (Division of Seismology and Geothermal Studies, Earth Physics Branch) staff would undertake to provide an estimate of the design basis seismic ground motion (DBSGM) for Ontario Hydro's Darlington G.S. site by 01 January 1976. This report provides a summary of the investigations undertaken and the resulting estimate of DBSGM for the Darlington site. Because of the short time available for the study, the investigations have not been exhaustive. All of the investigations deemed necessary by the draft code section N289.2 (EMR, 1975) have not been undertaken and this report does not comply fully with the intent of the draft code section. It is, however, believed that sufficient information on potential earthquake effects at the Darlington site are presented to allow AECB to judge the adequacy of the seismic design parameters that have been or may be suggested for the Darlington site.

HISTORICAL SEISMICITY

The Earth Physics Branch (EPB) earthquake data file, containing information on all earthquakes in published and soon-to-be-published Canadian earthquake catalogues, has been searched for all earthquakes within a region bounded by latitudes 40° to 50°N and longitudes 72.5° to 84°W. This rectangular region contains 800 historical earthquakes which will be used in the evaluation of the Darlington DBSGM, and whose epicentres are computer-plotted in Figure 1. The earthquakes plotted in Figure 1 date from 1568 in the Atlantic coastal area, from 1661 in the area near Montreal, and from 1823 in the general area of the eastern Great Lakes.

As the quality of this historical earthquake information varies considerably over the long time interval available, it is necessary to make a number of judgments about the completeness and reliability of the information. With the time available to this study, such an assessment of the data has been far from exhaustive. The following and later sections give accounts of the treatment of the information and where necessary indicate the absence of some investigations that are considered necessary for a full assessment of the earthquake data.

Epicentral Accuracy

Earthquakes in the pre-instrumental era have been assigned to the locations of the maximum reported intensity. It is quite possible that this procedure could lead to errors of up to a few hundred km from the true epicentre. In the early part of this century the larger earthquakes were beginning to be located by observations made from the primitive seismographs of the day; the smaller earthquakes could not be detected adequately and were still assigned to the location of the maximum reported intensity. From 1928 onward, the earthquake locations were based largely, but not entirely, on seismograph recordings (Smith, 1966); in the modern era all earthquake locations are based on instrumental data. Well-recorded earthquakes should have an epicentral accuracy of approximately 20 km, but smaller, less well-recorded, events may have epicentral uncertainties of as much as 50 km.

No attempt has been made as part of this study to assess the epicentral accuracy of any of the earthquakes plotted in Figure 1; each is plotted at the presently accepted epicentre as given in the EPB earthquake file.

Given the assumption of a random distribution of earthquakes within a geographically delimited zone of earthquake occurrence, it is sufficient to establish that a particular earthquake occurred either within or outside the zone. However, for a zone of earthquake occurrence whose boundaries are based almost exclusively on the patterns of historical seismicity, as is the case in this study, inaccurate epicentres will in general tend to make the zone with the higher seismicity broader than it actually is.

Magnitude Accuracy

In order to determine reliable rates of earthquake recurrence, it is important to have reliable estimates of magnitude for all of the larger earthquakes. There are two effects that have contributed to inaccurate magnitudes for the earthquakes on the EPB file. Firstly, many of the older historical events have been assigned tentative magnitudes converted directly from the maximum reported intensities for the earthquakes. The work of A.E. Stevens at EPB on reassessment of many historical Canadian earthquakes has shown that in many, but not all, cases the maximum reported intensity is not representative of intensity of the general epicentral region, i.e., is not a representative I_o that can reliably be converted to magnitude.

The second contribution to magnitude errors has been the use on eastern Canadian earthquakes prior to 1968 of the Richter M_L magnitude scale. Stevens et al. (1973) demonstrated that when the M_L scale was applied to earthquakes in eastern Canada recorded at large distance it tended to overestimate magnitude by as much as 1½ magnitude units. A revised procedure (see e.g. Stevens et al. 1975) was adopted for all 1968 and later earthquakes, which is believed to be providing reliable magnitude estimates.

For the purposes of this study, all of the earthquakes in Figure 1 with previously assigned (EPB file) magnitude ≥ 4 (except for the Atlantic Coastal Area; see below) have been checked to determine if the intensity or instrumental data from which the magnitude was determined may have been unreliable. For the reassessment of epicentral intensity, only the earthquake effects listed by Smith (1962, 1966) and by Coffman and von Hake (1973) have been employed; no additional sources of information on earthquake effects were searched. In assessing the validity of M_L values for pre-1968 earthquakes, a judgment is used, based on recent experience with the effects of various magnitude scales and knowledge of the station distances involved, to alter some of the file magnitudes. For purposes of estimating earthquake recurrence rates, as described in following sections, each earthquake has been assigned to one of the following magnitude categories: M<4, M4, M4.5, M5, M5.5, M6 and M>6. No check of any kind has been made of earthquakes with assigned file magnitudes M<4; they are simply counted. Separate symbols for earthquakes in each of these magnitude categories are used in Figure 1.

Atlantic Coastal Area

The Atlantic coastal area (see Figure 1) contains earthquakes that predate the rest of the region by a full century. There are many significant historical earthquakes in the area, an assessment of which will be very important in the delineation of zones of earthquake occurrence over a broad region of eastern North America. A proper evaluation of these earthquakes has not been possible in the time available to this study. They are separated from the rest of the region by the arbitrary line labelled "A" in Figure 1, and will not be considered further.

These earthquakes would have an important influence on the Darlington DBSGM if some future work were to show, for example, that they must be assumed to be part of a continuous zone that extends northward as far as northern New York State and Ontario. The present assessment assumes that this will not be the case.

WESTERN QUEBEC ZONE OF EARTHQUAKE OCCURRENCE

Zone Boundaries

The historically most active earthquake area in the region of the Darlington site is the scatter of earthquakes sometimes referred to as the "Ottawa-Boston Zone" or the "Timiskaming-Montreal Zone". Neither of these names is really appropriate as the continuity of the zone southeast to the Boston area has recently been seriously questioned, and the northwestern limits of the zone have never been clearly defined. In this report we will use the name "Western Quebec Zone" to refer to the zone of earthquakes around which a tentative boundary has been drawn in Figure 1. The zone is principally confined to western Quebec, but does extend into the northeastern U.S. and eastern Ontario.

The northwestern boundary of the zone has not been determined and is shown arbitrarily extended by a dashed line to include the 01 Dec. 1928

M5 earthquakes at $50^{o}N$, $81.5^{o}W$. In the following determination of the Western Quebec earthquake rates, only that section of the zone to the southeast of the arbitrary line labelled "B" will be considered. (It is hoped that future studies of the seismicity, including the influence of the historical population distribution and of the capabilities of the seismograph network as it developed, will clarify the extent of the zone to northwest.) The southwestern boundary is drawn to enclose the 10 Feb. 1914 M5.5 earthquake at $45^{o}N$, $77^{o}W$. A.E. Stevens has recently reassessed the data for this earthquake and has shown the magnitude to be reliable but the location to be in some doubt. If it actually occurred nearer to or within the main Western Quebec cluster, the boundary might be drawn about 40 km further northeast, i.e., further from the Darlington site. The southeastern boundary of this seismicity appears to be confined to the western side of a line extending north from Lake Champlain. The boundary line is drawn, somewhat arbitrarily, a few 10's of km east of this north-south line. The seismicity thins out gradually to the northeast and the boundary is drawn, again somewhat arbitrarily, to the southwest of the Gouin Reservoir and crossing the St. Lawrence River about 80 km downstream from Montreal.

It is emphasized that the boundary drawn around the Western Quebec Zone in Figure 1 is based solely on the above judgments with respect to the observed distribution of historical epicentres. No attempt has been made in the time available to consult geological literature or geological authorities to assess the validity for such a boundary or to explain the seismicity on the basis of the known or inferred geological structure or tectonic history of the region.

Incremental Earthquake Recurrence Rates

The Western Quebec Zone historical earthquakes are tabulated in Table 1 as a function of magnitude category and time. The time intervals are 50 yr. up to 1799, 20 yr. from 1800-1839 and decades from 1840 to the present. These are the data available to establish an earthquake recurrence relationship for the zone.

Figure 2 shows the relationship between the annual earthquake recurrence rates in four magnitude categories and the starting year of the time period included. The annual recurrence rates will be too low for time periods too short to include a representative number of earthquakes in a certain magnitude category (the rates could be too high if a relatively infrequent earthquake has occurred recently); they will also be too low for time periods too long to have complete information available on the number of earthquakes that actually occurred. Both of these effects can be seen in Figure 2. The annual rates can be distorted to too large or too small values if there has been an inappropriate assignment of magnitude categories to some of the earthquakes. The rates chosen to represent magnitude recurrence for the Western Quebec Zone must be established as well as possible from this data.

The M4 annual rate is the least well determined as there appears to be too many M4 earthquakes in the 1930 and 1940 decades compared to the number in the past 25 years. There were a large number of M<4 earthquakes in the 1930 and 1940 decades (see Table 1), and on the assumption that too many of these earthquakes have been assigned M4, the annual rate chosen for M4 has not placed much weight on these years. The annual rates for M4.5, M5 and M5.5 appear reasonably well defined, but the rate for M5 appears too low compared to that for M4.5 and M5.5. For each of the four magnitude categories an estimated annual recurrence rate and range of uncertainty is shown opposite the curve.

Figure 1 and Table 1 show three earthquakes in the Western Quebec Zone with $M \geq 6$. These are the Montreal earthquake of 16 September 1732, which has been assigned an epicentral intensity of IX and is assumed to be M>6, the Timiskaming earthquake of 01 November 1935 with an instrumental magnitude of 6¼ (rounded to M6) and the Cornwall-Massena earthquake of 05 September 1944 with an instrumental magnitude of 5.9 (rounded to M6). The historical time period is not sufficiently long to use these three earthquakes to estimate annual rates for $M \geq 6$. The annual recurrence rates for the four magnitude categories determined in Figure 2 are shown plotted as a function of magnitude in Figure 3.

Cumulative Earthquake Recurrence Rate

Over the observed range of magnitudes, a negative exponential equation fits the recurrence rate data as well as other, more complicated expressions. We assume therefore that the earthquake recurrence equation has the general form

$$dN = N_o e^{-\beta M} dM \qquad (1)$$

where N is the average number of earthquakes per unit time of magnitude M, and N_o and β are constants.

In determining the recurrence equation for a particular zone, it is necessary for purposes of counting to group the earthquakes in increments of magnitude (μ); for the Western Quebec Zone discussed above, $\mu = 0.5$. The number of earthquakes in the magnitude range $Mx - \mu/2$ to $Mx + \mu/2$ is then, from equation (1)

$$N_{Mx} = \int_{Mx-\mu/2}^{Mx+\mu/2} N_o e^{-\beta M} dM$$

$$= \frac{2N_o \sinh(\beta\mu/2)\, e^{-\beta Mx}}{\beta} \tag{2}$$

Equation (2) provides an expression for N_o as a function of Mx and μ of the form

$$N_o = \frac{\beta N_{Mx} e^{\beta Mx}}{2 \sinh(\beta\mu/2)}$$

Replacing N_o in equation (1) yields the general form of the earthquake magnitude recurrence density equation

$$dN = \left(\frac{\beta N_{Mx} e^{\beta Mx}}{2 \sinh(\beta\mu/2)}\right) e^{-\beta M} dM \tag{3}$$

The four plotted points in Figure 3 are the data available to define the relationship between Mx and N_{Mx} for the Western Quebec Zone. The four points have been fit with a straight line with an assumed slop of 1.0 on the semi-log plot, which yields a value of $\beta = \ln 10 \approx 2.3$, and the equation of the line is

$$N_{Mx} = (5.6 \times 10^3) e^{-2.3Mx} \tag{4}$$

Note that Mx is the magnitude (e.g. M4.5) at which the number of earthquakes counted in the interval Mx − $^{\mu}/2$ to Mx + $^{\mu}/2$ (e.g. M4.25 to M4.75) is plotted.

The constants in equation (3) can now be determined as follows:

$$\beta = 2.3$$

$$\mu = 0.5$$

$$N_{Mx}\ e^{2.3Mx} = 5.6 \times 10^{3} \text{ (from equation (4))}$$

$$2 \sinh (\beta\mu/2) = 1.2\ (\simeq \beta\mu\ )$$

Thus, the magnitude recurrence density equation for the Western Quebec Zone becomes

$$dN = (1.1 \times 10^{4})\ e^{-2.3M} dM \tag{5}$$

For purposes of exceedence estimates, it is useful to have the cumulative form of the magnitude recurrent equation

$$N\ (\geq M) = \int_{M}^{M_{max}} dN$$

Integrating equation (5) leads to

$$N\ (\geq M) = (4.8 \times 10^{3})\ e^{-2.3M} \tag{6}$$

for unlimited upper magnitude, and

$$N\ (\geq M) = (4.8 \times 10^{3}) e^{-2.3M} \left[1 - e^{-2.3(M_{max} - M)}\right]$$

for an upper limit magnitude of M_{max}. The correction term on the right-hand side of the latter equation is not significant for $(M_{max} - M) \geq 1$ magnitude unit. Equation (6) is plotted in Figure 4 and will be employed to represent cumulative magnitude recurrence for the Western Quebec Zone.

Equation (6), the "predictive" equation for cumulative earthquake recurrence for the Western Quebec Zone, is compared in Figure 5 with the actual cumulative numbers of earthquakes that have occurred since 1860. Because equation (6) is derived to represent recurrence at $\geq$ a specific M, the earthquake data in Table 1 is cumulated by counting half of the earthquakes in the designated interval, plus all of the earthquakes of greater magnitude. That is, for actual recurrence of $M \geq Mx$, it is necessary to count only the earthquakes in the Mx category having magnitudes between Mx and Mx + $\mu/2$. Figure 5 provides a check of equation (6), which will be used to estimate future earthquake recurrence rates, in terms of its validity looking into the past. It is judged on the basis of this evidence to be an adequate representation of the earthquake recurrence rates.

Area Normalization

In order to discuss the relative seismicity of different zones, and in order to provide estimates of design earthquake placement distances from a site within a zone, it is necessary to normalize the earthquake recurrence rates to unit area. For the purposes of this study the extent of the Western Quebec Zone is assumed to be that to the southeast of the arbitrary line labelled "B" in Figure 1. The total area of this effective zone is about 1.6×10^5 km^2. The area-normalized cumulative recurrence rate is therefore

$$N(\geq M) = (3.0 \times 10^{-2})\ e^{-2.3M} \qquad (7)$$

giving the annual rate (N) of earthquakes $\geq$ M per km^2. This equation is plotted in Figure 6.

EASTERN GREAT LAKES AREA

Seismicity Trends

The remainder of the region of the map area in Figure 1, to the southwest of the Western Quebec Zone and to the northwest of the Atlantic coastal area, needs to be assessed in terms of the seismicity that has occurred historically. For descriptive purposes, this broad area is called the Eastern Great Lakes Area. It is not being called a zone of earthquake occurrence within the definition of the draft seismic design code because insufficient work has been done to establish the appropriate boundaries for the seismicity. It is deemed sufficient to consider the Eastern Great Lakes Area seismicity in a variety of ways to assess its potential influence on the Darlington site.

The known seismicity can be described as a number of diffuse trends. In the United States, south of the Western Quebec Zone, there is scattered seismicity in New York State, extending from the Western Quebec Zone down the Hudson River and into the Atlantic coastal area, and scattered seismicity in eastern Pennsylvania. In both of these areas the seismicity may be connected with that in the Atlantic coastal area. Scattered seismicity is present across northern New York State with a higher concentration south of the western end of Lake Ontario extending through the Niagara Peninsula into Ontario as far as the vicinity of Hamilton. Seismicity similar to that of northern New York occurs in eastern Ontario between the Western Quebec Zone and Lake Ontario. The region of Lake Erie contains scattered earthquakes with a greater concentration to the south in Ohio than in southern Ontario. Scattered epicentres are also seen in, and north of, Georgian Bay.

The two broad areas in Figure 1 that contain no historical earthquakes are the areas of north-central Pennsylvania south of the eastern end of Lake Erie and all of Lake Huron and the area to the north of it.

The manner in which the potential influence of this broad area of seismicity on the Darlington site should be determined is by no means straightforward. Neither is it certain that much additional work would lead to any clear understanding of its nature. For the purposes of this study, the Eastern Great Lakes Area seismicity has been assessed in four ways as described below.

The Entire Eastern Great Lakes Area

The entire area of the eastern Great Lakes, excluding only the top left-hand corner northeast of the arbitrary line marked "C" in Figure 1, is assessed as if it were one continuous zone. (Note that the placement of line "C" is an arbitrary one for the purposes of the Darlington evaluation. In future, evaluations for sites in the vicinity of Georgian Bay or Lake Huron would need to treat the seismicity in a different manner.) The number of earthquakes as a function of time and magnitude category are shown in Table 2.

Difficulty in establishing a reliable recurrence equation for this broad area is anticipated, but the data in Table 2 can be used to provide a rough estimate of the seismicity of the total area relative to that of the Western Quebec Zone. Table 2 has given the problematic result of an approximately equal number of M4.5 and M5 earthquakes during the historical time interval available. If the two magnitude categories are added together ($\mu = 1.0$) and the rate assumed stable since about 1900, there are eleven M4.5 and M5 earthquakes in 75 years, or approximately 0.15 per annum. Dividing this number by two to convert to $\mu = 0.5$, gives 0.075 per annum at Mx = M4.75, compared to 0.10 for the Western Quebec Zone at Mx = M4.75 (see Figure 3).

