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RADIO AND ELECTRICAL ENGINEERING DIVISION

SITE SURVEY FOR A NATIONAL RADIO ASTRONOMY OBSERVATORY

C. F. PATTENSON, N. W. BROTEN, G. AITKEN

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ABSTRACT

[A search for possible sites for a radio astronomy observatory was made in British Columbia, and in Ontario and Quebec. Radio noise measurements in the frequency range 55 to 4000 mc/s were made at 15 of the sites investigated. A suitable site was found near Penticton, B.C., and three possible sites were found in Ontario, all of which are subject to some radar interference.]

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SITE SURVEY FOR NATIONAL RADIO ASTRONOMY OBSERVATORY

- C.F. Pattenson, N.W. Broten, and G. Aitken* -

INTRODUCTION

Since the end of World War II the Radio and Electrical Engineering Division of the National Research Council has operated a radio astronomy observatory on the southern outskirts of Ottawa and has maintained an active program of solar observation in the 3000-mc/s band. Since continued expansion of this program is necessary if the Division is to maintain its role in the field, extension of the present facilities is foreseen for the near future. Consideration is also being given to establishment of a national radio astronomy observatory staffed and operated by the National Research Council, which would require facilities for observation at a number of frequencies. The present site at Goth Hill is most unsatisfactory, even for the current program of the National Research Council, and would be totally unsuitable for development into a national radio astronomy observatory.

The disadvantages of the Goth Hill site are as follows:

1) It is located on a ridge about 15 miles south of Ottawa and is thus completely exposed to interference from all directions.

2) It is situated within four miles of Uplands Airport, a major civil and military aerodrome, and is located almost in line with one of the main runways. As a result, interference from airport radars, communications equipment, and from low-flying aircraft has severely limited observing time over the past several years.

3) The site is very small in terms of present requirements. The available flat area is only a few acres. It would be completely inadequate for the installation of elaborate interferometer antennas.

4) There has been a continual increase in building in the area since the observatory was first opened with a corresponding increase in the level of man-made radio noise.

In December 1956, therefore, the decision was taken to conduct a search during the following summer for a more suitable observing site. As the Dominion Observatory was also planning a similar survey to locate a site in British Columbia suitable for observation of 21-cm radiation, it was decided to make the initial survey a cooperative undertaking between the Observatory and the National Research Council.

Personnel on the survey work included J.L. Locke and E.W. Argyle of the Dominion Observatory, C.F. Pattenson, N.W. Broten, and G. Aitken, from the National Research Council. The western survey was conducted by Locke, Argyle,

* NRC Summer Student, 1957

Pattenson, and Aitken and the eastern survey by Pattenson and Broten.

Locke and Argyle, during April and May, measured radio noise intensities in the 50 to 1000 mc/s band at two of the American sites: Greenbank, W.V., and Big Pine, Cal., so that comparison might be made between Canadian and American sites. Following this, they made preliminary measurements at several sites in British Columbia. During July and August, the combined NRC/Observatory group completed measurements at three of the most promising British Columbia sites and on the basis of these measurements, chose a site near Penticton as being the most suitable for the Dominion Observatory telescope. Subsequent to the location of this site, the NRC party, for the sake of completeness, made measurements at several sites in Rocky Mountain valleys as far east as Banff. The eastern Canada survey was carried out in the Laurentian region of Quebec and in northeastern Ontario, from August through October.

BASIC SITE REQUIREMENTS

The basic factors to be considered in assessing a potential site are:

a) freedom from radio noise

b) size of site

c) location

d) meteorological conditions

e) accessibility

f) staff accommodation

g) cost of development

(a) Radio Noise

The level of radio noise at wavelengths of interest to the radio astronomer must be extremely low. The sensitivity of present radio telescopes is of the order of 10^{-25} watts/sq. m./cycle/second bandwidth, and new developments in receiver systems are likely to improve this considerably. Therefore the following factors must be considered in order to obtain freedom from radio interference.

1) The site should be as far as possible from large centers of population and concentrations of industry, which are serious sources of interference.

2) The number of inhabitants close to the site should be as small as possible.

3) The site should not be near high-tension electrical transmission lines which are sources of radio noise because of corona discharge and other reasons.

4) The site should not be located on well-travelled air routes or near large aerodromes.

5) The site should not be in a region which is potentially favourable to the development of industry.

6) The site should be in a valley with surrounding mountains providing a 10° to 15° horizon in all directions, if possible, and should be surrounded with further ranges of high mountains to reduce direct propagation from nearby radio stations and sources of man-made radio noise, and to reduce propagation of distant interference into the site by diffraction.

(b) Size of Site

The site should be large enough to accommodate radio interferometers such as the Mills Cross, and to provide for adequate separation between antennas and space for plant and laboratory buildings. The area of the site should not be less than a square mile, and ideally, the surface elevation should not vary more than ± 10 feet if the cost of improvement is not to be too great. The tolerable variation in surface elevation, however, will depend on the ease with which the terrain can be worked.

(c) Location of Site

In order that the galactic center may be observed, a site with a 10° southern horizon cannot be at a latitude greater than 51°. A site farther south would allow observation of a larger part of the southern celestial sphere. The southerly limit for possible sites would thus be the Canadian-U.S. border.