The Eastern Great Lakes Area being assessed has an area of approximately 5×10^5 km^2. Taken as a continuous zone it has, therefore,

$$\frac{0.075}{0.10} \times \frac{1.6 \times 10^5}{5 \times 10^5} = 0.24$$

times as many M4.75 earthquakes per km^2 as does the Western Quebec Zone.

With a lack of definitive information, β is accepted as 2.3 and scaling down a factor 0.24 from equation (7) yields the equation

$$N(\geq M) = (7.2 \times 10^{-3})\ e^{-2.3M} \qquad (8)$$

for the cumulative magnitude recurrence per km^2 for the Eastern Great Lakes Area as a whole.

<u>The Niagara Area</u>

Figure 1 shows a clear concentration of historical seismicity in the area between Lake Ontario and Lake Erie. Because of the nearness of this area to the Darlington site, it is prudent to assess the area as if it were a delimited zone. For descriptive purposes, it is called the Niagara Area and is outlined by a dashed rectangular box in Figure 1. The nearest earthquakes to the Niagara Area in magnitude categories $M \geq 4$ are near the centre of Lake Erie and in the Western Quebec Zone.

The number of Niagara Area earthquakes as a function of time and magnitude category is shown in Table 3. Again the data are too sparse to establish an independent recurrence rate, but if the M4.5 category is assumed stable and representative since 1900, they are recurring at about 0.03 times per annum ($N_{Mx} = 0.03$, Mx = M4.5). $N_{Mx} = 0.18$ for the Western Quebec Zone at Mx = M4.5; thus the Niagara Area as a whole has

$$\frac{0.03}{0.18} = 0.17$$

times as many M4.5 earthquakes as does the Western Quebec Zone. Applying this factor to equation (6), the cumulative recurrence equation for the Niagara Area is

$$N(\geq M) = (8.2 \times 10^2)\ e^{-2.3M} \qquad (9)$$

This equation is shown plotted in Figure 4. With an area of 1.2×10^4 km^2, the Niagara Area has

$$\frac{0.03}{0.18} \times \frac{1.6 \times 10^5}{1.2 \times 10^4} = 2$$

times as many earthquakes as the Western Quebec Zone per km^2. Applying this factor to equation (7) produces the area normalized Niagara Area cumulative recurrence equation

$$N(\geq M) = (6.0 \times 10^{-2})\ e^{-2.3M} \qquad (10)$$

which is shown plotted in Figure 6.

A Circular Area of Radius 150 Km around Darlington

It can be seen in Figure 1 that all earthquakes in magnitude categories $M \geq 4$ within a radius of 200 km of the Darlington Site fall within the rectangular Niagara Area. If the Niagara Area earthquakes were normalized with an area of $\pi(200)^2$, the area normalized cumulative recurrence rate would be approximately equivalent to that of the Eastern Great Lakes Area as a whole (equation (8)). That is, a circular area with radius 200 km from the Darlington site is seen to be as seismic as the entire Eastern Great Lakes Area.

However, these earthquakes in magnitude categories $M \geq 4$ are actually contained within a circle of radius 150 km from Darlington, so it is prudent to use this radius for area normalization. This leads to an area normalized recurrence equation of

$$N(\geq M) = (1.2 \times 10^{-2})\ e^{-2.3M} \qquad (11)$$

for the seismicity within 150 km of the Darlington site. As this result indicates greater ambient seismicity in the vicinity of the Darlington site than did the treatment of the Eastern Great Lakes Area as a whole, the latter area need not be retained for consideration of Darlington site DBSGM. Equation (11) is shown plotted in Figure 6.

The Clarenden-Lynden Structure

U.S. authorities are actively investigating a sub-surface fault trace in the vicinity of Attica, New York. Present day microearthquake activity appears to outline a fault surface at depth, called the Clarenden-Lynden structure, but for which there is only a minor topographic expression on the surface. It is believed that the 12 August 1929 M5.5 Attica earthquake was associated with this structure and that later, smaller earthquakes and the microearthquakes represent continuing activity.

The U.S. authorities have tentatively traced the structure in the direction of Lake Ontario, approximately in the position shown by the solid line in Figure 1, and are presently planning a project of seismic sounding in Lake Ontario in an attempt to establish the continuation or absence of the structure beneath the lake.

The Geological Survey of Canada has available a small amount of lake-bottom profiling data from previous seismic sounding experiments in Lake Ontario. The profiles in the vicinity of the tentative extension of the structure across Lake Ontario have been studied by EPB staff. These data shown no evidence for an active basement fault beneath the Canadian territorial waters of the lake, although the data are barely adequate to detect one if it did exist.

For U.S. nuclear power plant site investigations, as specified in 10 CFR Part 100, Appendix A, (U.S. NRC, 1975a) it would be necessary to establish the "capability" of such a fault structure and the extent over which it could be considered "capable". Should such a structure be shown to be a "capable" fault, U.S. NRC policy (U.S. NRC, 1975b) would require that any nuclear plant in the general vicinity be located away from the structure in a region with a demonstrable absence of 'capable' faults.

Although the outcome of U.S. studies cannot be anticipated at this time, it is prudent to assume the "worst" in assessing the potential influence of the Clarenden-Lynden seismicity on the Darlington site. Assuming it is a "capable" fault with roughly the position shown in Figure 1, the Canadian draft seismic design code specifies (section 3.4.2.): "An area of capable faulting, which has an observed, inferred or estimated earthquake recurrence rate associated with it, shall be delineated as a zone of earthquake occurrence within this definition and the equivalent information shall be provided....".

The only earthquakes in the EPB file which might be associated with such a structure are those shown closely grouped near Attica, New York, on Figure 1. (Smaller earthquakes detected only by U.S. agencies are not included in the EPB file.) The Attica group contains 10 earthquakes, all occurring in 1929 and later, one each of M5.5, M4.5 and M4, and the rest M<4. With no recorded historical seismicity prior to 1929, it is not possible to estimate a stable time period of representative seismicity and, thereby, a per annum recurrence rate. It is therefore necessary to fall back on a rule-of-thumb and assign an earthquake, say, one magnitude unit larger than the largest historical earthquake; in this case one unit larger than the 1929 M5.5 Attica earthquake, M6.5.

The Attica earthquakes have, above, been treated in three ways: as part of the Niagara Area seismicity, as part of the ambient seismicity within 150 km of the Darlington site, and as representative historical seismicity on the postulated Clarenden-Lynden structure. The three possibilities are essentially mutually exclusive. However, notwithstanding this triple treatment of the Attica earthquakes and the double treatment of the other Niagara Area earthquakes, the three sets of results described above will be used independently in assessing the Darlington design earthquakes.

DARLINGTON DESIGN EARTHQUAKES

The seismicity in the region of Figure 1, as it has been analyzed and presented in the above sections, can now be employed to determine the potentially severe (design) earthquakes for the Darlington site. These design earthquakes are to be chosen on the basis of the four separate treatments of the regional seismicity:

a) the Western Quebec Zone,

b) the ambient seismicity within 150 km of the Darlington site,

c) the Niagara Area, and

d) the Clarenden-Lynden structure.

The two delimited zones are the Western Quebec Zone and the tentative Niagara Area for which equations (6) and (9), respectively, give the cumulative earthquake recurrence rates. The magnitudes appropriate to selected recurrence rates in these two zones are as follows:

N (per annum)	Western Quebec	Niagara
	M ≥	
10^{-2}	5.7	4.9
10^{-3}	6.7	5.9
10^{-4}	7.7	6.9

The magnitudes for selected values of N are also directly readable from Figure 4. Thus, earthquakes greater than or equal to the magnitudes given will occur at random within the Western Quebec Zone and Niagara Area at the given annual recurrence rates. The cumulative earthquake recurrence equations allow the selection of any annual recurrence rate believed appropriate. For this assessment, a value of $N = 10^{-3}$ is selected as the reference annual rate, but the results for other rates can be determined from the data presented.

The assumption of random earthquake occurrence precludes a determination of specific locations for these earthquakes. Given the geographic setting of these zones with respect to the Darlington site (see Figure 1), M6.7 and M5.9 (rather than $M \geq 6.7$ and $M \geq 5.9$) are chosen and, for purposes of estimating the Darlington DBSGM, these earthquakes are placed on the boundaries of the zones at their nearest approach to the Darlington site. Thus, two of the design earthquakes become M6.7 on the southwestern boundary of the Western Quebec Zone about 200 km from the Darlington site and M5.9 on the northern boundary of the Niagara Area about 60 km from the Darlington site.

The Clarenden-Lynden design earthquake becomes M6.5 (with no associated annual recurrence rate) placed on the postulated extension of the Clarenden-Lynden structure at its nearest approach to the Darlington site, i.e., at a distance of about 110 km (see Figure 1).

The ambient seismicity within a circular area of radius 150 km from the Darlington site is estimated by equation (11) to be

$$N(\geq M) = (1.2 \times 10^{-2})\ e^{-2.3M}$$

per annum per km^2. Earthquakes <u>within</u> a circle of radius r km from the Darlington site recur with a per annum rate given by

$$N(\geq M) = \pi r^2 (1.2 \times 10^{-2})\ e^{-2.3M}$$

This equation leads to the following result for $N = 10^{-3}$ and M5, 6:

$M \geq 5$ at $r \leq 50$ km ?

$M \geq 6$ at $r \leq 160$ km. ?

Note that the selection of $M \geq 6$ implies an extension of the Darlington ambient seismicity to a distance of 10 km beyond the radius upon which the area-normalized recurrence rate was based. The "double exceedence" nature of these results suggests prudent placement of the design earthquakes would be

$$M5 \text{ at } \Delta = 20 \text{ km}$$

$$M6 \text{ at } \Delta = 70 \text{ km}$$

i.e., at distances somewhat less than r/2.

It is seen in the above results that, when the earthquakes in magnitude categories $M \geq 4$ in the vicinity of the Darlington site are confined to a hypothetical Niagara Area zone, the resulting design earthquake is M5.9 at 60 km, the nearest approach to the Darlington site. When the same earthquakes are assessed as general ambient seismicity within 150 km of the Darlington site, one resulting design earthquake is M6 at 70 km. As no assessment of specific propagation paths (see below) is being made in the time available for this review, the Niagara Area design earthquake will be considered redundant. The Clarenden-Lynden design earthquake, which is based on part of the same seismicity, will, however, be retained for the reasons presented.

The reader is reminded of the lack of a full investigation in this assessment by the following quotation from section 4.2.1 of the draft seismic design code: "For each of the cases....attention will also be given to the possibility of: a) there being earthquakes in the zone with sufficiently different parameters, e.g., focal depth, that they will produce most severe ground motion at a site in different frequency ranges; and b) there being sufficient areal differences in the regional seismological parameters, e.g., a narrow region of high seismic propagation efficiency, that equivalent earthquakes in different areas of the zone will produce ground motion at a site of a different nature, e.g., in time duration, in frequency, in horizontal or vertical component motion." Although some account will be taken of the efficient seismic wave propagation in eastern North America in setting the response spectrum level, this assessment does not in general comply with the above quoted requirement of the draft code. The intent of the draft code would be met by an attempt to establish whether the seismic wave propagation properties are sufficiently different that earthquakes, for example, at equivalent distances in northern New York and eastern Ontario would produce different seismic ground motion at the Darlington site.

The four design earthquakes retained for determination of the Darlington DBSGM are summarized in Table 4.

DARLINGTON DESIGN BASIS SEISMIC GROUND MOTION

It is intended to present the Darlington DBSGM in terms of as many ground motion parameters as possible. The writer, however, does not have a full understanding of the engineering requirements and procedures, so some of the parameters presented may be less relevant than others. Some needed parameters may not be presented; a later attempt can be made to provide them if EPB is informed of the specific requirement.

Peak Acceleration

W.G. Milne (personal communication, 1975) has recently derived peak ground motion attenuation equations on the basis of the strong ground motion records presently available. The equation for peak acceleration as a function of magnitude (M) and hypocentral distance (R) is

$$acc.(g) = 0.06\ e^{0.92M} R^{-1.38} \qquad (12)$$

where $R = (\Delta^2 + h^2)^{\frac{1}{2}}$. Milne is recommending that for eastern Canadian sites the peak acceleration be determined as the greater value determined from equation (12) and the previous Milne-Davenport relationship (Milne and Davenport, 1969). This combined relationship is shown in Figure 7 for magnitudes M4 to M7. In Figure 6 equation (12) is computed with h = 18 km.

The peak acceleration equation represents a least-squares fit to very scattered empirical peak acceleration data, and is predicting the average peak acceleration for specified M and R. The average peak accelerations for the four Darlington design earthquakes are given in Table 5.

The empirical peak acceleration data show a standard deviation of an individual observation with respect to the best-fitting line of about a factor of two (Milne, 1975; see also Orphal and Lahoud, 1974, and Donovan, 1974). Given the occurrence of the design earthquake, there is then an 84 percent probability that the peak acceleration will not exceed two times the average value, assuming the logarithmic data have a normal distribution with respect to the best-fitting line. The design peak accelerations are, therefore, accepted as two times the average values as shown in Table 5.

The philosophy here is as follows. A design earthquake is, by definition, an earthquake whose possible effects the plant must be designed to withstand. As possible effects include peak accelerations covering a broad range both sides of the average value, it is prudent to include as the possible effect a peak acceleration at least one standard deviation above the average value.

Peak Velocity

The Milne (1975) equation for peak velocity as a function of magnitude and hypocentral distance is

$$\text{vel. (cm/sec)} = 0.43\ e^{1.31M_R - 1.36} \tag{13}$$

The average and design peak velocity for the four Darlington design earthquakes are presented in Table 6. The design values are scaled up a factor of two from the average values for reasons identical to those discussed above for peak acceleration.

Peak Displacement

The Milne (1975) equation for peak displacement is

$$\text{displ. (cm)} = 0.18\ e^{1.11M_R - 1.0} \tag{14}$$

The average and design peak displacements for the four Darlington design earthquakes are presented in Table 7, with the design values again scaled up a factor of two.

Ground Motion Response Spectrum

The design parameters presented in Tables 5, 6 and 7 will be discussed here in terms of setting the appropriate levels of the ground response spectrum; they will be used in the following section to determine representative strong motion time histories appropriate as input for the engineering analysis.

It appears to be accepted procedure to use estimated design values of peak acceleration, velocity and displacement to set the levels of the acceleration-, velocity- and displacement-flat portions of the standard smoothed response spectrum. It has not, however, been established how a set of, for example, peak accelerations from a set of design earthquakes would be used for this purpose. There is clear evidence from earthquake strong motion recordings that smaller, nearer earthquakes produce peak ground motion at a site that has higher dominant frequencies than that produced by larger, distant earthquakes. There is, however, no available empirical law that allows a prediction of a specific band of dominant frequencies as a function of magnitude and epicentral distance. It is assumed here that, within each of the flat portions of the standard smoothed response spectrum, the larger design earthquakes will contribute to the lower frequencies and the smaller design earthquakes will contribute to the higher frequencies.

If the uncertainties in each stage of the development of the DBSGM are borne in mind, from the initial treatment of the regional seismicity to the application of the empirical attenuation laws, it must be concluded that very little resolution remains in the resulting peak ground motion design parameters. In the end we can accept the results at face value, or we can use them as a general guide in setting design levels. I have chosen to do the latter to produce a ground motion response spectrum whose design levels are representative of a recurrence rate of 10^{-3} per annum.

Table 5 shows that the Darlington DBSGM should include a peak acceleration of 0.12g from an M5 earthquake at 20 km distance. All available evidence (see following sections) indicates that this will be a high frequency acceleration of very short duration. It is not, therefore, considered appropriate as a design level for the entire frequency range of the acceleration-flat portion of the response spectrum. The intermediate design earthquakes in Table 5 indicate design peak accelerations in the range near 0.08g, and this level is adopted for the acceleration-flat portion of the response spectrum (see Figure 8).

Tables 6 and 7 indicate that the Darlington DBSGM should include peak velocity and peak displacement up to 7 cm/sec (2.8 in/sec) and 4.4 cm (1.7 in) respectively. These results (equations (13) and (14)) are derived from predominantly western U.S. attenuation conditions, and no adjustment has been made for eastern Canadian conditions, as was done in the case of peak acceleration by adopting the Milne-Davenport law at greater distances. It is accepted that the same seismic waves, e.g., the crustal S wave, will produce equivalent peak ground motion at the nearer distances in both eastern Canadian and western U.S. crustal conditions. This is the justification for adopting the western U.S. peak acceleration data for eastern Canadian sites in the near distance range. The same is true of peak velocities and displacements, but in the case of the lower frequencies of strong ground motion another phenomenon must be accounted for. In the eastern Canadian crust at distances greater than several focal depths, the dominant low frequency energy will be carried by the Lg wave, higher mode surface waves and fundamental mode surface waves. Each of these waves is either absent or more highly attenuated in the more complicated western U.S. crust. The specific amount by which such waves will contribute greater peak velocities and displacements in eastern Canada has not been determined, but in order to account in some manner for them the response spectrum velocity and displacement levels are set 30 per cent higher than the peak design values for the intermediate design earthquakes given in Tables 6 and 7, respectively. Thus, in Figure 8, the Darlington ground response spectrum is set with a velocity level of 9.1 cm/sec (3.6 in/sec) and a displacement level of 5.7 cm (2.2 in.).

The differences between the resulting Darlington ground motion response spectrum and the velocity-normalized standard smoothed response spectrum of Duff (1975) are evident in Figure 8. The shift of the Darlington spectrum to the left in Figure 8 can, in general terms, be viewed as a shift that pertains to the dominance of larger earthquakes at a distance rather than smaller earthquakes nearby (see, for example, Figure 12 of Whitham and Hasegawa, 1975).

A specific requirement of the draft seismic design code is an alteration of the response spectrum to account for the soil and foundation conditions at the site. As the soil and foundation conditions that will obtain at Darlington are not known to the writer, no account has been made for them in Darlington response spectrum in Figure 8.

Although not specifically stated in the foregoing, the peak ground motion parameters and the resulting ground motion response spectrum are representative of the horizontal component. Neither the EPB staff nor the CNA subcommittee have, to date, provided a recommendation on the relationship between the horizontal and vertical components of the DBSGM. It can be noted that the U.S. NRC (U.S. AEC, 1973) employs the same ground motion spectrum for the horizontal and vertical components, but applies smaller amplification factors for the vertical component at frequencies below 3.5 Hz. Until more earthquake mechanisms are evaluated, one cannot determine whether such a procedure is valid for eastern Canadian conditions.

Duration of Strong Ground Motion

The duration of strong ground motion is recognized as being one of the most important factors in producing excessive damage. Although there does not appear to be a consensus among earthquake engineers on an appropriate definition of duration, a number of definitions and relationships have appeared in the literature. For comparative purposes, some of the more recent ones are presented below.

Lee and Chan (1972) tested available data with durations (D) in seconds defined as the total length of time on an accelerogram between the first and last acceleration peak having a value either greater than 0.05g, greater than 0.25 a_{max}, or greater than 0.50 a_{max}. They presented an upper bound curve for D as a function of magnitude for the first criterion but found the data scatter for the other two criteria so wide that it did not appear useful. It would seem that the latter criteria might prove quite useful for lower level accelerations if a rough estimate as a function of M and Δ could be found.

Bolt (1974) also defined duration at a particular frequency as the elapsed time between the first and last acceleration excursions greater than 0.05g. For frequencies greater than 2 Hz within 25 km of the fault rupture, he found the durations are not likely to exceed

$$D = 17.5 \tanh(M-6.5) + 19.0.$$

This relation is presented in Bolt's Figure 5 and Table 2.

Donovan (1974) defined duration as the time period containing 90 per cent of the total cumulative acceleration squared. This led to the empirical result

$$D = 4 + 11(M-5)$$

Trifunac and Brady (1975), in the most exhaustive analysis to date, defined duration as the interval of time during which between 5 and 95 per cent of the integrated squared acceleration (velocity or displacement) contributes to the total integrated squared acceleration (velocity or displacement). They summarized their general findings as follows. "Correlations of the duration of strong-motion acceleration, velocity, and displacement with site conditions, earthquake magnitude, and epicentral distance indicate that the average duration on a "soft" site is 5 to 6 sec longer than on "intermediate" site and about 10 to 12 sec longer than on a "hard" site. For each magnitude unit the duration increases by 2 (for acceleration) to about 5 (for displacement), while for every 10 km of distance it increases by about 1 to 1.5 sec." For an "intermediate" site for horizontal acceleration the Trifunac and Brady relation is

$$D = -4.88 + 2.33M + 0.149\,\Delta.$$

DBSGM Time Histories

Dynamic analysis of plant structures and components and seismic qualification tests require input functions that are representative time histories of the DBSGM. The CNA subcommittee has not yet made a final recommendation on the manner in which the time histories are to be defined.

There are two basic options: generation of synthetic time histories that contain the important characteristics of the DBSGM, or selection of actual time histories, with modifications as necessary, that are representative of the selected design earthquakes.

A clearer understanding of the analytical methods to be employed in the Darlington design would be required to make specific recommendations on Darlington DBSGM time histories. The following, based on the available seismological evidence, is intended as a guide in the selection of the appropriate time histories.

The best source of guidance, without doubt, is the comprehensive collection of strong motion earthquake accelerograms assembled by the Earthquake Engineering Laboratory, California Institute of Technology (Cal. Tech., 1970-1975). These examples provide information on the detailed characteristics of time histories, which, in conjunction with the magnitude and distance of the Darlington design earthquakes and the specific Darlington DBSGM parameters described above, would enable appropriate Darlington time histories to be determined.

For example, one Darlington time history should be an accelerogram with peak acceleration in the range near 0.12g at relatively high frequencies (e.g., near 10 Hz). This time history should be a transient signal of short duration. The Bolt (1974) and Donovan (1974) relations indicate a duration of about 3 seconds would be appropriate for this signal (DE4 in Table 5). The Trifunac and Brady (1975) relations would suggest a slightly longer duration.

The larger Darlington design earthquakes, DE1, DE2 and DE3 in Table 5, would have more complex time histories with peak accelerations in the range near 0.08g. The Trifunac and Brady relation indicates a duration of about 20 seconds for DE3, 30 seconds for DE2, and 40 seconds for DE1. The appropriate frequency bands for these time histories could be estimated from the Cal. Tech. records.

SUMMARY

This investigation of the historical seismicity in the region of the Darlington site has been undertaken to provide an estimate of the DBSGM for Ontario Hydro's planned nuclear generating station. An attempt has been made throughout the report to justify the assumptions made in the analysis and to indicate clearly those aspects of a desired, full investigation that have not been undertaken within the time available.

The Darlington DBSGM, representative of a recurrence rate of 10^{-3} per annum, can be summarized as follows. It would include all possible effects of a magnitude 5 earthquake at mid-crustal depth at an epicentral distance of 20 km, a magnitude 6 earthquake at an epicentral distance of 70 km, a magnitude 6.5 earthquake at an epicentral distance of 110 km on the south shore of Lake Ontario and a magnitude 6.7 earthquake at an epicentral distance of 200 km in eastern Ontario. These effects include a high frequency transient acceleration with duration about 3 seconds and peak acceleration about 0.12g, and strong motion time histories with durations up to about 40 seconds and peak accelerations, velocities and displacements up to about 0.08g, 7 cm/sec and 4.6 cm, respectively. The ground motion response spectrum representation of the DBSGM would have acceleration-, velocity- and displacement-flat segments set to about 0.08g, 9 cm/sec and 6 cm respectively, with further adjustment, as necessary, to account for the influences of local site conditions.

This is not a unique interpretation of the Darlington DBSGM in terms of the regional seismicity, but it is believed that sufficient information has been presented in the body of this report to enable an independent judgment to be made of the adequacy of suggested Darlington seismic design parameters.

ACKNOWLEDGEMENTS

I am grateful for discussions with and contributions from D.H. Weichert, H.S. Hasegawa, M.J. Berry and A.E. Stevens.

REFERENCES

Bolt, B.A. 1974. Duration of strong ground motion. Proc. Fifth World Conference on Earthquake Engineering, Vol. 1, 1304, Rome.

Cal. Tech. 1970-1975. Strong motion earthquake accelerograms: digitized and plotted date, Volume II - Corrected accelerograms and integrated ground velocity and displacement curves. Earthquake Engineering Laboratory, California Institute of Technology.

Coffman, J.L., and von Hake, C.A., (Eds). 1973. Earthquake History of the United States, U.S. Dept. of Commerce, Pub. 41-1.

Donovan, N.C. 1974. Earthquake hazards for buildings. Dames and Moore Eng. Bull. 46, 3-20.

Duff, G.C. 1975. Simplified method for development of earthquake ground and floor response spectra for nuclear power plant design. Conference Preprints, Second Canadian Conference on Earthquake Engineering, Hamilton, Ontario.

EMR. 1975. Seismic design requirements for CANDU nuclear power plants. Part II Ground Motion. Partial draft for CNA Standard N289.2, Earth Physics Branch, Dept. of Energy, Mines and Resources.

Lee, K.L., and Chan, K. 1972. Number of equivalent significant cycles in strong motion earthquakes. Proc. Internat. Conf. on Microzonation, Vol. II, 609-627.

Milne, W.G., and Davenport, A.G. 1969. Distribution of earthquake risk in Canada. Bull. Seism. Soc. Am. 59, 729-754.

Orphal, D.L. and Lahoud, J.A. 1974. Prediction of peak ground motion from earthquakes. Bull. Seism. Soc. Am. 64, 1563-1574.

Smith, W.E.T. 1962. Earthquakes of eastern Canada and adjacent areas 1534-1927. Pub. Dom. Obs. 26, 271-301.

Smith, W.E.T. 1966. Earthquakes of eastern Canada and adjacent areas 1928-1959. Pub. Dom. Obs. 32, 87-121.

Stevens, A.E., Milne, W.G., Wetmiller, R.J. and Leblanc, G. 1973. Canadian earthquakes - 1967. Seism. Series Earth Physics Branch, No. 65.

Stevens, A.E., Milne, W.G., Horner, R.B., Wetmiller, R.J., Leblanc, G., and McMechan, G.A. 1975. Canadian earthquakes - 1968. Seism. Series Earth Physics Branch, No. 71.

Trifunac, M.D., and Brady, A.G. 1975. A study on the duration of strong earthquake ground motion. Bull. Seism. Soc. Am. 65, 581-626.

U.S. AEC. 1973. Design response spectra for seismic design of nuclear power plants. U.S. Atomic Energy Commission, Regulatory Guide 1.60.

U.S. NRC. 1975a. Seismic and geologic siting criteria for nuclear power plants. Appendix A of Reactor Site Criteria, U.S. Nuclear Regulatory Commission, Rules and Regulations, Title 10, Chap. 1.

U.S. NRC. 1975b. Surface Faulting. U.S. Nuclear Regulatory Commission, Standard Review Plan, Sec. 2.5.3.

Whitham, K., and Hasegawa, H.S. 1975. The estimation of seismic risk in Canada - a review. Pub. Earth Physics Branch, 45, No. 2, in press.

Table 1

Time and Magnitude Distribution of Western

Quebec Zone Earthquakes

Years	M<4	M4	M4.5	M5	M5.5	M6	M>6
(1661)-1699					1		
1700-1749							1
1750-1799							
1800-1819	2			1	1		
1820-1839							
1840-1849	5			1			
1850-1859	8						
1860-1869	1		1	1	1		
1870-1879	12		3	1			
1880-1889	26						
1890-1899	8		1	1	1		
1900-1909	9		2				
1910-1919	5	3	3		1		
1920-1929	13	3	1				
1930-1939	50	7	5	1		1	
1940-1949	68	11	1			1	
1950-1959	69	6	2	1			
1960-1969	74	5	2				
1970-1974	66	1	1				

Table 2

Time and Magnitude Distribution of Eastern

Great Lakes Area Earthquakes

Years	M<4	M4	M4.5	M5	M5.5
1820-1839	1				
1840-1849	4	1		1	
1850-1859	3	1		2	
1860-1869	1				
1870-1879	7		2	1	
1880-1889	14		1		
1890-1899	2				
1900-1909	2	2			
1910-1919	2	1	2		
1920-1929	15				1
1930-1939	29	2	1	2	
1940-1949	17	3	1		
1950-1959	22	6		2	1
1960-1969	19	2	2	1	
1970-1974	5				

Table 3.

Time and Magnitude Distribution of

Niagara Area Earthquakes

Years	M<4	M4	M4.5	M5	M5.5
1840-1849		1			
1850-1859	2			1	
1860-1869					
1870-1879	3		1		
1880-1889	4				
1890-1899	1				
1900-1909					
1910-1919	1		1		
1920-1929	4				1
1930-1939	4				
1940-1949					
1959-1959	4	1			
1960-1969	6		1		
1970-1974	1				

Table 4.

Darlington Design Earthquakes*

Design Earthquake	M	Δ(km)	Remarks
DE1	6.7	200	On the southwestern boundary of the Western Quebec Zone.
DE2	6.5	110	On an extension of the Clarenden-Lynden structure on the south shore of Lake Ontario
DE3	6	70	In any direction from the Darlington site.
DE4	5	20	In any direction from the Darlington site.

*Mid-crustal focal depths (h = 18 km) will be assumed for all earthquakes.

Table 5.

Peak Acceleration (g) for Darlington Design Earthquakes

Design Earthquake	M	Δ	Average	Design Peak Acceleration
DE1	6.7	200	0.027	0.06
DE2	6.5	110	0.038	0.08
DE3	6	70	0.041	0.08
DE4	5	20	0.063	0.12

Table 6.

Peak Velocities for Darlington Design Earthquakes

Design Earthquake	M	Δ	Average Peak Vel. (cm/sec)	Design Peak Velocity cm/sec	in/sec
DE1	6.7	200	2.1	4.2	1.7
DE2	6.5	110	3.5	7.0	2.8
DE3	6	70	3.3	6.6	2.6
DE4	5	20	3.4	6.8	2.7

Table 7

Peak Displacements for Darlington Design Earthquakes

Design Earthquake	M	Δ	Average Peak Displ. (cm)	Design Peak Displacement (cm)	(in)
DE1	6.7	200	1.5	3.0	1.2
DE2	6.5	110	2.2	4.4	1.7
DE3	6	70	2.0	4.0	1.6
DE4	5	20	1.7	3.4	1.3

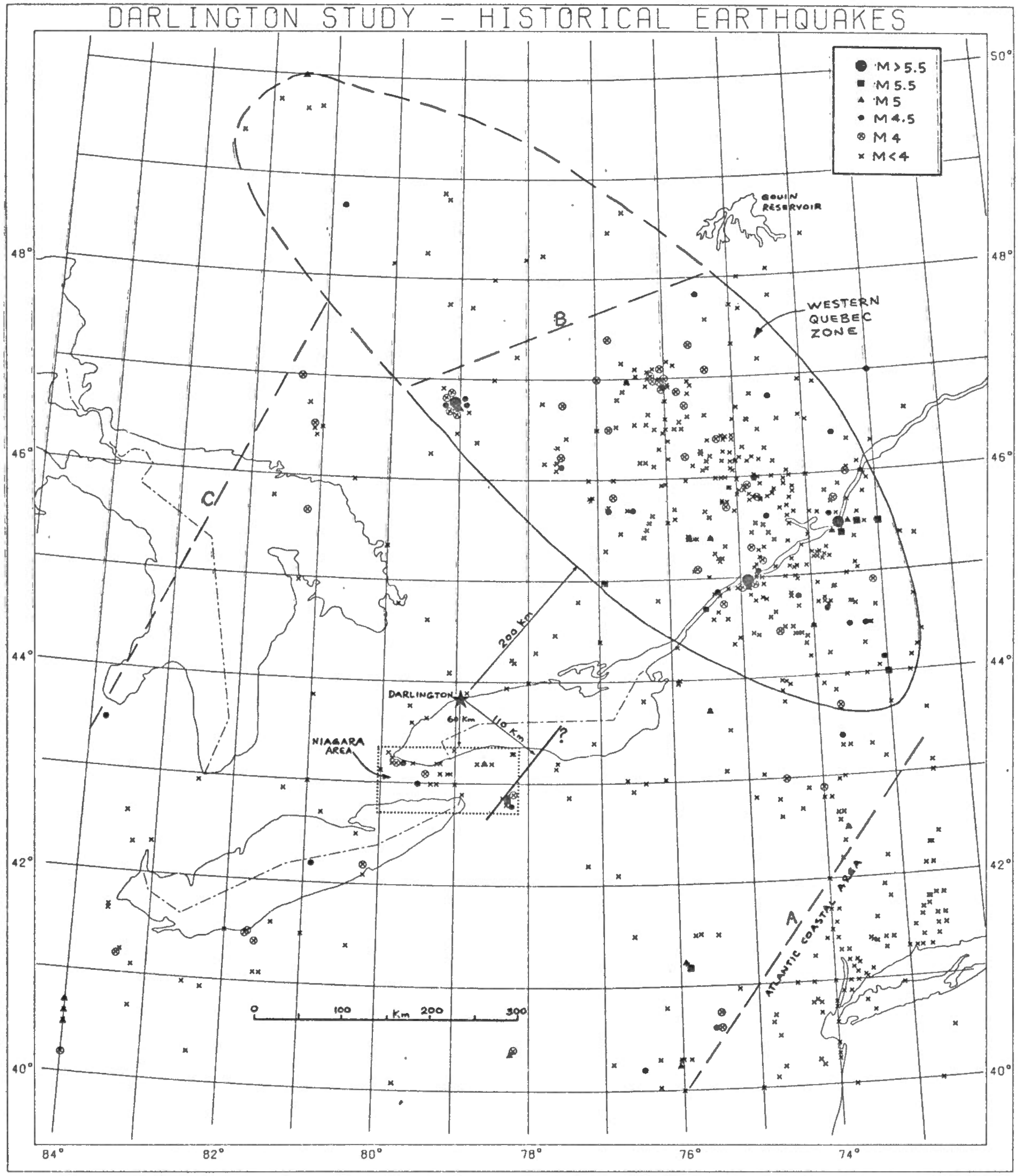

DARLINGTON STUDY - HISTORICAL EARTHQUAKES
M > 5.5
M 5.5
M 5
M 4.5
M 4
M<4
GOUIN RESERVOIR
WESTERN QUEBEC ZONE
B
C
A
ATLANTIC COASTAL AREA
DARLINGTON
200 Km
60 Km
110 Km
?
NIAGARA AREA
0
100
Km 200
300
50°
48°
46°
44°
42°
40°
84°
82°
80°
78°
76°
74°

FIGURE 1.

FIGURE 2.