(d) Meteorological Considerations

1) Precipitation Areas of heavy snowfall and those having excessive icing conditions should be avoided because of snow and ice loads on large antenna structures, and because of the excessive outage time and difficulty of operating and maintaining equipment under such conditions.

2) Winds The site should not be located in an area of heavy prevailing winds or in an area subject to violent winds or tornadoes because of the possibility of wind damage to the telescope antenna and because of the reduced positioning accuracy due to wind loading.

3) Temperature The site should not be located in an area where large variations in temperature or where extremely low temperatures are encountered because of the problems caused by dimensional changes in antennas due to large temperature changes, and because of the difficulty of operation and maintenance of equipment in the cold.

4) Humidity Areas of high humidity and salty atmosphere are undesirable be-

cause of the accelerated deterioration of equipment exposed to these conditions.

(e) Accessibility

The site should be located near other institutions at which physical research of an allied nature is being carried on, and should be within easy reach by aeroplane, railway, or automobile.

(f) Staff Accommodation

Ideally, the site should be located within easy commuting distance of a small community with modern and adequate facilities for living, education, shopping and recreation, so that it would not be necessary to provide these facilities at the site.

(g) Cost of Development

1) The site should not be in an area of high land values if the cost of acquisition is not to be excessive.

2) If the cost of site improvement is not to be high, the site should not be heavily wooded, and the soil and subsurface should be fairly easy to work, and at the same time suitable for foundations of buildings and structures.

3) Commercial power should be available within a few miles.

4) The site should not be too far from a good road.

METHOD OF LOCATING SITES

The principal factor in the preliminary selection of a site was considered to be the topography. Since the objective was a large flat area surrounded by hills, contoured topographical maps were used, where available, to locate suitable areas. Maps of southern British Columbia, of eastern Ontario, and of western Quebec were obtained from the Department of Mines and Technical Surveys, Map Distribution Office, Ottawa. Prospective sites could be chosen rapidly from regions for which maps were available in a scale of 1: 50,000 and 1: 63,360. However, since contour maps were not always available for the terrain which seemed most promising, it was necessary to use aerial photographs or to do ground reconnaissance to locate possible sites.

A stereoscope is necessary to obtain elevations from aerial photographs, and to obtain an accuracy equal to that of a 1: 50,000 map small-scale photographs covering only a few square miles must be used. Since several hundred maps are required to search a large area, selection of potential sites by this method consumes too much time; hence it was used only for those probable areas for which no other information was available.

Since the minimum contour interval on most maps was 50 feet, areas which appeared flat on them could have variations greater than could be tolerated in a site. Therefore, it was necessary to inspect each site to determine its suitability prior to moving the radio equipment vehicle in for noise measurements. This ground survey was extended to cover regions for which maps were not available, and resulted in several prospective sites being eliminated and in uncovering some unexpected ones in unmapped territory.

Finally, radio-frequency noise measurements were made on sites which were topographically suitable, as well as on sites taken as control points for comparison of the intensity of received radiation.

EQUIPMENT AND PROCEDURE

Receivers used on the survey consisted of a Nems-Clark Model 1502, an Eddystone model 770AU, a Stoddart Model NM-50A, a Rohde and Schwarz model USVD, and a Polarad model R. The 1502, 770AU, NM-50A, and Model R were used on the western portion of the survey with dipole antennas. During the eastern portion of the survey the 1502 was used as before, but the USVD was used in place of the 770AU and the NM-50A. In addition, the 1502 was used as a narrow band I-F amplifier with the Model R, and in the frequency range 2600-4000 mc/s a low-noise TWT preamplifier was also used. High-gain horn antennas were used above 500 mc/s in place of the dipole antennas. These measures increased the effective sensitivity of the receiving equipment considerably. Two recorders were used: a Varian Model G10 in the range 55 to 950 mc/s and a Brush Model BL222 in the range 55 to 4000 mc/s. All equipment was carried in an ex-wireless lorry and powered by a 3-kw 110-volt portable generator.

The measurement procedure was as follows. On arrival at a site, the 55-260-mc/s antenna system was erected and the antennas oriented true north. A frequency sweep was then made and a record of all signals on this bearing was obtained. The antenna was then rotated 90° to the east and a similar record was obtained. This procedure was repeated at the four major points of the compass. Signal levels were obtained by tuning manually and rotating the antenna for maximum signal. A similar procedure was used with the other receivers until the frequency range 55-4000 mc/s had been searched.