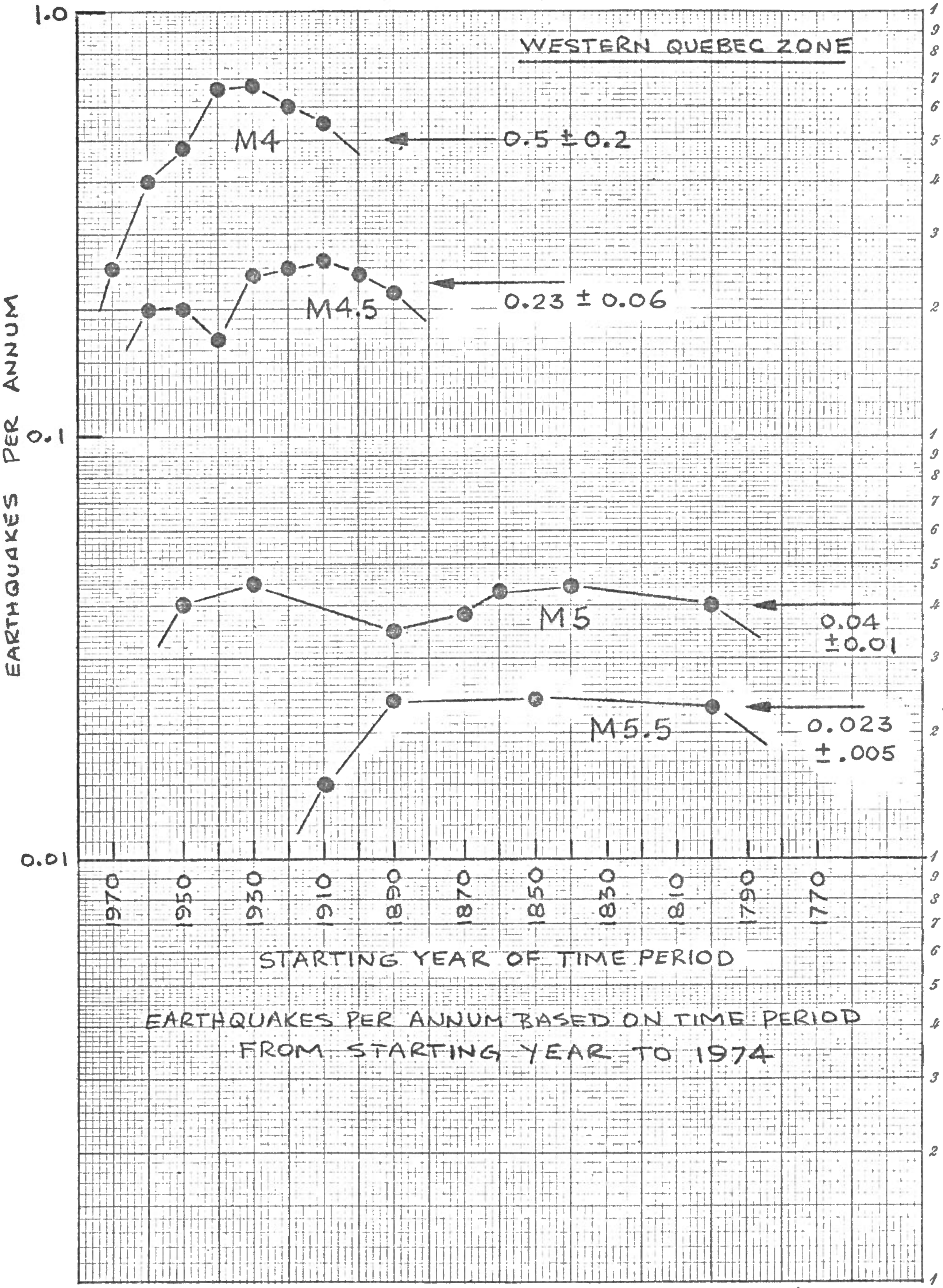
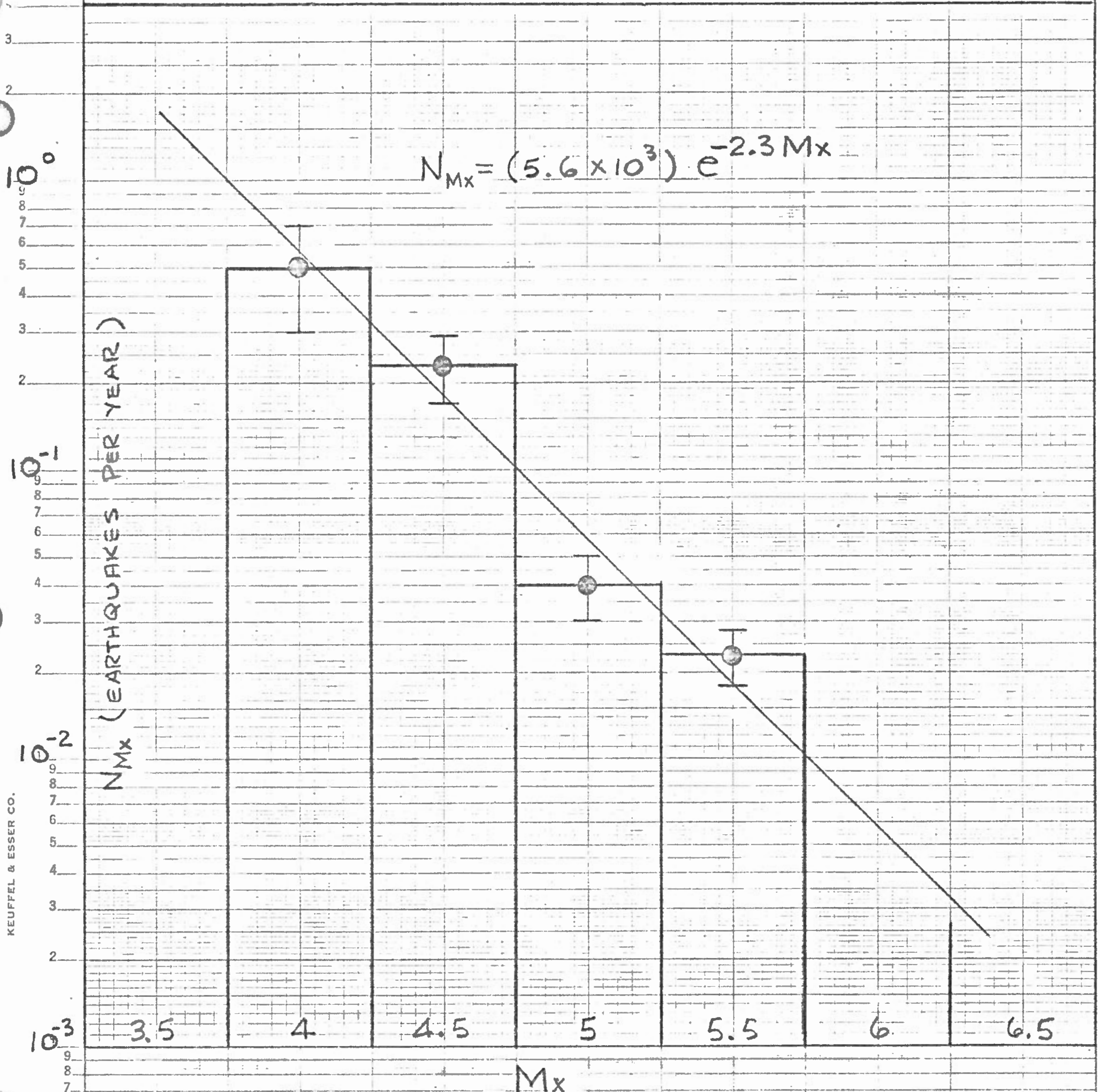
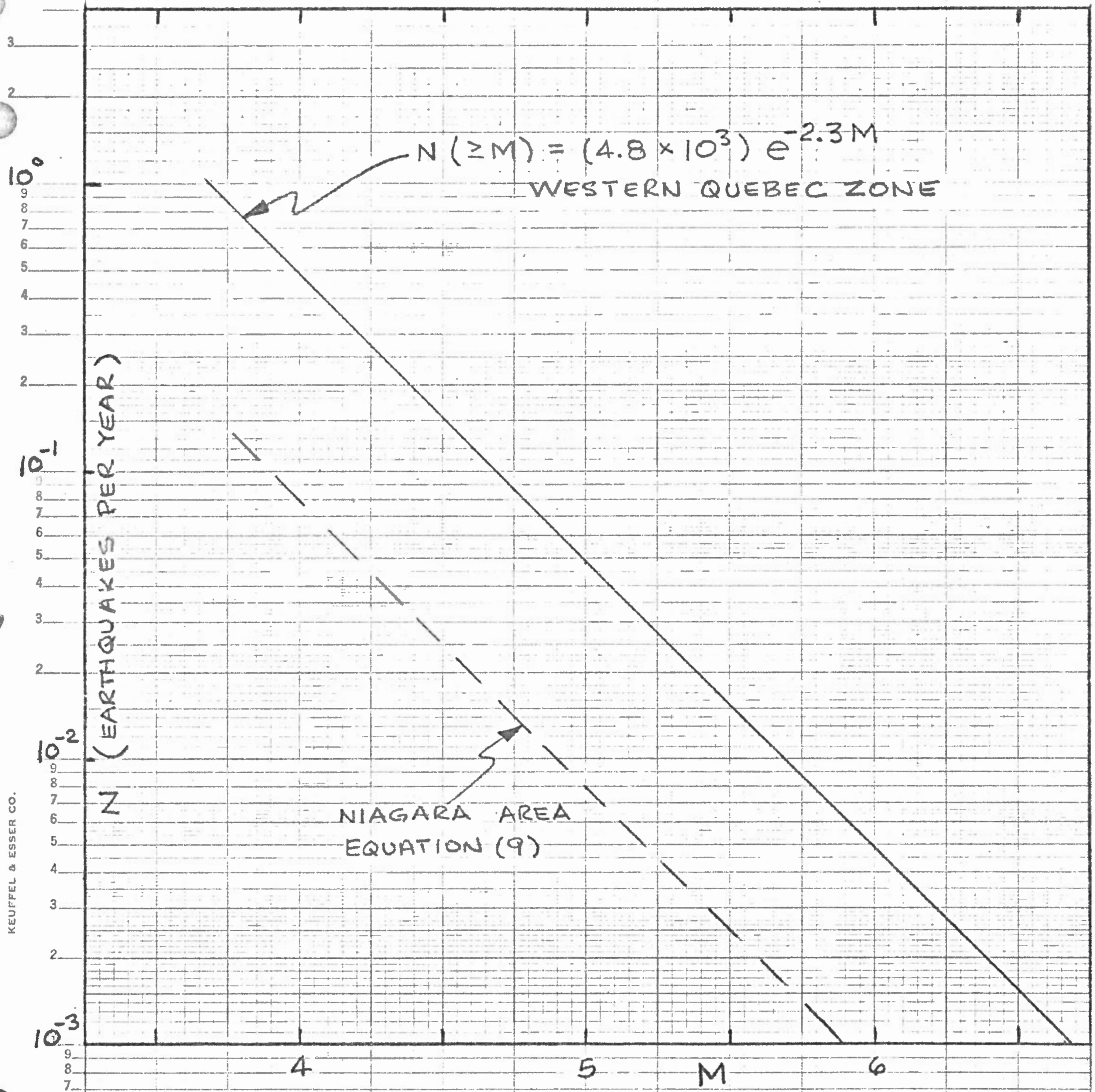

WESTERN QUEBEC ZONE
1.0
0.1
0.01
EARTHQUAKES PER ANNUM
M4
0.5 ± 0.2
M4.5
0.23 ± 0.06
M5
0.04
±0.01
M5.5
0.023
±.005
1970
1950
1930
1910
1890
1870
1850
1830
1810
1790
1770
STARTING YEAR OF TIME PERIOD
EARTHQUAKES PER ANNUM BASED ON TIME PERIOD
FROM STARTING YEAR TO 1974

FIGURE 3.



WESTERN QUEBEC ZONE HISTORICAL EARTHQUAKE RECURRENCE

FIGURE 4.



CUMULATIVE MAGNITUDE RECURRENCE EQUATIONS

FIGURE 5

ACTUAL VS. PREDICTIVE CUMULATIVE EARTHQUAKE RECURRENCE IN WESTERN QUEBEC ZONE SINCE 1860

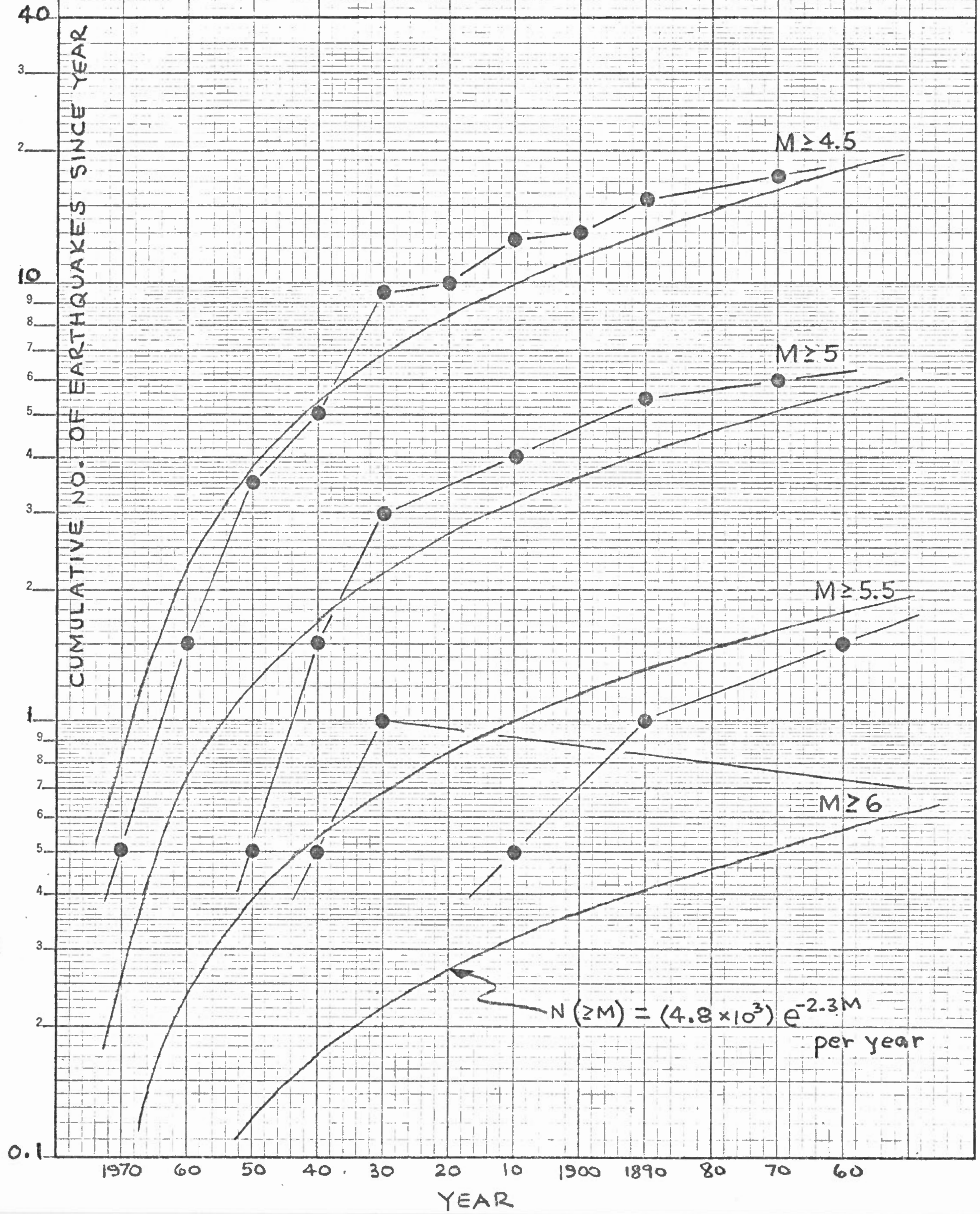
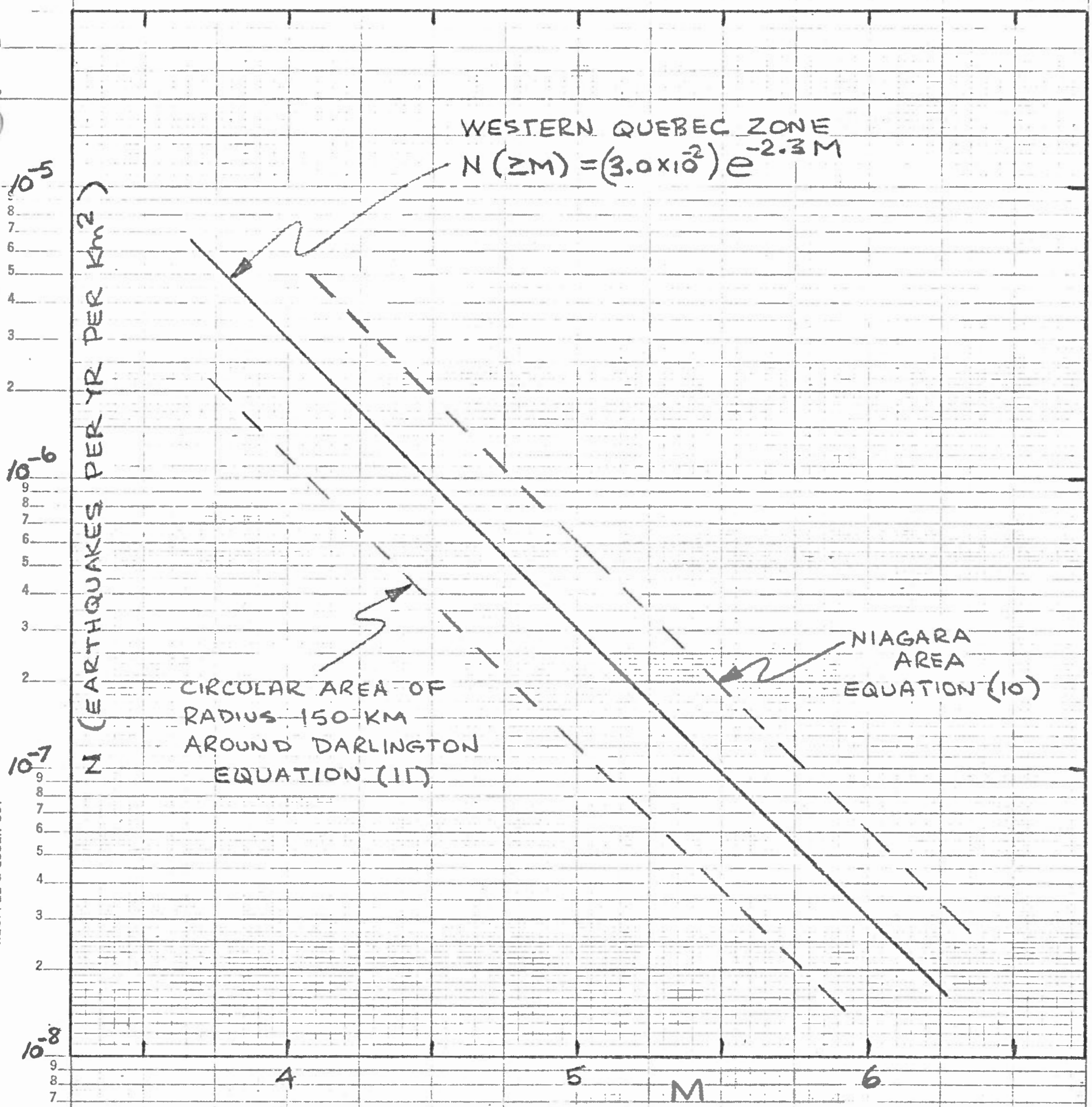
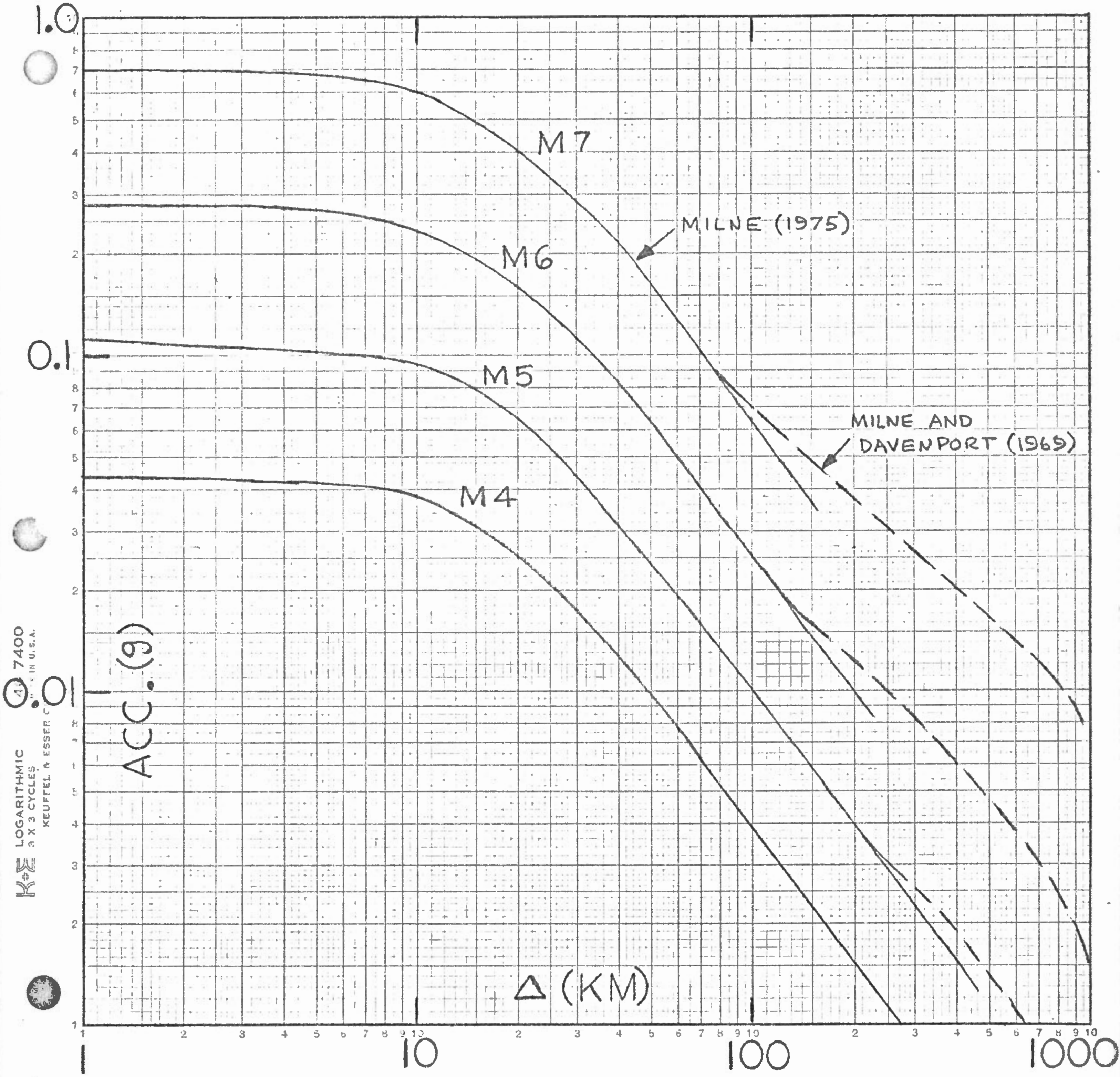


FIGURE 6.



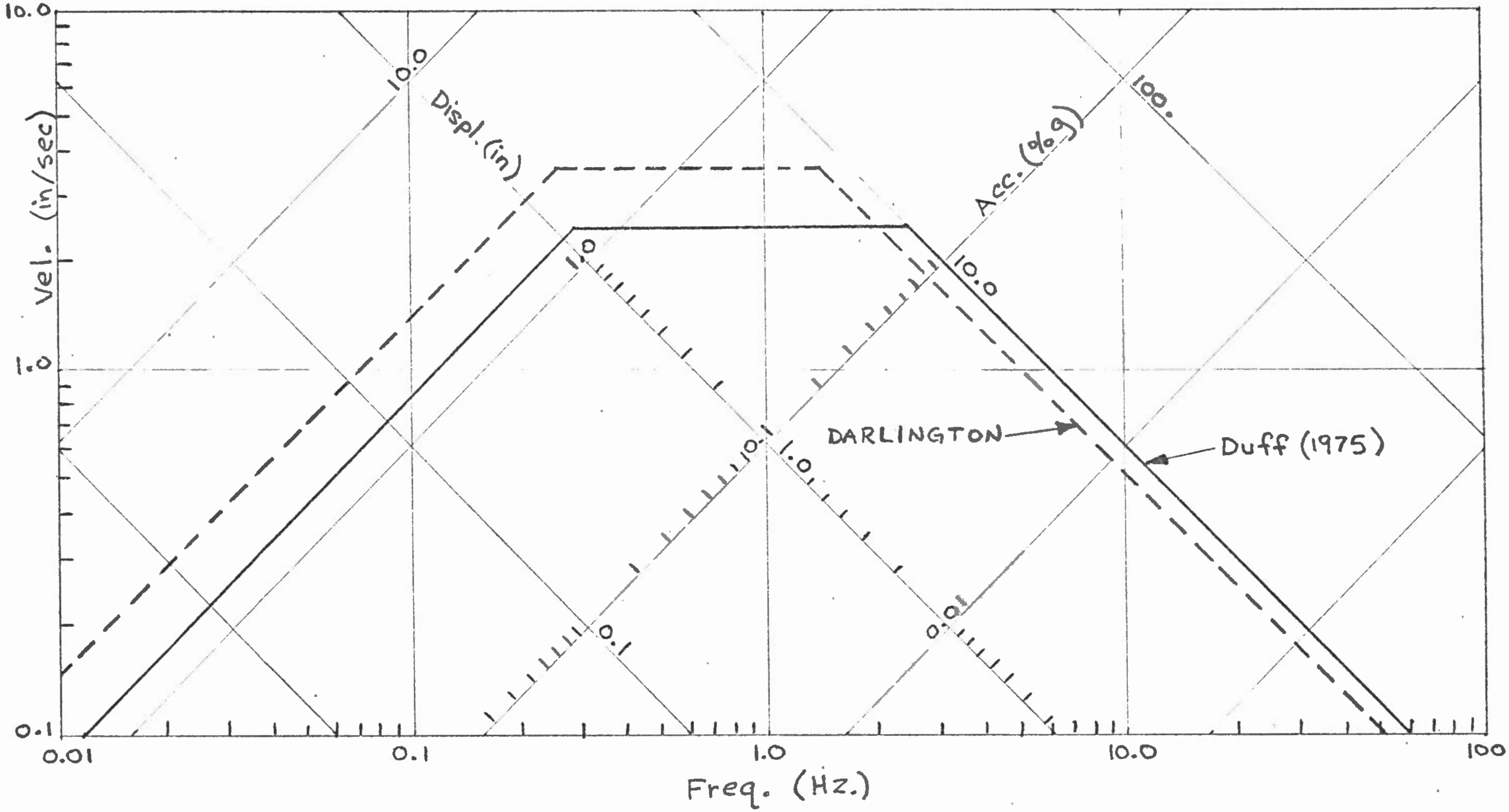
AREA-NORMALIZED CUMULATIVE MAGNITUDE RECURRENCE EQUATIONS

FIGURE 7.



PEAK ACCELERATION ATTENUATION IN EASTERN CANADA

FIGURE 8.



GROUND MOTION RESPONCE SPECTRA

APPENDIX

<u>List of Historical Earthquakes in the</u>
<u>Region of the Darlington Site</u>

Appendix to "Design Basis Seismic Ground Motion for Darlington Nuclear Generating Station A" by P.W. Basham. Seismological Service of Canada, Internal Report 75-16, December 1975.

The following table is a list of all historical earthquakes in the region of the Darlington site extracted from the Earth Physics Branch earthquake data file. The list contains all earthquakes on the file with epicentres within the region bounded by latitudes 40° to 50°N and longitudes 72.5° to 84°W.

The "file magnitudes" are the magnitudes that have been assigned to the earthquake in the data file. In the pre-instrumental era these are magnitudes converted from the maximum reported intensity; in the instrumental era they are instrumental magnitudes (see text). The column headed "magnitude category" shows the magnitude assigned to earthquakes with file magnitude ≥4 for purposes of evaluating the Darlington DBSGM. A brief description of the manner in which the magnitude category was chosen is given in the text. The notation "AC" in the magnitude category column denotes an earthquake in the Atlantic coastal area (see Figure 1) with file magnitude ≥4, but for which no reassessment of magnitude has been made.

YEAR	M	D	H	M	S	LAT(N)	LON(W)	FILE MAGNITUDE	MAGNITUDE CATEGORY
1568	-0	-0	-0	-0	0.0	41.500	72.500	5.7	AC
1574	-0	-0	-0	-0	0.0	41.600	72.500	5.7	AC
1584	-0	-0	-0	-0	0.0	41.600	72.600	5.7	AC
1592	-0	-0	-0	-0	0.0	41.500	72.600	5.7	AC
1661	2	10	12	-0	0.0	45.500	73.000	5.7	5.5
1698	-0	-0	-0	-0	0.0	41.380	73.470	3.7	
1702	-0	-0	-0	-0	0.0	41.400	73.500	3.7	
1711	-0	-0	-0	-0	0.0	41.400	73.500	3.7	
1729	8	6	-0	-0	0.0	41.400	73.500	3.7	
1732	9	16	16	0	0.0	45.500	73.600	7.0	>6
1737	12	18	-0	-0	0.0	40.600	74.000	5.7	AC
1783	11	29	-0	-0	0.0	41.000	74.500	5.0	AC
1792	8	28	-0	-0	0.0	41.500	72.500	3.7	
1792	10	24	6	0	0.0	41.500	72.500	3.7	
1793	1	11	13	-0	0.0	41.500	72.500	3.7	
1793	7	6	11	-0	0.0	41.500	72.500	3.7	
1794	3	9	19	-0	0.0	41.500	72.500	3.7	
1804	5	18	-0	-0	0.0	40.750	74.000	3.0	
1816	9	9	-0	-0	0.0	45.500	73.600	5.7	5.5
1816	9	16	-0	-0	0.0	45.500	73.600	5.0	5.0
1819	8	15	-0	-0	0.0	45.600	74.300	3.0	
1819	11	10	-0	-0	0.0	45.500	73.600	3.0	
1823	5	30	-0	-0	0.0	41.500	81.000	3.7	
1837	4	12	-0	-0	0.0	41.700	72.700	4.4	AC
1840	8	9	20	30	0.0	41.500	72.900	4.4	AC
1840	9	10	-0	-0	0.0	43.200	79.850	4.4	4.0
1841	1	25	-0	-0	0.0	40.750	74.000	3.0	
1842	11	9	-0	-0	0.0	46.000	73.200	5.0	5.0
1843	3	14	-0	-0	0.0	44.400	72.500	3.7	
1844	11	-0	-0	-0	0.0	45.500	73.600	3.7	
1845	1	1	-0	-0	0.0	41.500	72.500	3.0	
1845	10	26	-0	-0	0.0	42.500	73.700	5.0	5.0
1847	1	8	20	0	0.0	44.000	78.000	3.0	
1847	1	11	-0	-0	0.0	42.650	73.750	2.4	
1847	1	14	-0	-0	0.0	44.200	78.200	3.0	
1847	7	9	14	-0	0.0	43.300	73.600	3.0	
1847	11	-0	-0	-0	0.0	45.500	73.600	3.0	
1848	5	23	-0	-0	0.0	45.500	73.600	3.0	
1848	9	8	-0	-0	0.0	40.400	74.000	4.4	AC
1848	12	11	8	0	0.0	45.500	73.600	3.0	
1849	2	15	-0	-0	0.0	42.100	72.600	3.0	
1851	1	30	22	0	0.0	45.600	74.300	3.0	
1851	12	25	-0	-0	0.0	44.000	73.300	3.0	
1852	2	11	10	40	0.0	45.600	73.600	3.0	
1852	12	15	-0	-0	0.0	43.300	78.200	3.0	
1853	3	12	7	0	0.0	43.700	75.500	5.0	5.0
1853	3	13	10	-0	0.0	43.100	79.400	4.4	4.0
1853	5	24	-0	-0	0.0	45.400	75.700	2.4	
1854	12	4	-0	-0	0.0	45.100	74.200	3.0	
1855	1	13	10	40	0.0	45.600	73.600	3.0	

YEAR	M	D	H	M	S	LAT(N)	LON(W)	FILE MAGNITUDE	MAGNITUDE CATEGORY
1855	1	17	-0	-0	0.0	40.800	73.600	2.4	
1855	2	6	-0	-0	0.0	42.000	74.000	5.0	AC
1855	12	17	-0	-0	0.0	43.300	73.700	3.7	
1856	3	12	-0	-0	0.0	41.400	72.600	3.7	
1856	5	1	-0	-0	0.0	45.400	75.700	2.4	
1856	6	10	-0	-0	0.0	43.100	72.500	2.4	
1856	12	28	-0	-0	0.0	45.400	75.700	2.4	
1857	6	30	-0	-0	0.0	41.500	72.500	3.0	
1857	10	23	20	15	0.0	43.200	78.600	5.0	5.0
1858	1	15	-0	-0	0.0	43.100	79.100	2.4	
1858	6	27	-0	-0	0.0	41.400	72.800	3.7	
1858	6	30	-0	-0	0.0	41.300	73.000	3.7	
1861	3	5	-0	-0	0.0	40.700	74.200	3.0	
1861	7	12	-0	-0	0.0	45.400	75.400	5.7	5.0
1861	10	-0	-0	-0	0.0	45.600	73.700	4.4	4.5
1862	2	2	-0	-0	0.0	41.500	72.500	3.7	
1864	10	21	9	10	0.0	45.500	73.600	3.7	
1867	12	18	3	0	0.0	44.000	73.000	5.7	5.5
1869	4	9	13	0	0.0	42.700	80.800	3.0	
1870	3	4	-0	-0	0.0	45.500	73.600	2.4	
1870	10	23	-0	-0	0.0	42.100	72.600	3.0	
1871	1	3	-0	-0	0.0	45.600	74.600	4.4	4.5
1872	2	6	-0	-0	0.0	43.500	83.800	4.4	4.5
1872	7	11	-0	-0	0.0	40.900	73.800	3.7	
1873	3	18	-0	-0	0.0	44.600	75.200	2.4	
1873	3	21	-0	-0	0.0	45.500	73.600	3.0	
1873	4	25	19	0	0.0	44.800	74.200	4.4	4.5
1873	4	30	-0	-0	0.0	43.300	79.900	3.7	
1873	4	30	-0	-0	0.0	45.000	74.700	3.7	
1873	7	6	14	30	0.0	43.000	79.500	5.0	4.5
1873	9	30	11	50	0.0	46.500	76.000	3.7	
1873	9	30	11	50	0.0	45.500	73.200	3.7	
1873	11	4	-0	-0	0.0	44.500	73.200	3.0	
1874	1	5	-0	-0	0.0	44.700	75.500	2.4	
1874	12	10	-0	-0	0.0	40.900	73.800	4.4	AC
1875	4	30	-0	-0	0.0	45.100	74.500	3.0	
1875	6	18	-0	-0	0.0	40.200	84.000	5.7	5.0
1875	7	28	-0	-0	0.0	41.800	73.200	4.4	AC
1875	9	25	-0	-0	0.0	41.300	73.300	2.4	
1876	1	8	-0	-0	0.0	43.200	78.700	2.4	
1877	5	2	-0	-0	0.0	43.900	78.850	3.0	
1877	5	14	-0	-0	0.0	42.800	73.900	2.4	
1877	8	17	-0	-0	0.0	42.300	83.300	3.7	
1877	9	10	-0	-0	0.0	40.100	74.800	3.7	
1877	11	4	-0	-0	0.0	44.500	74.000	5.7	5.0
1877	11	14	14	40	0.0	45.000	74.700	3.0	
1877	12	18	6	0	0.0	45.700	76.850	3.0	
1877	12	18	10	0	0.0	45.700	76.850	4.3	4.5
1878	2	5	-0	-0	0.0	40.000	73.800	4.4	AC
1878	10	4	-0	-0	0.0	41.500	74.000	4.4	AC