Equipment

a) Receivers and Antennas

1) 55-260 mc/s   Nems-Clark Model 1502
NF: 6 db (max.)
Bandwidth: 230 kc/s
Antennas: three series rhombics [1] with automatic switching and rotating gear to cover the frequency ranges

55-88, 88-165, 165-260 mc/s; gain, 10 db
System sensitivity: 0.07 - 0.5 μV/M

2) 250-500 mc/s Eddystone Model 770AU (used on western part of survey only)
NF: 15 db
Bandwidth: 15 kc/s
Antenna: broadband dipole [2]; gain, -2 to 0 db
System sensitivity: 0.5 to 2 μV/M

3) 500-950 mc/s Stoddart Model NM-50A (used on western part of survey only)
Sensitivity: 100-350 μV/M

4) 950-4000 mc/s Polarad Model R (western portion of survey only)
NF: 30-43 db
Bandwidth: 3.5 mc/s
Antenna: Discone; gain, -3 to 2.6 db
System sensitivity: 35 to 350 μV/M

5) 950-2600 mc/s Polarad Model R with Nems-Clark 1502 as I-F amplifier (eastern portion of survey only)
NF: 21-35 db
Bandwidth: 230 mc/s
Antenna: horn; gain, 7.5 to 16 db
System sensitivity: 5 to 25 μV/M

6) 2600-4000 mc/s Model R with Nems-Clark as I-F and low-noise TWT pre-amplifier (used on eastern part of survey only)
NF: 8-16 db
Bandwidth: 230 mc/s
Antenna: horn; gain, 20 db
System sensitivity: 1.5 to 5 μV/M

7) 330-950 mc/s Rohde and Schwarz Model USVD (eastern part of survey only)
NF: 16 db
Bandwidth: 300 kc/s
Antenna: Broadband dipole, 330-950 mc/s; horn 500-950 mc/s
Horn gain: 10 db
System sensitivity: 0.9 to 2 μV/M

b) Recorders

a) 55-950 mc/s, Varian model G10, response time: 1 second

b) 55-4000 mc/s, Brush Model BL222, response time: 0.01 second

Derivation of Receiving System Sensitivity

For receivers operated so that fluctuations due to receiver noise are visible in the output, the limiting sensitivity is related to the noise generated in the receiver, the pre-detection and post-detection bandwidths, and the noise energy contributed by the antenna system and the signal.

Since the noise energy associated with a resistor is related to its temperature by the well-known Nyquist theorem, the concept of the equivalent temperature of radiation resistance is a convenient way of expressing the noise energy of the antenna system. Similarly minimum detectable signal power can be expressed in terms of minimum detectable change in antenna temperature.

For a conventional superheterodyne receiver with image rejection, the rms fluctuation in the noise output power, expressed in terms of equivalent antenna temperature fluctuation is given by [3, 4]:

$$\Delta t = \tfrac{1}{2}\left[FT_0 + (t - T_0)\right](B_0/B)^{\frac{1}{2}},$$

where F = noise factor of the receiver
T_0 = 290°K
B = pre-detection bandwidth of the receiver (cycles/s)
B_0 = post-detection bandwidth
t = equivalent antenna temperature.

The tangential sensitivity of the receiver (when signal power is equal to peak-to-peak noise fluctuations) is given by:

$$P_{min} = kB(6\Delta t) \text{ watts at the receiver input,}$$

where k = Boltzmann's constant, 1.38×10^{-23} joules/degree.

The minimum detectable field strength is given by:

$$E_{min} = \left[kB(6\Delta t) \times \frac{L}{A}\left(\frac{\mu_0}{\epsilon_0}\right)^{\frac{1}{2}}\right]^{\frac{1}{2}},$$

where E_{min} = minimum detectable field strength in microvolts per meter
A = effective area of antenna
L = fractional loss of cable connecting receiver to antenna
μ_0 = permeability of free space
ϵ_0 = dielectric constant of free space
$\left(\frac{\mu_0}{\epsilon_0}\right)^{\frac{1}{2}} = \eta$ = 377 ohms, "intrinsic impedance" of free space.

AREA OF SEARCH

The search for a suitable site was carried out in two main areas: British Columbia; Ontario and Quebec. The width of British Columbia between the Canadian-U.S. border and latitude 52°N was surveyed from Vancouver Island to the provincial boundary. Most of the British Columbia sites were investigated by Locke and Argyle and lay in the area between the Okanagan Valley and the coast. The locations of the sites at which complete measurements were made are shown on the map of southern British Columbia (see Plate I). Field intensity measurements in the 50 to 1000 mc/s range were made at several sites in this region, and detailed field intensity measurements in the 50 to 4000 mc/s band were made at promising sites at White Lake and Myers Flat near Penticton in the Okanagan Valley, and at Westwold, 50° 30' N., 119° 35' W. Visual inspection was made of several areas along the route — Penticton, Grand Forks, Nelson, Creston, Cranbrook, Golden, Radium, and Banff. Topographically suitable areas were found at Grand Forks and at Creston, but the former had no protection from the town of Grand Forks, and the latter, in addition to being too close to the town of Creston, was intensively cultivated.

The Rocky Mountain Trench did not appear suitable, as the only flat areas large enough were on benches on each side of the river, and these were exposed to interference from the south. North of Columbia Lake, the valley narrowed and no suitable area was apparent from there north to Golden. However, measurements were made at three sites in the Trench: at Kimberly Airport, Canal Flats, and Shuswap, in order to establish interference levels. At these sites considerable interference was picked up from a high voltage transmission line which runs along the valley.

The last site (Kootenay Crossing) investigated in Kootenay National Park was extremely quiet. It is probable that sufficient area might be found for a site at the southern end of the Kootenay Valley, near Sinclair Canyon.