YEAR	M	D	H	M	S	LAT(N)	LON(W)	FILE MAGNITUDE	MAGNITUDE CATEGORY
1878	12	24	-0	-0	0.0	40.000	73.800	2.4	
1878	12	28	-0	-0	0.0	42.700	74.300	3.0	
1879	6	11	-0	-0	0.0	45.600	73.600	3.7	
1879	8	21	8	0	0.0	43.200	79.200	3.7	
1879	10	24	-0	-0	0.0	41.300	72.900	2.4	
1880	2	8	-0	-0	0.0	45.400	75.700	2.4	
1880	4	3	-0	-0	0.0	45.400	75.700	2.4	
1880	5	31	-0	-0	0.0	45.200	75.300	3.7	
1880	7	22	7	0	0.0	45.400	75.700	3.0	
1880	9	6	5	30	0.0	45.200	73.800	3.7	
1880	9	6	7	0	0.0	45.000	74.700	3.0	
1880	9	23	-0	-0	0.0	44.300	73.300	2.4	
1881	3	18	-0	-0	0.0	42.800	73.900	3.0	
1881	4	21	-0	-0	0.0	40.950	73.100	3.0	
1881	6	19	-0	-0	0.0	45.400	75.700	2.4	
1881	9	25	-0	-0	0.0	42.100	76.800	2.4	
1881	12	4	23	30	0.0	45.100	74.200	3.0	
1882	4	2	7	-0	0.0	42.900	74.200	2.4	
1882	10	10	11	0	0.0	45.500	73.600	2.4	
1882	11	27	23	30	0.0	43.000	79.250	3.7	
1882	12	4	23	30	0.0	43.000	79.250	2.4	
1883	1	9	8	0	0.0	45.100	74.200	2.4	
1883	3	11	16	-0	0.0	45.350	72.500	3.0	
1883	3	12	-0	-0	0.0	45.100	74.500	3.7	
1883	3	23	14	25	0.0	45.100	74.200	2.4	
1883	4	1	6	0	0.0	43.250	79.850	3.0	
1884	5	31	-0	-0	0.0	40.600	75.500	4.4	4.5
1884	8	10	19	7	0.0	40.600	74.000	5.6	AC
1884	10	24	5	15	0.0	45.100	74.200	3.0	
1884	10	24	14	-0	0.0	45.100	74.200	3.0	
1884	12	4	-0	-0	0.0	42.300	72.600	2.4	
1885	1	4	-0	-0	0.0	41.300	73.900	3.0	
1885	1	15	-0	-0	0.0	40.300	76.300	3.0	
1885	1	31	-0	-0	0.0	41.300	73.800	3.0	
1885	2	3	5	20	0.0	45.100	74.200	3.0	
1885	2	25	5	30	0.0	45.100	74.200	3.0	
1885	3	11	15	57	0.0	45.350	72.500	3.0	
1885	3	23	-0	-0	0.0	45.100	74.200	3.0	
1885	4	28	-0	-0	0.0	41.300	72.700	3.0	
1885	9	4	14	40	0.0	44.300	77.900	3.0	
1886	2	13	-0	-0	0.0	43.950	78.300	2.4	
1886	8	12	-0	-0	0.0	46.000	74.000	3.7	
1886	8	19	8	0	0.0	43.600	79.600	3.0	
1886	9	2	-0	-0	0.0	43.200	79.250	2.4	
1886	9	5	-0	-0	0.0	41.500	72.500	3.7	
1887	2	19	-0	-0	0.0	45.350	80.000	3.7	
1887	3	19	-0	-0	0.0	45.350	80.000	2.4	
1888	1	6	19	30	0.0	45.100	74.200	2.4	
1888	1	11	9	0	0.0	45.800	77.100	3.7	
1888	2	5	-0	-0	0.0	45.400	75.700	2.4	

YEAR	M	D	H	M	S	LAT(N)	LON(W)	FILE MAGNITUDE	MAGNITUDE CATEGORY
1888	3	2	21	30	0.0	45.100	74.200	3.0	
1888	7	1	21	-0	0.0	45.500	73.600	2.4	
1888	7	10	-0	-0	0.0	44.400	77.000	3.0	
1889	3	8	-0	-0	0.0	40.000	76.000	4.4	AC
1890	9	26	8	3	0.0	45.500	73.600	3.0	
1890	10	29	22	30	0.0	45.600	75.900	3.0	
1892	12	26	-0	-0	0.0	45.100	74.300	3.0	
1893	3	9	-0	-0	0.0	40.600	74.000	4.4	AC
1893	11	27	16	50	0.0	45.500	73.300	5.7	5.5
1894	2	23	-0	-0	0.0	43.650	79.400	2.4	
1894	4	10	-0	-0	0.0	41.600	72.500	3.7	
1894	4	17	16	15	0.0	45.600	73.300	3.7	
1894	8	27	5	44	0.0	45.500	73.600	3.0	
1895	5	28	-0	-0	0.0	43.000	72.500	3.0	
1895	9	1	-0	-0	0.0	40.700	74.800	5.0	AC
1895	12	9	5	25	0.0	45.500	73.600	3.0	
1897	3	7	-0	-0	0.0	43.100	79.200	3.7	
1897	3	23	-0	-0	0.0	45.500	73.600	5.7	5.0
1897	3	26	70	-0	0.0	45.500	73.600	3.7	
1897	5	27	-0	-0	0.0	44.500	73.500	5.0	4.5
1897	9	5	-0	-0	0.0	41.500	72.500	3.7	
1898	1	7	6	0	0.0	45.100	74.300	3.7	
1899	5	16	-0	-0	0.0	41.500	72.500	4.4	AC
1903	12	25	12	30	0.0	44.700	75.500	4.4	4.5
1906	5	8	13	30	0.0	41.500	72.500	3.7	
1906	6	27	-0	-0	0.0	41.400	81.600	4.4	4.0
1906	11	17	14	-0	0.0	45.610	75.410	3.7	
1907	1	24	11	30	0.0	42.800	74.000	3.7	
1907	1	25	6	-0	0.0	44.100	79.100	3.7	
1907	11	14	5	0	0.0	45.470	76.680	3.7	
1908	2	5	8	20	0.0	41.400	73.200	3.7	
1908	5	31	17	42	0.0	40.600	75.500	5.0	4.0
1908	6	16	20	41	52.0	45.100	74.800	4.3	4.5
1908	7	17	7	10	0.0	45.430	76.350	3.7	
1908	8	16	-0	-0	0.0	44.670	73.120	3.0	
1909	0	20	10	40	0.0	45.510	73.570	3.0	
1909	2	1	8	20	0.0	45.510	73.570	3.7	
1909	5	9	-0	-0	0.0	46.050	74.280	3.7	
1909	6	8	8	25	0.0	46.050	74.280	3.7	
1909	12	10	6	24	10.0	45.400	75.600	3.7	
1910	2	25	-0	-0	0.0	43.200	79.800	3.7	
1910	3	3	-0	-0	0.0	44.200	74.070	3.0	
1910	5	1	-0	-0	0.0	40.700	73.500	2.4	
1911	1	29	-0	-0	0.0	44.700	75.500	3.0	
1912	5	27	12	52	0.0	43.200	79.700	4.3	4.5
1913	4	29	0	28	57.0	44.870	75.330	4.4	4.5
1913	6	8	6	30	0.0	45.680	74.400	3.7	
1913	8	10	5	15	0.0	44.000	74.000	3.7	
1913	11	15	-0	-0	0.0	41.500	72.500	3.0	
1914	2	10	18	31	0.0	44.980	76.920	5.5	5.5

YEAR	M	D	H	M	S	LAT(N)	LON(W)	FILE MAGNITUDE	MAGNITUDE CATEGORY
1914	2	14	9	34	0.0	46.400	73.600	4.3	4.5
1915	2	21	23	41	0.0	44.700	73.400	3.7	
1916	1	5	13	56	0.0	43.700	73.700	4.4	4.0
1916	2	2	16	26	0.0	42.900	74.000	4.0	4.0
1916	4	24	16	7	45.0	47.000	77.000	4.3	4.0
1916	6	8	21	15	0.0	41.000	73.800	3.7	
1916	11	2	2	32	0.0	43.300	73.700	4.4	4.5
1917	1	26	7	35	48.0	46.800	74.500	4.3	4.5
1917	3	11	-0	-0	0.0	41.500	72.500	3.0	
1917	5	22	9	0	26.0	45.100	75.600	4.0	4.0
1917	10	2	2	14	0.0	43.300	73.600	3.0	
1920	11	8	-0	-0	0.0	46.010	73.430	4.0	4.0
1921	1	19	10	0	0.0	43.300	73.700	3.7	
1921	1	26	23	40	0.0	40.000	75.000	4.4	AC
1921	1	27	-0	-0	0.0	43.300	73.700	3.7	
1921	8	27	8	12	16.0	47.000	76.000	4.0	4.0
1921	9	27	4	32	0.0	42.100	80.200	3.0	
1922	3	16	9	30	0.0	42.950	82.470	3.0	
1922	12	8	16	24	0.0	44.350	75.120	0.0	
1924	7	15	0	10	0.0	45.700	76.500	4.7	4.5
1924	11	14	1	32	0.0	45.500	76.300	3.7	
1925	4	7	20	18	0.0	43.030	76.130	3.0	
1925	5	23	-0	-0	0.0	43.400	77.100	3.0	
1925	10	19	12	5	17.0	47.000	73.000	4.3	4.5
1925	10	24	1	30	0.0	41.400	73.300	3.0	
1925	11	14	8	4	0.0	41.500	72.500	4.4	AC
1925	11	16	6	20	0.0	41.770	72.700	3.7	
1926	1	26	23	40	0.0	40.000	75.000	4.4	AC
1926	1	27	-0	-0	0.0	44.330	74.120	3.7	
1926	5	12	3	30	0.0	40.900	73.900	4.3	AC
1926	5	22	-0	-0	0.0	41.420	73.930	2.4	
1926	10	28	7	42	0.0	41.630	83.550	3.0	
1927	2	16	12	30	0.0	45.430	75.720	2.4	
1927	2	17	4	30	0.0	40.970	82.520	3.7	
1927	3	12	22	12	0.0	44.600	75.200	3.7	
1927	3	14	14	15	0.0	44.600	75.400	3.7	
1927	3	29	20	30	0.0	43.030	76.130	3.0	
1927	3	30	-0	-0	0.0	41.670	72.780	3.7	
1927	3	31	21	0	0.0	43.030	76.130	3.0	
1927	6	1	12	23	0.0	40.300	74.000	5.0	AC
1927	10	24	11	0	0.0	44.730	73.750	3.7	
1927	11	12	-0	-0	0.0	43.100	79.060	3.7	
1928	3	18	15	25	0.0	44.500	74.300	4.1	4.0
1928	3	19	19	7	0.0	46.600	72.500	2.3	
1928	4	1	-0	-0	0.0	45.520	74.650	2.4	
1928	9	9	21	0	0.0	41.500	82.000	3.6	
1928	12	1	-0	-0	0.0	50.000	81.500	5.0	5.0
1928	12	8	4	12	0.0	41.800	72.500	2.4	
1929	4	30	18	53	18.0	45.420	75.700	1.6	
1929	6	5	7	0	0.0	44.800	74.300	3.0	

YEAR	M	D	H	M	S	LAT(N)	LON(W)	FILE MAGNITUDE	MAGNITUDE CATEGORY
1929	8	12	6	0	0.0	42.200	77.200	3.0	
1929	8	12	8	45	0.0	42.870	78.350	3.0	
1929	8	12	11	24	48.0	42.870	78.350	5.8	5.5
1929	9	9	3	30	0.0	46.380	75.970	2.4	
1929	9	9	18	43	48.0	46.200	75.970	2.0	
1929	12	2	22	14	0.0	42.800	78.300	3.6	
1929	12	3	12	50	0.0	42.800	78.300	3.6	
1930	1	4	-0	-0	0.0	43.100	75.300	2.4	
1930	1	17	-0	-0	0.0	42.800	78.300	1.7	
1930	2	16	12	17	0.0	42.500	80.310	3.0	
1930	2	19	11	38	54.0	45.420	75.700	2.4	
1930	3	27	19	30	0.0	42.100	72.700	3.0	
1930	6	26	21	45	0.0	40.500	84.000	3.7	
1930	6	27	7	23	0.0	40.500	84.000	3.0	
1930	7	11	0	15	0.0	40.700	83.200	2.4	
1930	9	29	21	15	0.0	40.300	82.400	3.0	
1930	10	15	-0	-0	0.0	44.230	78.230	2.0	
1930	11	2	2	35	0.0	44.800	74.300	3.0	
1930	11	20	-0	-0	0.0	42.600	83.400	3.0	
1931	1	7	7	21	30.0	45.400	75.720	2.0	
1931	3	21	15	48	0.0	40.300	82.400	2.4	
1931	4	6	20	50	35.0	45.420	75.700	1.7	
1931	4	20	19	54	0.0	43.400	73.700	5.0	4.5
1931	4	22	-0	-0	0.0	42.900	78.900	3.6	
1931	5	4	10	17	0.0	42.400	72.500	3.0	
1931	5	4	16	43	0.0	44.800	77.300	1.7	
1931	6	7	0	0	0.0	43.200	77.600	2.4	
1931	7	1	2	45	0.0	41.600	73.400	3.6	
1931	9	23	22	47	37.0	47.000	76.070	4.5	4.0
1931	11	3	15	30	0.0	44.600	75.200	2.4	
1932	1	21	-0	-0	0.0	41.100	81.600	3.7	
1932	3	9	5	23	38.8	46.470	74.670	3.8	
1932	7	20	23	30	0.0	42.200	73.200	2.4	
1932	12	7	3	15	0.0	44.400	74.100	3.6	
1932	12	7	16	45	0.0	44.400	74.100	3.0	
1932	12	21	11	20	16.0	45.420	75.700	2.0	
1933	1	21	16	4	39.5	45.300	74.650	3.8	
1933	1	25	2	0	0.0	40.200	74.700	4.3	AC
1933	2	23	4	20	0.0	40.300	82.400	3.0	
1933	2	25	2	32	0.0	45.020	75.440	3.0	
1933	5	20	19	57	0.0	44.800	74.700	3.0	
1933	6	26	14	10	0.0	41.000	73.800	3.0	
1933	7	14	4	48	40.0	45.420	75.700	3.9	
1933	10	29	-0	-0	0.0	43.000	73.700	3.6	
1934	1	30	10	30	0.0	41.800	72.600	3.6	
1934	2	2	16	35	8.0	45.420	75.700	2.4	
1934	4	11	3	0	0.0	44.000	72.700	3.0	
1934	4	11	3	24	0.0	44.000	72.700	3.0	
1934	4	15	2	58	13.0	44.670	73.800	4.5	4.5
1934	4	15	18	5	0.0	44.800	74.300	3.0	