In Eastern Canada, the following areas were examined: the Gatineau region, as far north as, and including, La Verendrye Park; eastern Ontario, west of Ottawa and north of No. 2 Highway, west to North Bay and Georgian Bay. A preliminary ground reconnaissance of the Quebec area showed no particularly suitable sites — any flat hill-surrounded areas were too small, and the hills were low and afforded poor protection, especially to the south. A preliminary map search of the Ontario region indicated the most likely area was west of a line through Ottawa, north of No. 7 Highway and included Algonquin Provincial Park. Several promising sites were chosen using topographic maps and by questioning individuals familiar with the areas. These were at Constan Lake, Griffith, Little Rapids, Elephant Lake, McGarry Flats, Lake Clear, Madawaska Aerodrome, Basin Depot, Montgomery Lake, and Lake Traverse. The last three sites are in Algonquin Provincial Park and were located after questioning the staff of the Department of Lands and Forests. Plate II shows the location of the sites at which radio noise measurements were made.

RESULTS

Measurements were made at a total of 15 sites. Seven of these were in British

Columbia and eight in Ontario. Of the British Columbia sites, White Lake has been chosen as the site for the Dominion Observatory radio telescope, while Myers Flat, immediately south of White Lake, is second in order of preference, and Westwold, third. None of the Rocky Mountain Trench sites measured were suitable. It is probably that there is sufficient area in Kootenay Park, near Sinclair Canyon, for the development of a site.

In eastern Canada, 12 possible sites were investigated in Quebec and Ontario. Of these, two in La Verendrye Park, and Elephant Lake and Lake Clear were rejected as unsuitable during the initial ground survey. Detailed radio field strength measurements were made at the remaining sites. In addition to VHF and UHF signals from broadcast and communication transmitters, varying degrees of microwave radar interference were encountered at all sites where measurements were made.

Signal intensities at all of the eastern sites are presented in Tables II to IX and histograms of received signals are shown in Figs. 1 to 9 for all of the Canadian and two of the U.S. sites. The minimum detectable signal is indicated in the site histograms by the lower dashed line. Signals whose intensities approached the minimum detectable level are doubtful, especially those in the microwave region. At some of the sites the 50 to 260 mc/s receiver saturated at a fairly low level which is indicated by the upper line. There is also evidence that the 2800 mc/s signal encountered at the Goth Hill site blocked the receiver. Calculations indicate that the intensity of the signal should have been about 40 volts per meter instead of 1.2 millivolts per meter, as was recorded.

55 to 260 mc/s records obtained at three of the eastern sites are shown in Plate XII. The difference in the number and intensities of the signals at the three sites is obvious. Galactic radiation is evident in the general slope of the record obtained at the Lake Traverse site.

A record of the interference produced by interaction between the direct signal ray and one reflected from a passing aircraft is shown in the upper left-hand record (see Plate XII). Microwave interference at Goth Hill is shown in the upper right-hand record. The signal at 2710 mc/s was identified as originating from a transmitter at the Radio and Electrical Engineering Laboratories on the Montreal Road. The remaining arrows indicate successive scans of the airport radar. The receiver had a double-cavity preselector and when it was tuned continuously across the band the upper and lower frequency limits of detection of the airport radar were recorded.

COMPARISON OF SITES

The sites were all assessed on the basis of the original criteria:

1) Freedom from radio interference

2) Protection by surrounding hills from interference

3) Size of site

4) Nearness to a center of population

5) Ease and cost of acquisition and development

6) Accessibility

Site No. 1 — Constan Lake

When this site was selected from a topographical map, it appeared to have good possibilities. The elevation of the site is about 700 feet and a ridge of about 1200 feet runs east and west to the south of the site giving good protection to the south. However, an investigation of the site area showed that the flat land available was small, partly swampy, and with rock close to the surface over a large part of the area. Finally, it was found that the area was flooded with microwave radiation in both S- and L-band by a nearby radar station. This site, however, provided a valuable reference for comparison of interference levels at the other sites.

Site No. 2 — Clear Lake

Although this site looked good on a topographic map, it was not considered further, because of the results obtained at Constan Lake and because of its proximity to the radar station.

Site No. 3 — Griffith

The site area here lies on the west side of the Madawaska River, south of Highway 41. The area is a mile in length along the river and nearly a mile wide, from the river to the base of the hills on the west. The surrounding hills provide a 3° to 5° horizon. Power is available along a secondary road which follows the west side of the river. As it is not near a large town, accommodation would have to be provided for the staff. UHF and VHF signals were normal, but strong radar interference was encountered both on L- and S-band.

Site No. 4 — Little Rapids

This area is south-east of Comberemere on Highway 515, between Wingle and Quadeville on the Madawaska River, and has an area of three to four square miles. It is quite isolated, and has a small rural population. The possible site location is at an elevation of 950 feet and the surrounding hills rise to 1300 feet. Radio measurements were not made at this site because it is only some 15 to 20 miles southwest of the radar station, and the results obtained at the Griffith site indicated that strong interference could be expected.

Site No. 5 — Elephant Lake

This site was found unsuitable. The available flat area was small, quite swampy in part, and would require heavy clearing over the remainder.