YEAR	M	D	H	M	S	LAT(N)	LON(W)	FILE MAGNITUDE	MAGNITUDE CATEGORY
1934	6	5	20	11	0.0	44.800	74.300	3.0	
1934	10	29	20	7	0.0	42.200	80.200	4.3	4.0
1935	1	28	6	0	0.0	44.800	74.300	3.7	
1935	1	28	9	1	32.0	44.800	74.300	3.2	
1935	7	17	21	56	30.0	45.420	75.700	2.4	
1935	11	1	6	3	40.0	46.780	79.070	6.2	6.0
1935	11	1	6	30	0.0	44;250	72.580	2.4	
1935	11	1	6	30	0.0	42.630	74.580	2.4	
1935	11	1	17	2	40.0	46.780	79.070	4.6	4.5
1935	11	2	0	42	17.0	46.780	79.070	4.7	4.5
1935	11	2	13	51	21.0	46.780	79.070	3.0	
1935	11	2	13	55	42.0	46.780	79.070	2.7	
1935	11	2	14	31	58.0	47.230	78.170	5.4	5.0
1935	11	5	10	10	48.0	46.780	79.070	4.5	4.0
1935	11	7	16	47	4.0	46.780	79.070	2.4	
1935	11	15	16	11	20.0	46.780	79.070	3.0	
1935	11	25	6	19	19.0	46.780	79.070	4.7	4.5
1935	11	27	19	31	49.0	46.780	79.070	4.6	4.0
1935	12	15	10	15	0.0	46.470	79.040	3.0	
1936	1	20	6	1	0.0	46.780	79.070	4.5	4.0
1936	1	31	7	30	0.0	41.100	83.200	2.4	
1936	3	25	1	27	25.0	46.780	79.070	4.6	4.0
1936	6	21	3	40	0.0	44.700	74.200	3.0	
1936	8	26	8	55	0.0	41.400	80.400	3.0	
1936	12	14	-0	-0	0.0	46.270	79.420	2.4	
1937	2	21	-0	-0	0.0	42.100	75.800	2.4	
1937	3	2	14	48	0.0	40.700	84.000	5.3	5.0
1937	3	9	5	45	0.0	40.600	84.000	5.5	5.0
1937	3	10	5	30	0.0	44.600	75.200	3.7	
1937	3	31	17	9	52.8	45.080	75.650	2.8	
1937	6	9	0	4	0.0	40.300	75.900	2.4	
1937	7	14	23	1	20.8	45.400	74.020	2.8	
1937	7	28	0	17	0.0	46.720	79.080	2.7	
1937	9	24	6	45	36.5	45.520	73.570	2.5	
1937	9	30	22	8	22.0	40.830	74.250	3.0	
1937	10	12	3	0	0.0	41.200	73.800	2.4	
1937	11	6	14	31	20.9	46.730	75.720	4.0	4.0
1937	11	12	14	43	44.3	45.920	74.330	3.6	
1937	11	12	16	57	32.5	45.920	74.330	3.7	
1937	12	2	22	1	0.0	44.500	73.200	2.3	
1938	1	6	13	28	42.2	44.900	75.180	3.2	
1938	1	24	5	29	2.0	45.570	76.270	3.0	
1938	2	23	17	56	35.7	46.380	75.400	3.2	
1938	3	13	-0	-0	0.0	42.320	83.050	2.4	
1938	4	12	18	55	47.0	46.720	79.080	3.2	
1938	4	13	1	-0	0.0	43.170	73.120	2.4	
1938	5	5	0	33	.3	45.370	74.500	3.0	
1938	5	16	19	25	0.0	40.800	74.300	2.7	
1938	6	14	4	2	0.0	41.370	73.420	2.4	
1938	6	14	19	30	0.0	41.370	73.420	1.7	

YEAR	M	D	H	M	S	LAT(N)	LON(W)	FILE MAGNITUDE	MAGNITUDE CATEGORY
1938	7	15	22	45	47.0	40.370	78.230	4.3	4.0
1938	7	29	7	44	7.0	41.000	73.700	3.0	
1938	8	2	9	2	30.0	41.080	73.700	3.4	
1938	8	23	3	36	34.0	40.250	74.250	4.6	AC
1938	8	23	5	4	55.0	40.250	74.250	4.8	AC
1938	8	23	5	18	23.0	41.200	73.700	3.0	
1938	8	23	7	3	29.0	40,250	74.250	4.6	AC
1938	8	23	7	11	46.0	41.200	73.700	3.0	
1938	8	23	11	11	6.0	40.200	74.200	3.7	
1938	8	27	22	36	25.0	40.200	74.200	3.0	
1938	9	7	23	18	18.9	45.870	74.900	3.4	
1938	10	21	7	18	55.0	41.170	73.670	2.3	
1938	11	18	22	19	6.0	44.750	75.250	4.0	4.0
1938	11	26	7	47	57.5	47.030	76.200	4.2	4.0
1938	12	6	19	38	0.0	40.800	74.300	3.0	
1938	12	25	7	46	19.2	47.580	75.370	3.9	
1939	1	14	8	10	16.0	43.250	79.850	3.3	
1939	1	15	1	28	53.0	46.380	75.170	2.7	
1939	2	6	5	21	45.0	46.500	81.000	3.0	
1939	2	9	15	11	18.0	46.280	74.580	2.8	
1939	2	21	-0	-0	0.0	44.830	74.300	2.3	
1939	2	24	0	20	0.0	42.870	78.280	3.0	
1939	3	16	20	21	3.0	46.420	77.450	3.6	
1939	4	2	2	30	0.0	40.030	76.300	2.3	
1939	6	1	3	36	0.0	44.600	75.200	3.0	
1939	9	4	5	17	1.5	45.950	76.020	2.7	
1939	9	13	1	22	4.0	40.800	74.000	2.3	
1939	9	21	20	30	1.0	41.420	74.080	2.3	
1939	10	21	8	59	33.0	43.300	73.300	2.3	
1939	10	25	14	46	39.0	42.200	73.800	2.3	
1939	12	2	20	25	16.0	45.440	74.580	2.5	
1940	1	5	0	34	14.0	46.720	79.080	3.0	
1940	2	10	20	57	17.3	46.500	76.830	4.0	4.0
1940	3	2	4	15	36.0	41.500	72.500	3.0	
1940	3	13	1	29	0.0	41.500	72.500	3.0	
1940	4	12	1	58	10.0	42.800	74.600	2.3	
1940	4	13	8	23	26.6	44.830	74.870	2.6	
1940	5	16	14	0	17.1	45.800	73.200	3.6	
1940	5	20	1	26	0.0	44.600	75.200	2.3	
1940	5	28	20	6	0.0	40.260	76.900	2.3	
1940	5	31	16	0	0.0	41.100	81.520	2.3	
1940	6	16	1	30	0.0	40.930	82.280	3.0	
1940	7	28	8	30	0.0	40.930	82.280	2.3	
1940	8	4	16	20	52.0	46.150	74.470	3.1	
1940	8	7	23	57	35.3	45.770	74.830	3.0	
1940	8	15	9	35	0.0	40.930	82.280	2.3	
1940	8	19	2	30	0.0	40.930	82.280	2.3	
1940	9	26	23	30	14.5	44.700	73.400	2.9	
1941	2	1	18	28	0.0	44.600	75.200	2.3	
1941	3	4	18	1	42.5	46.130	76.180	2.8	

YEAR	M	D	H	M	S	LAT(N)	LON(W)	FILE MAGNITUDE	MAGNITUDE CATEGORY
1941	3	5	7	29	23.2	46.270	75.500	3.0	
1941	4	3	19	52	58.2	44.730	73.920	2.5	
1941	4	4	8	10	43.7	44.730	73.920	3.3	
1941	4	29	14	5	35.0	40.500	72.500	2.5	
1941	6	26	4	5	44.9	47.400	76.830	4.1	4.0
1941	7	28	19	24	10.0	41.130	73.750	3.0	
1941	10	9	22	7	0.0	43.970	75.920	2.3	
1941	10	20	21	29	0.0	43.970	75.920	2.3	
1941	10	21	5	23	45.0	44.460	74.480	2.2	
1941	10	21	6	10	41.0	44.770	74.800	3.3	
1941	10	24	14	13	59.3	45.700	74.300	3.6	
1941	12	12	23	28	57.1	44.870	73.700	2.7	
1942	1	31	4	11	56.7	44.730	73.920	2.7	
1942	2	18	7	55	12.0	46.830	74.770	3.1	
1942	4	23	20	40	1.0	41.300	72.830	2.0	
1942	5	20	12	19	22.8	45.770	74.670	4.4	4.0
1942	5	24	7	15	14.0	44.730	73.830	2.9	
1942	5	24	11	33	57.0	44.730	73.830	3.9	
1942	8	26	17	54	22.3	46.750	77.500	4.1	4.0
1942	9	15	22	32	46.0	46.780	76.000	3.3	
1942	10	1	20	58	21.7	44.000	73.580	2.5	
1942	10	2	22	29	50.5	42.570	73.800	3.0	
1942	10	24	17	27	3.6	40.970	75.250	3.4	
1942	11	16	0	13	29.4	46.420	75.050	3.6	
1942	12	5	21	10	51.2	46.970	76.070	4.2	4.0
1942	12	9	18	0	0.0	41.770	72.680	2.3	
1943	2	16	16	51	5.2	45.780	74.670	3.0	
1943	2	28	16	40	1.2	46.500	75.770	3.7	
1943	3	9	3	25	34.0	42.200	80.900	5.5	4.5
1943	3	31	11	30	0.0	42.300	72.630	3.0	
1943	5	9	11	3	12.5	44.770	73.830	3.2	
1943	7	6	22	10	14.8	44.920	73.130	4.1	4.0
1943	7	24	5	18	36.0	40.000	72.700	2.5	
1943	10	15	23	0	1.8	44.430	74.230	2.5	
1943	12	6	7	19	40.0	47.680	74.870	3.2	
1944	1	16	10	-0	0.0	43.150	77.620	2.3	
1944	1	22	21	55	9.1	45.830	76.780	4.3	4.0
1944	2	5	16	22	.5	40.800	76.200	3.7	
1944	3	8	12	49	56.1	46.680	78.870	4.1	3.5
1944	6	4	2	8	30.0	44.150	72.670	3.0	
1944	6	24	23	48	38.5	46.000	74.250	3.7	
1944	9	5	4	38	45.0	44.970	74.900	5.9	6.0
1944	9	5	8	30	49.0	44.980	74.900	3.4	
1944	9	5	8	51	6.0	44.980	74.900	4.6	4.0
1944	9	5	10	56	51.0	44.980	74.900	3.3	
1944	9	5	11	10	54.0	44.970	74.900	2.8	
1944	9	7	13	55	14.0	44.970	74.900	2.5	
1944	9	8	10	11	14.0	44.970	74.900	2.5	
1944	9	8	19	35	21.0	44.970	74.900	2.8	
1944	9	9	23	24	48.0	44.980	74.900	4.1	3.5

YEAR	M	D	H	M	S	LAT(N)	LON(W)	FILE MAGNITUDE	MAGNITUDE CATEGORY
1944	9	13	22	0	28.0	44.970	74.900	2.7	
1944	9	24	19	30	26.0	44.970	74.900	2.0	
1944	10	4	0	36	26.0	44.970	74.900	2.3	
1944	10	9	1	45	56.0	44.970	74.900	2.3	
1944	10	13	2	33	58.0	44.970	74.900	2.7	
1944	10	31	8	42	25.0	44.980	74.900	4.0	3.5
1944	11	5	19	7	53.0	48.720	80.800	5.1	4.5
1944	12	14	3	15	0.0	41.600	72.800	3.6	
1945	4	15	13	15	0.0	43.000	76.400	3.0	
1945	6	12	7	58	15.1	47.080	75.400	4.3	4.0
1945	7	2	13	29	52.1	48.470	76.800	3.9	
1945	8	5	17	20	0.0	43.620	72.520	3.0	
1945	9	12	9	36	42.6	45.000	74.370	2.8	
1946	3	16	4	20	0.0	44.900	74.880	2.3	
1946	3	20	2	1	0.0	44.330	75.920	3.0	
1946	4	21	5	5	55.5	45.730	73.430	3.6	
1946	6	20	23	9	0.0	44.430	74.180	2.3	
1946	6	27	21	6	22.0	44.650	74.530	3.0	
1946	8	28	9	10	16.3	45.730	76.850	2.7	
1946	9	4	19	30	0.0	44.900	74.880	3.0	
1946	9	19	0	53	28.8	47.720	75.000	3.2	
1946	10	28	20	36	6.0	41.500	76.600	3.6	
1946	11	10	11	41	23.1	42.870	77.450	3.1	
1946	11	24	10	20	47.2	45.170	74.680	3.1	
1946	11	28	22	0	0.0	43.850	73.750	3.0	
1946	12	25	4	48	2.7	44.900	74.900	3.3	
1947	1	4	18	51	4.0	41.030	73.580	4.3	AC
1947	1	19	0	45	1.7	46.800	76.700	3.9	
1947	3	26	23	6	14.0	46.170	75.000	2.5	
1947	4	1	13	25	54.0	41.000	74.280	3.0	
1947	8	8	5	39	8.3	46.530	81.120	4.4	4.0
1947	9	1	13	32	20.1	46.770	77.800	2.8	
1947	9	14	19	29	48.5	47.000	81.330	4.3	4.0
1947	11	3	19	51	45.0	45.670	81.170	4.5	4.0
1948	2	28	21	19	13.2	47.170	74.620	2.8	
1948	4	4	2	44	34.0	44.220	73.800	2.5	
1948	5	7	12	2	26.0	45.750	73.630	4.0	4.0
1948	6	9	3	4	12.2	45.230	73.870	3.7	
1948	7	7	7	38	1.4	45.180	73.900	3.5	
1948	9	10	1	22	5.0	45.570	76.000	2.2	
1948	11	22	23	32	49.8	44.430	74.270	2.9	
1949	2	3	1	31	46.0	45.250	75.350	1.7	
1949	2	7	6	17	0.0	44.900	74.900	3.0	
1949	10	16	23	33	42.3	45.300	74.830	4.2	4.0
1950	1	6	23	18	32.4	46.330	77.580	2.3	
1950	3	6	16	14	11.8	46.000	74.500	4.0	3.5
1950	3	20	22	55	11.5	41.500	75.800	3.3	
1950	3	29	14	43	2.0	41.050	73.600	3.6	
1950	4	14	18	20	48.5	47.830	75.500	4.9	4.5
1950	8	4	14	29	28.7	45.200	74.720	4.0	4.0

YEAR	M	D	H	M	S	LAT(N)	LON(W)	FILE MAGNITUDE	MAGNITUJE CATEGORY
1950	8	5	23	59	7.0	45.070	74.750	3.5	
1950	10	29	5	59	26.0	45.820	77.120	3.0	
1951	1	26	3	27	0.0	41.500	72.500	3.3	
1951	8	8	9	36	24.1	45.930	74.670	3.3	
1951	9	3	21	26	24.5	41.250	74.250	4.4	AC
1951	9	25	15	45	0.0	46.220	75.370	3.7	
1951	10	25	7	7	52.8	45.270	74.730	3.8	
1951	10	25	7	30	30.0	45.130	74.770	2.8	
1951	11	6	17	54	41.5	45.000	73.500	3.7	
1951	11	23	6	45	36.0	40.600	75.500	3.6	
1951	12	3	7	2	0.0	41.600	81.400	3.6	
1951	12	8	4	37	0.0	41.700	73.900	2.7	
1951	12	28	22	33	.8	45.830	74.500	2.7	
1951	12	31	20	15	54.4	45.830	74.500	2.9	
1952	1	24	9	29	47.5	47.000	77.000	2.8	
1952	1	30	4	0	0.0	44.500	73.200	5.0	4.5
1952	3	17	4	14	41.0	47.100	76.170	3.8	
1952	4	26	4	59	44.4	47.000	78.500	3.7	
1952	7	19	1	16	17.0	46.870	75.830	4.3	4.0
1952	8	25	0	7	0.0	43.000	74.500	4.3	4.0
1952	10	8	21	40	0.0	41.700	74.000	4.3	AC
1952	11	20	-0	-0	0.0	42.920	76.570	3.0	
1952	12	21	12	0	0.0	44.900	74.900	2.3	
1952	12	25	4	28	32.5	43.850	80.970	3.6	
1953	2	28	6	24	2.5	48.070	74.430	3.5	
1953	3	27	8	50	0.0	41.100	73.500	4.3	AC
1953	3	31	2	50	0.0	43.700	73.000	3.0	
1953	3	31	12	58	34.3	44.070	73.120	4.0	3.5
1953	4	26	1	20	0.0	44.720	73.450	3.7	
1953	6	11	-0	-0	0.0	41.670	83.550	3.7	
1953	8	17	4	22	50.0	41.000	74.000	3.7	
1953	9	17	5	53	30.9	45.800	74.770	2.4	
1953	11	28	15	47	7.4	45.930	73.130	2.7	
1954	1	7	7	25	0.0	40.300	76.000	5.0	5.0
1954	1	24	3	30	0.0	40.280	76.030	3.0	
1954	2	1	0	37	50.0	43.030	76.650	3.3	
1954	2	21	20	0	0.0	41.220	75.920	5.7	5.5
1954	2	24	3	55	0.0	41.200	75.900	5.0	5.0
1954	3	31	21	25	0.0	40.250	74.000	3.6	
1954	4	12	21	22	1.0	46.900	76.050	4.3	4.0
1954	4	21	15	45	0.0	44.720	73.470	3.6	
1954	4	27	2	14	8.0	43.100	79.200	4.1	3.5
1954	5	20	22	1	18.0	44.970	74.200	2.7	
1954	6	26	7	44	47.0	46.700	74.970	2.4	
1954	8	11	3	40	0.0	40.280	76.030	3.6	
1954	9	11	18	55	52.0	47.330	75.630	4.6	4.0
1954	9	24	11	0	0.0	40.280	76.030	2.3	
1954	9	29	3	50	0.0	43.980	75.920	1.6	
1954	12	13	3	53	52.0	44.600	74.600	3.6	
1954	12	15	17	35	0.0	44.780	74.650	2.3	