Site No. 6 — McGarry Flats

From the point of view of site area, soil condition, protection by surrounding hills, proximity to a town of moderate size, accessibility and availability of power, this is the best site so far located in eastern Canada. It is located on an arm of Baptiste Lake, ten miles north of the town of Bancroft on Highway 62, and four miles west of the highway on a county road. An area approximately a mile square is available, with small surface variations of not more than four or five feet at the most over the greater part of the area. There are only two breaks in the general flatness and both are on the eastern side: one is a rock mound, about an acre in extent, while the other is a rocky hill, 50 to 75 feet high, covering about the same area. The elevation of the site is about 1200 feet and the surrounding hills rise to 1500 feet. Plate III is a copy of a 1: 50, 000 map showing the site area marked, and Plate IV is a copy of an air-photo mosiac of the same area.

The soil appears to be extremely poor and sandy. Two or three small farms are in operation, and the remainder of the area has been allowed to go back to second-growth pine and scrub trees. In fact, some of the area has been put back under pine plantation by the Department of Lands and Forests. There are about eight families living in the area, and five or six summer cottages are grouped on the edge of the lake. A 4600-volt, single-phase power line, which was installed within the last year, runs through the middle of the area. The county road in from the highway is in poor shape and would need improvement. Bancroft is a growing community owing to the mining development in the area, and both grade and high schools are available. Shopping facilities appear to be reasonably good. Housing was not investigated. The mining development is to the south of Bancroft, away from the site, so that the mines would not appear to be a potential source of interference. Nothing is known of the ownership of the surrounding hills, but since the site is in a mineral bearing area, it is possible that acquisition of property to protect it might be difficult.

Radio field intensity measurements were carried out at the site on two occasions. On both occasions the normal number and intensity of VHF and UHF signals were recorded. Broadcast reception in the Bancroft area is particularly poor. On the first occasion no microwave radar interference was noted, and only one unidentified c-w 3000-mc/s signal was recorded for a period of about 20 minutes and this was not repeated. There is a strong possibility that it was from tellurimeter surveying equipment. On the second visit, L-band interference was definitely recorded and there was an indication of S-band interference. Propagation trials were conducted over a path between a transmitting site in the town of Bancroft and the test area using an S-band signal of 1000 watts radiated power. No signal could be detected at the end of the path at McGarry Flats. It can therefore be assumed that there is protection of approximately 180 db against wide-band noise originating in the town. The path loss would be some 30-db greater than plane-earth loss.

Site No. 7 — Madawaska Airport

Madawaska Airport is an abandoned TCA auxiliary airstrip about two miles north of the hamlet of Madawaska. It is located in a bowl in the hills on a bend of the Madawaska River (see Plates V and VI). The area of the flat is over a square mile but it is bisected by the river. The airstrip itself is entirely flat, and roughly triangular in shape, with the base to the north and the axis running slightly west of north. It is approximately a mile north to south, and perhaps about three-quarters of a mile across the widest part. The soil is sandy and could be worked easily. The airstrip proper has been planted recently in young pine. The number and intensity of VHF and UHF signals encountered are comparable with those at the other sites. L-band radar interference was again encountered.

Site No. 8 — Basin Depot

The area designated as Basin Depot is on the Bonnechere River at 45° 40' 20" N, 77° 40' 45" W, about four miles inside the southeastern boundary of Algonquin Park. It lies in the Valley of the Bonnechere at the confluence with Basin Creek (see Plates VII and VIII). The valley runs roughly NW/SE and is quite open to the southeast where the land develops into a broad flat valley in which lie Round and Golden Lakes. A ridge runs parallel to the river on the south and there are ridges to the north and northeast around the lake. The soil varies from sand to heavy gravel, and in the main is covered with a heavy stand of jack pine, which made it rather difficult to determine the actual land contours in the area. However, there were indications of considerable outcropping of small rocky ridges in the area of interest. The site is presently occupied by a main camp of the Shoosplin Lumber Company, a Pembroke firm which is engaged in lumber and pulp operations in the area. The nearest power line is about 13 miles away by road on Highway 62. The site is readily accessible by a gravelled road maintained by the lumber company.

Radio noise measurements made at the site indicated reasonably good protection against VHF and UHF interference, but strong L- and S-band interference was picked up from a radar station, as might be expected considering its commanding position. The site, in common with the other Algonquin Park sites, does have the appeal of being in a government controlled wilderness area and there is little likelihood of population growth or commercial development within any significant distance.

The site fails to satisfy basic requirements because of its open nature, lack of protection to the southeast, and strong radar interference. The nearest town of any size is Pembroke, 35 miles away.

Site No. 9 — Lake Traverse

The Lake Traverse site, shown in Plate IX, is situated at the south end of Lake Traverse in Algonquin Park at 45° 57' N, 78° 04' W, and lies on the main line of the Canadian National Railway, the nearest station being Lake Traverse. The terrain is extremely sandy, the main features consisting of small sand hillocks and ridges, sparsely covered with second growth jack pine, the area having been logged over some years past. The area is quite open, with the land rising gradually to ridges four to five miles away from the site. Thus, protection against diffracted radiation is poor. The area which is suitable for development might amount to four or five square miles, but considerable earth moving would be required to improve the site sufficiently for use with long antenna arrays.

In addition to being accessible by railway, the site can be reached by quite a good gravelled road which is maintained by the Department of Lands and Forests and by the lumber companies. The approach by road is through the Dominion Forest Experiment Station at Chalk River, and the distances from the site to Highway 17 is about 40 miles. There is a sawmill at the south end of the lake and a fishing lodge on the west side. The main activity in the immediate area seems to be the trucking of pine logs to the siding at Stuart for shipment.

Signal levels recorded at this site were comparable with those at the other sites. Microwave interference from radar was again present.

The area is the most isolated of any of the sites considered as possibilities for an observatory site. There is no commercial power in the immediate area, the nearest power transmission line being the main line running south through the Park from the Des Joachims hydro-electric plant on the Ottawa River, which is ten miles to the east.

Site No. 10 — Montgomery Lake

The Montgomery Lake site is on the west band of an expansion of the Petawawa River known as Montgomery Lake, and is located at 45° 55' N, 77° 33' W (see Plate X). It is on Petawawa Forest Experiment Station land just outside the eastern boundary of Algonquin Park. An area of two or three square miles is possibly available. The soil is sandy with some outcroppings. The area is bounded by rocky ridges to the west, south, and east, and to the north by ridges on the opposite side of the river. The main part of the area is occupied by experimental forestry plantations.

The usual VHF and UHF signals were recorded as well as L- and S-band radar interference.

The site is quite accessible by road through the Petawawa Experiment Station and the road is usually open all year. It is some ten miles by road from Highway 17. The nearest major towns, for schools and shopping, would be Pembroke and Deep River. The nearest power transmission line is about two miles to the east.

British Columbia Sites

Although a large number of potential sites were investigated by Locke and Argyle in the interior of British Columbia and on Vancouver Island the greater number of these failed to satisfy the basic site requirements. Three sites: White Lake, Meyers Flat, and Westwold were considered to be worth thorough investigation.

1) White Lake is located on the west side of the Okanagan Valley, some 11 miles south of the center of Penticton (see Plate XI). The site is an arid bowl at a general elevation of 1700 to 1800 feet, surrounded by ridges rising to 3000 feet. The flat area of the site is some three-quarters of a mile east and west, and somewhat less than this distance north and south. Protection from distant signals is excellent, the site ranking fourth of all the sites in freedom from interference. Protection from interference originating in the town of Penticton was calculated to be 132 db, and was measured at greater than 125 db.

The site rates high in respect to the other site criteria; Penticton has excellent facilities for schooling, shopping, and accommodation for staff. Commercial power is available about four miles from the site and the site is less than a day's drive from Vancouver.

2) Meyers Flat lies about four miles to the south of White Lake and is similar in size but the area is intensively cultivated (see Plate XI). Protection is about the same as at White Lake but is somewhat poorer to the south. Some low-intensity power line noise originating from a power transmission line running east and west about four miles south of the site was measured in the 50 to 250 mc/s region.

3) Westwold This site lies in a fairly broad valley, west of the town of Falkland and about 30 miles south of Kamloops (see Plate I). Protection is good and the available flat area is large. However, the area is under irrigation and quite populated. A main highway and a power transmission line run through the middle of the area. The smallest number and lowest intensity of signals recorded at any of the sites, were recorded here. However, strong broad-band noise was measured at 85 and 165 mc/s, and ignition noise from vehicles passing on the highway was detected. The incidence of locally-generated noise as well as the isolated nature of the site, low winter temperature, and complete lack of suitable facilities for shopping, schooling, and housing in the area caused it to be placed third in order of preference of the B.C. sites.

The sites at Kimberley Airport, Canal Flats, and Shuswap were not suitable; however, radio noise measurements were made at these locations to establish the general level of interference in the region. The Kootenay Valley is potentially excellent from the point of view of protection, but a further, detailed ground survey would be necessary to determine the exact size of flat land available for a site.

Green Bank and Big Pine Sites

The Green Bank, West Virginia, site of the Associated Universities is described elsewhere [5]. Interference measurements made by Locke and Argyle at this site agree closely with those of Jansky and Bailey [6]. The histograms for this site and the one at Big Pine, California, are shown in Fig. 5. These measurements were taken to provide a basis of comparison between American and Canadian sites.

Figure of Interference

In the Associated Universities' site survey the sites were rated for freedom of interference on the basis of a numerical figure of interference which was obtained by adding the intensity of all signals observed in the frequency range 50 to 10,000 mc/s. For the sake of comparison the same method has been used in assessing the Canadian sites. Although the present survey was carried only to 4000 mc/s it is felt that a valid comparison can be made since the Jansky and Bailey results show no interference above this frequency. In addition, it was felt that both day and night measurements were unnecessary except at the most promising sites, since in all cases where both sets of measurements were made daytime signals were more numerous.