YEAR	M	D	H	M	S	LAT(N)	LON(W)	FILE MAGNITUDE	MAGNITUDE CATEGORY
1955	1	20	3	0	0.0	40.300	76.030	3.6	
1955	1	21	8	40	0.0	42.970	73.780	4.3	4.0
1955	2	3	2	30	0.0	44.500	73.220	4.3	4.0
1955	3	3	21	3	51.0	45.800	74.720	2.0	
1955	4	3	6	14	9.0	45.800	74.570	2.0	
1955	5	26	18	9	23.0	41.480	81.730	4.3	4.0
1955	6	28	19	16	0.0	41.500	81.700	4.3	4.0
1955	6	29	1	15	33.0	41.480	81.730	3.6	
1955	6	29	1	17	40.0	43.770	79.630	3.0	
1955	8	16	7	35	0.0	42.890	78.280	4.3	4.0
1955	10	7	18	9	52.0	45.220	73.900	3.5	
1955	11	1	7	45	52.0	46.500	75.870	3.5	
1955	11	26	6	50	9.0	46.330	73.380	2.0	
1955	12	3	11	38	18.0	45.670	75.050	2.4	
1956	1	10	12	8	18.0	45.670	75.470	3.3	
1956	1	27	11	3	27.0	40.500	84.000	4.4	4.0
1956	2	2	19	24	16.0	45.450	74.820	3.1	
1956	2	11	10	29	55.0	46.000	75.300	2.0	
1956	2	16	10	29	31.0	45.870	74.970	2.0	
1956	3	6	23	38	10.0	44.850	75.380	3.1	
1956	5	26	0	44	17.0	45.520	73.570	1.6	
1956	6	15	0	53	37.0	47.100	76.430	3.9	
1956	7	27	1	34	44.0	44.700	73.780	3.4	
1956	8	3	22	11	6.0	44.930	74.680	2.3	
1956	8	3	22	11	6.0	44.930	74.680	2.3	
1956	8	22	16	38	12.0	45.400	75.630	2.4	
1956	11	4	11	53	24.0	46.220	75.730	4.0	4.0
1956	11	16	7	17	55.0	46.200	74.770	2.9	
1956	12	1	14	0	0.0	49.420	82.430	2.3	
1956	12	28	1	41	25.0	45.170	74.270	2.7	
1957	2	20	15	45	0.0	44.930	74.880	3.6	
1957	3	23	19	2	0.0	40.630	74.830	4.8	AC
1957	5	13	8	7	36.0	46.600	74.070	2.8	
1957	5	25	12	27	49.0	45.970	74.330	2.8	
1957	6	29	11	25	9.0	42.920	81.320	4.2	3.5
1957	8	21	2	40	33.0	44.800	76.170	3.0	
1957	10	4	0	15	26.0	45.320	75.200	2.1	
1957	10	27	8	48	27.0	46.380	78.750	3.2	
1957	11	2	4	0	16.0	46.200	74.950	2.6	
1957	11	30	6	27	51.0	45.020	74.770	2.5	
1958	1	11	16	36	0.0	44.930	74.880	3.6	
1958	1	24	-0	-0	0.0	44.980	81.250	3.5	
1958	2	2	1	54	44.0	46.630	75.430	2.8	
1958	2	12	13	29	54.0	44.830	75.300	2.6	
1958	3	1	17	41	49.0	46.900	76.030	3.9	
1958	3	19	6	39	25.0	46.000	77.130	3.1	
1958	4	7	7	42	5.0	46.170	75.200	2.7	
1958	5	1	22	46	31.0	41.480	81.730	4.3	3.5
1958	5	6	19	0	0.0	42.650	73.820	3.6	
1958	5	14	17	41	21.0	46.970	76.550	5.4	5.0

YEAR	M	D	H	M	S	LAT(N)	LON(W)	FILE MAGNITUDE	MAGNITUDE CATEGORY
1958	7	13	21	32	49.0	46.170	76.380	2.4	
1958	7	22	1	46	40.0	43.000	79.500	4.3	3.5
1958	7	25	3	45	11.0	46.570	75.800	3.8	
1958	8	4	20	25	58.0	43.130	80.000	3.9	
1958	8	22	14	25	5.0	43.000	79.000	3.6	
1958	9	30	0	13	58.0	45.180	73.730	3.7	
1958	10	22	8	34	33.0	45.870	74.470	2.4	
1959	2	9	-0	-0	0.0	43.000	81.000	2.4	
1959	4	13	21	20	19.0	41.920	73.270	3.4	
1959	5	21	9	38	51.0	46.550	76.450	3.9	
1959	5	24	10	52	3.0	48.800	79.200	3.5	
1959	5	29	2	16	49.0	46.530	76.720	3.0	
1959	10	18	7	47	22.0	45.900	75.120	2.6	
1960	1	20	20	7	40.0	46.970	75.670	3.7	
1960	1	22	20	53	22.0	41.500	75.500	3.4	
1960	4	1	17	11	12.0	46.930	75.630	2.5	
1960	7	9	7	39	59.0	46.300	73.030	2.6	
1960	7	23	5	49	7.0	45.720	73.670	2.9	
1960	11	3	4	11	47.0	48.000	74.870	2.7	
1960	12	19	19	27	57.0	45.750	75.220	2.9	
1961	2	22	3	45	0.0	41.200	83.400	4.3	4.0
1961	3	13	10	55	45.0	45.170	75.280	3.2	
1961	3	22	12	2	56.0	45.830	77.080	2.2	
1961	4	20	13	13	0.0	45.000	74.780	2.0	
1961	9	12	9	54	23.0	45.200	75.250	2.8	
1961	9	14	21	17	0.0	40.750	75.500	4.3	4.0
1961	10	7	22	36	51.0	48.670	76.580	3.8	
1961	11	1	3	41	21.0	46.920	79.250	2.9	
1961	12	27	12	6	0.0	40.500	74.750	4.3	AC
1962	1	27	12	11	17.0	45.920	74.850	4.3	4.0
1962	3	27	6	35	5.0	43.000	79.330	3.0	
1962	4	10	14	30	48.0	44.150	73.050	5.0	4.5
1962	6	21	2	6	48.0	45.370	72.700	3.9	
1962	8	19	14	-0	0.0	46.170	77.770	2.3	
1962	12	6	-0	-0	0.0	46.130	75.620	2.3	
1963	1	30	14	50	0.0	44.000	75.900	3.0	
1963	2	16	8	0	17.0	44.880	73.680	2.6	
1963	2	27	6	0	0.0	43.200	79.570	3.0	
1963	3	2	20	24	32.0	41.510	75.730	3.4	
1963	5	19	19	14	18.0	43.500	75.230	3.5	
1963	7	1	19	59	12.0	42.370	73.750	3.3	
1963	8	15	14	8	6.0	45.000	74.860	2.0	
1963	8	26	2	41	1.8	45.900	74.880	2.2	
1963	8	26	16	29	35.0	45.180	73.950	3.5	
1963	10	15	12	7	57.0	46.170	77.590	3.0	
1963	10	15	12	29	2.0	46.170	77.590	4.4	4.0
1963	10	15	13	59	53.0	46.180	77.590	4.5	4.5
1963	10	17	5	13	41.0	46.170	77.590	3.0	
1964	1	8	8	59	28.0	46.230	77.530	3.3	
1964	1	8	10	3	26.0	46.230	77.530	3.9	

YEAR	M	D	H	M	S	LAT(N)	LON(W)	FILE MAGNITUDE	MAGNITUDE CATEGORY
1964	1	8	10	4	31.0	46.230	77.530	3.8	
1964	2	13	19	46	42.0	40.400	78.200	5.2	5.0
1964	3	29	4	16	0.0	44.900	74.900	4.3	4.0
1964	4	5	5	40	28.0	45.630	73.980	2.3	
1964	4	5	13	21	6.0	46.420	81.080	3.8	
1964	5	12	6	45	17.0	40.200	76.590	4.5	4.5
1964	6	4	23	40	51.0	44.670	75.330	2.8	
1964	6	16	13	0	44.0	45.000	74.230	2.7	
1964	6	27	19	17	46.0	47.750	79.170	3.7	
1964	7	24	10	34	11.0	46.650	76.250	3.3	
1964	8	4	4	49	54.0	46.250	75.080	2.3	
1964	8	15	1	26	40.0	48.150	80.030	3.0	
1964	8	25	11	18	20.0	46.250	75.080	2.5	
1964	9	9	6	16	26.0	48.400	73.870	3.1	
1964	9	9	11	47	44.0	45.830	75.000	2.6	
1964	10	3	21	37	20.0	45.270	73.770	2.3	
1964	10	28	9	22	26.0	45.980	75.730	2.5	
1964	11	17	17	8	0.0	41.200	73.700	4.3	AC
1964	11	21	5	30	3.0	44.900	75.050	2.4	
1964	11	30	0	34	55.0	42.830	74.920	2.6	
1964	12	4	22	40	15.0	46.550	73.970	2.6	
1965	1	1	13	9	18.0	44.470	77.630	2.9	
1965	1	8	12	29	45.0	48.000	78.500	3.5	
1965	1	11	12	35	34.0	45.620	73.870	1.8	
1965	2	3	9	44	27.0	46.000	76.770	2.8	
1965	2	19	10	25	49.0	44.620	79.420	2.0	
1965	3	4	18	8	16.0	46.920	73.830	2.6	
1965	3	5	12	11	1.0	47.720	78.830	3.2	
1965	4	1	6	30	20.0	46.000	80.500	3.4	
1965	7	16	11	6	55.0	43.200	78.500	3.5	
1965	8	27	1	55	55.0	44.780	79.830	3.3	
1965	9	15	17	56	28.0	46.720	79.050	3.8	
1965	10	8	2	17	27.0	40.080	79.750	3.3	
1965	11	7	20	57	44.0	47.100	76.060	4.5	4.0
1965	11	14	4	11	59.0	46.950	74.050	2.4	
1965	11	24	21	28	1.0	46.930	76.280	3.7	
1965	12	19	1	5	52.0	47.030	76.420	3.5	
1966	1	1	11	29	20.0	42.850	78.280	3.0	
1966	1	1	13	23	38.0	42.900	78.200	4.7	4.5
1966	3	19	22	51	46.0	46.580	74.830	2.7	
1966	3	20	23	45	33.0	46.500	76.160	3.2	
1966	6	25	0	5	51.0	45.160	73.830	3.4	
1966	9	11	4	25	30.0	46.500	77.000	2.4	
1966	9	23	1	20	6.0	46.000	75.160	2.3	
1966	10	22	6	2	33.0	47.330	75.000	2.5	
1966	11	13	15	43	29.0	47.000	76.250	3.6	
1967	1	11	19	0	30.0	44.750	72.580	1.9	
1967	4	8	5	21	23.0	45.830	73.750	1.7	
1967	5	14	20	23	52.0	44.920	73.920	2.3	
1967	6	11	1	49	39.0	46.580	75.030	3.7	

YEAR	M	D	H	M	S	LAT(N)	LON(W)	FILE MAGNITUDE	MAGNITUDE CATEGORY
1967	6	13	19	8	54.0	42.900	78.200	3.9	
1967	7	8	2	44	20.0	47.000	76.080	2.5	
1967	7	9	6	40	57.0	46.170	74.670	2.2	
1967	7	9	11	59	25.0	46.920	76.000	2.4	
1967	7	12	6	32	48.0	46.170	75.420	2.5	
1967	8	7	9	9	12.0	46.100	75.420	2.2	
1967	8	10	2	47	42.0	46.020	74.750	2.2	
1968	5	20	0	58	13.0	46.160	75.010	1.7	
1968	10	10	20	10	41.0	45.800	81.660	3.4	
1968	10	19	10	37	18.0	45.300	74.120	3.2	
1968	11	3	20	50	49.0	46.170	76.300	3.1	
1969	3	19	7	0	37.0	45.640	76.220	2.8	
1969	4	25	0	14	42.0	40.800	74.200	0.0	
1969	6	4	9	36	2.0	49.670	81.450	3.1	
1969	6	12	11	0	11.0	46.920	75.950	2.9	
1969	8	7	4	57	38.0	46.410	75.140	2.7	
1969	8	13	2	42	24.0	43.300	78.220	2.5	
1969	10	10	0	7	7.0	46.420	75.200	4.2	4.0
1969	10	10	8	16	12.0	46.380	75.050	2.8	
1969	11	4	12	6	31.0	45.780	74.260	2.3	
1969	12	15	9	20	22.0	46.460	76.040	2.3	
1970	2	27	8	8	36.0	48.240	77.780	3.1	
1970	4	6	11	29	16.0	46.160	74.840	2.8	
1970	4	7	3	35	14.0	48.260	79.530	2.9	
1970	4	9	0	58	30.0	45.840	74.210	2.3	
1970	4	13	4	56	53.0	49.750	81.880	2.6	
1970	4	25	0	46	27.0	49.700	81.220	3.1	
1970	5	12	6	15	18.0	46.880	76.620	2.0	
1970	6	14	5	53	45.0	45.350	74.310	2.2	
1970	9	7	10	11	17.0	45.700	76.580	2.4	
1970	10	3	20	13	38.0	46.930	76.030	2.5	
1970	10	15	18	56	11.0	47.070	76.250	3.3	
1970	10	23	1	9	38.0	45.640	74.210	2.3	
1970	10	28	7	32	45.0	46.940	75.960	2.2	
1970	11	24	11	12	12.0	46.980	76.170	2.7	
1970	12	13	5	41	50.0	45.980	74.750	2.1	
1971	1	6	6	22	8.0	47.170	75.960	3.0	
1971	2	5	23	40	54.0	48.200	78.030	2.7	
1971	3	17	22	19	50.0	47.160	76.630	2.7	
1971	5	14	6	20	9.0	45.100	73.370	3.2	
1971	6	27	12	22	30.0	46.050	73.410	2.2	
1971	7	6	17	47	49.0	46.550	76.280	3.0	
1971	7	9	5	5	26.0	46.740	81.200	3.1	
1971	8	15	10	11	48.0	43.870	74.490	2.0	
1971	8	20	1	20	9.0	46.620	75.680	2.2	
1971	9	15	22	32	19.0	46.570	74.380	2.4	
1971	9	20	20	33	41.0	43.050	74.800	2.7	
1971	9	27	8	47	23.0	45.710	75.170	3.2	
1971	12	18	15	36	24.0	46.000	74.700	4.5	4.5
1972	3	25	17	3	12.0	45.360	73.360	1.7	

YEAR	M	D	H	M	S	LAT(N)	LON(W)	FILE MAGNITUDE	MAGNITUDE CATEGORY
1972	4	25	3	24	25.0	46.600	76.000	3.5	
1972	6	2	4	24	57.0	45.700	75.900	2.8	
1972	7	30	10	42	16.0	46.300	76.100	3.1	
1972	8	5	3	10	38.0	45.900	75.100	2.6	
1972	8	18	19	35	51.0	46.300	74.900	2.6	
1972	8	31	6	6	28.0	45.300	76.900	2.8	
1972	9	12	9	15	40.0	46.100	77.600	3.1	
1972	10	19	2	22	38.0	45.520	74.280	2.6	
1972	10	19	4	10	46.0	45.080	74.240	1.8	
1972	11	2	5	15	7.0	45.830	74.830	2.2	
1972	11	5	22	29	35.0	43.930	74.380	2.3	
1972	11	8	11	6	16.0	45.890	74.210	2.4	
1972	12	16	19	1	36.0	45.770	75.220	3.9	
1972	12	17	3	28	55.0	45.760	75.150	2.2	
1973	2	2	23	9	30.0	44.430	74.780	2.8	
1973	2	25	19	46	46.0	45.230	73.970	2.9	
1973	6	11	10	8	43.0	43.920	73.910	2.8	
1973	7	15	8	20	31.0	43.970	74.490	3.4	
1973	7	15	10	32	38.0	43.960	74.430	3.2	
1973	7	16	8	41	58.0	43.760	74.470	3.3	
1973	11	8	17	41	29.0	45.980	75.000	2.4	
1974	1	9	18	38	52.0	45.910	74.910	2.7	
1974	1	25	16	45	45.0	45.890	73.550	2.7	
1974	2	13	18	14	53.0	46.390	75.270	2.9	
1974	3	14	19	20	3.0	46.090	75.080	2.5	
1974	3	18	16	5	51.0	44.410	75.040	3.0	
1974	3	18	16	5	0.0	44.450	74.850	0.0	
1974	4	21	14	6	0.0	46.480	81.120	3.0	
1974	4	29	6	10	48.0	46.000	75.220	2.7	
1974	6	7	19	45	37.0	41.570	73.940	0.0	
1974	6	25	2	23	21.0	46.570	74.820	2.7	
1974	7	18	8	44	4.0	46.260	75.180	2.0	
1974	7	26	1	18	24.0	44.500	74.410	0.0	
1974	8	8	11	55	34.0	45.940	76.080	3.2	
1974	8	12	3	43	15.0	45.050	73.340	2.2	
1974	8	19	5	37	55.0	47.130	75.870	2.4	
1974	8	25	10	3	24.0	46.100	73.250	2.5	
1974	8	31	10	36	39.0	46.850	75.670	2.7	
1974	9	27	23	3	8.0	43.810	76.410	0.0	
1974	9	29	2	26	17.0	41.240	83.360	3.0	
1974	10	20	19	54	26.0	45.970	73.170	2.5	
1974	10	23	22	52	57.0	46.080	75.480	3.2	
1974	11	2	13	47	56.0	46.160	75.080	0.0	
1974	11	3	4	27	4.0	46.070	75.050	2.7	
1974	11	4	19	13	6.0	45.540	74.760	1.6	
1974	11	12	8	28	32.0	48.860	79.270	2.9	
1974	11	27	10	28	52.0	43.330	79.010	0.0	
1974	12	2	10	58	5.0	46.250	75.500	3.5	
1974	12	21	14	51	4.0	45.100	74.060	2.7	
1974	12	29	13	48	43.0	47.800	74.420	2.5	