TABLE I

FIGURE OF INTERFERENCE

SITE	NUMBER OF SIGNALS	FIGURE OF INTERFERENCE
Constan Lake	48	620
Griffith	35	351
McGarry Flats	49	133
Madawaska Airport	25	265
Basin Depot	18	118
Lake Traverse	28	52
Montgomery Lake	16	52
Goth Hill	99	24,940
Green Bank	24	339
Big Pine	42	869
White Lake	11	78
Meyers Flat	14	110
Westwold	2	0.4
Kootenay Crossing	4	17

TABLE II

SIGNAL INTENSITY AT CONSTAN LAKE

September 19, 1957, daytime

FREQUENCY (mc/s)	FIELD STRENGTH (μV/M)	REMARKS
55.25	35	Channel 2 video
59.75	35+	" " audio
61.25	25+	" 3 video
65.75	33+	" " audio
67.25	25+	" 4 video
71.75	1.0+	" " audio
77.25	1.0+	" 5 video
81.75	1.2+	" " audio
83.25	1.1	" 6 video
87.75	1.0	" " audio
92.75	1.0	FM Broadcast
93.5	1.7+	" "
94.25	1.0	" "
95.5	1.5	" "
96.0	0.2	" "
96.75	0.4	" "
97.50	1.0	" "
98.25	0.75	" "
99.25	0.2	" "
99.75	0.2	" "
100.25	1.4	" "
101.25	1.0	" "
102.5	0.6	" "
103.75	2.2+	" "
104.0	2.0+	" "
105.5	1.0	" "
106.0	0.8	" "
106.75	2.0+	" "
109	0.8	Aeronautical Beacon
116.25	1.8	" "
116.25	1.0	" "
120.25	3.0	Beacon
120.5	0.75	Aeronautical
123	2.6+	"
139	0.5	"
143	0.5	"

Table II (continued)

FREQUENCY (mc/s)	FIELD STRENGTH (µV/M)	REMARKS
150.5	0.5	Aeronautical
160.5	0.4	"
181.25	1.2	Channel 18 video
185.75	5.0+	" 8 audio
187.25	4.2	" 9 video
193.25	1.6	" 10 video
197.75	1.8	" 10 audio
205.75	1.6	" 12 video
209.75	1.2	" 12 audio
1285	310.0	Radar
1310	35.0	"
1540	40.0	"
2810	21.0	"

TABLE III

SIGNAL INTENSITY AT GRIFFITH

September 20, 1957, daytime
rain

FREQUENCY (mc/s)	FIELD STRENGTH (μV/M)	REMARKS
55.25	0.1	Channel 2 video
59.75	0.1	" 2 audio
61.25	0.1	" 3 video
65.75	0.6	" 3 audio
67.25	0.1	" 4 video
71.75	0.5	" 4 audio
72-82		Hash
77.25	0.8	Channel 5 video
81.75	0.5	" 5 audio
81.75	0.9	" 6 audio
83.25	0.8	" 6 video
92.75	0.3	FM Broadcast
93.50	2.0+	" "
94.25	1.3	" "
95.25	0.6	" "
96.75	0.6	" "
97.75	1.8	" "
99.0	0.7	" "
100.5	0.9	" "
102	0.1	" "
102.5	0.2	" "
104	1.5	" "
105.5	1.1	" "
106	1.1	" "
106.5	1.0	" "
175.25	1.0	Channel 7 video
181.25	2.4	" 8 video
182	2.0	—
185.75	4.0	Channel 8 audio
187.25	0.75	" 9 video
193.25	0.50	" 10 video
203.75	0.5	" 10 audio
205.25	0.5	" 12 video
209.75	0.6	" 12 audio
215.75	0.7	" 13 audio
1290	320+	Radar

TABLE IV

SIGNAL INTENSITY AT MCGARRY FLATS

September 22, 1957, afternoon

FREQUENCY (mc/s)	FIELD STRENGTH (μV/M)	REMARKS
55.25	0.6	Channel 2 video
55.5	0.3	——
59.75	0.6	Channel 2 audio
61.25	0.9	" 3 video
65.75	1.0	" 3 audio
67.25	0.3	" 4 video
71.75	0.9	" 4 audio
77.25	0.9	" 5 video
81.75	1.1	" 5 audio
83.25	0.75	" 6 video
87.75	1.1	" 6 audio
90.75	0.3	TV rcvr interference
91.25	0.4	TV rcvr interference
92.75	0.4	TV rcvr interference
93.5	1.6+	FM Broadcast
94.0	1.5	" "
95	1.0	" "
95.5	0.5	TV rcvr interference
96.25	0.7	TV rcvr interference
96.75	0.8	TV rcvr interference
97.5	0.5	TV rcvr interference
97.75	1.0	FM Broadcast
98.5	0.8	TV rcvr interference
100-104.5	0.2-0.75	TV rcvr interference
105.5	1.0	FM Broadcast
107	2.5+	" "
108	0.3	" "
109.5	2.5	Aeronautical beacon
111	1.5	Aeronautical
113	0.2	"
115.5	0.4	"
116.5	1.1	"
118.5	1.3	"
127	0.2	"
150	2.3	"
193.25	1.1	Channel 10 video
197.75	2.1	" 10 audio

TABLE V

SIGNAL INTENSITY AT MCGARRY FLATS

September 22, 1957, evening

FREQUENCY (mc/s)	FIELD STRENGTH (μV/M)	REMARKS
55.25	0.6	Channel 2 video
59.75	0.5	" 2 audio
61.25	1.0	" 3 video
65.75	1.1+	" 3 audio
67.25	0.8	" 4 audio
71.75	0.8	" 4 audio
77.25	0.8	" 5 video
81.75	1.2	" 5 audio
83.25	1.0	" 6 video
87.75	0.7	" 6 audio
90	very strong	FM Broadcast
106	" "	" "
106.5	2.5+	" "
116	1.7	Aeronautical
120	1.0	"
135	4.0	"
175.25	4.0	Channel 7 video
181.25	4.0	" 8 video
185.75	4.0	" 8 audio
187.25	4.2	" 9 video
193.25	3.2	" 10 video
195	6.2	—
197.75	6.8+	Channel 10 audio
199.25	3.0	" 11 video
203.75	4.5	" 11 audio
205.25	7.0+	—
209.75	7.0+	Channel 12 audio
211.25	2.0	" 12 video
215.75	2.0	" 13 audio
September 23, 1957		
1740*	2.5	Radar
2802	1.2	"
2915*	1.2	"
3063	2.5	CW (Possibly tellurimeter)
October 28, 1957		
1290	56	Radar
2800	3.5	"

* Doubtful

TABLE VI

SIGNAL INTENSITY AT MADAWASKA AIRPORT

October 26, 1957

FREQUENCY (mc/s)	FIELD STRENGTH (μV/M)	REMARKS
55.25	0.5	Channel 2 video
59.75	0.2	" 2 audio
61.25	0.5	Channel 3 video
64.5	0.1	——
65.75	0.6	Channel 3 audio
67.25	0.1	" 4 video
71.75	0.6	" 4 audio
77.25	0.2	" 5 video
81.75	0.3	" 5 audio
83.25	0.3	" 6 video
85	1.3	Unidentified noise modulated carrier
87.75	0.2	Channel 6 audio
94	0.5	FM Broadcast
98	0.5	" "
100	0.15	" "
104	0.15	" "
106	0.3	" " weak relative to impulsive noise present
120	1.5	Aeronautical beacon
139	2.5	Aeronautical
166	0.3	"
167	0.3	"
175.25	0.3	Channel 7 video
179.75	0.5	" 7 audio
181.25	4.0+	" 8 video
1290	250	Radar

TABLE VII

SIGNAL INTENSITY AT BASIN DEPOT

October 23, 1957, afternoon
heavy rain

FREQUENCY (mc/s)	FIELD STRENGTH (μV/M)	REMARKS
55.25	0.1	Channel 2 video
59.75	0.3	" 2 audio
65.75	0.3	" 3 audio
67.25	0.7	" 4 video
71.75	1.0	" 4 audio
77.0	0.1	——
77.25	0.1	Channel 5 video
81.75	0.1	" 5 audio
83.25	0.15	" 6 video
87.75	0.15	" 6 audio
97	0.4	FM Broadcast
105	0.2	" "
120	2.6	Aeronautical beacon
181.25	1.3	Channel 8 video
1290	70	Radar
1320	20	"
1585*	10	"
1695*	10	"

* Doubtful

TABLE VIII

SIGNAL INTENSITY AT LAKE TRAVERSE

October 24, 1957, afternoon
heavy rain

FREQUENCY (mc/s)	FIELD STRENGTH ($\mu V/M$)	REMARKS
55.25	0.3	Channel 2 video
56	0.2	——
56.75	0.2	——
59.75	0.6	Channel 2 audio
60	0.2	——
61.25	0.1	Channel 3 video
64	0.2	——
64.5	0.2	——
65.75	0.4	Channel 3 audio
67.25	0.6	" 4 video
71.75	0.6	" 4 audio
77.25	0.5	" 5 video
81.75	0.7	" 5 audio
83.25	0.15	" 6 video
87.75	0.2	" 6 audio
91	0.2	FM Broadcast
91.75	0.15	" "
92.5	0.15	" "
93	0.15	" "
94	1.3	" "
96	0.15	" "
99	0.5	" "
100	0.4	" "
101	0.15	" "
107	0.5	" "
120	1.2	Aeronautical beacon
179.75	1.5	Channel 7 audio
1290	40	Radar

TABLE IX

SIGNAL INTENSITY AT MONTGOMERY LAKE

October 25, 1957, morning

FREQUENCY (mc/s)	FIELD STRENGTH (μV/M)	REMARKS
59.75	0.4	Channel 2 audio
61.25	0.1	" 3 video
71.75	0.1	" 4 audio
77.25	0.1	" 5 video
81.75	0.6	" 5 audio
83.25	0.4	" 6 video
87.75	0.4	" 6 audio
91	0.15	FM Broadcast
96	0.15	" "
102	0.2	" "
104	0.4	" "
120	2.0	Aeronautical beacon
175.25	0.5	Channel 7 video
179.75	1.2	" 7 audio
191.75	0.5	" 9 audio
1290	45	Radar

TABLE X

SIGNAL INTENSITY AT GOTH HILL

January 9, 1958, daytime

FREQUENCY (mc/s)	FIELD STRENGTH (μV/M)	REMARKS
55.25	3.5	Channel 2 video
59.75	0.75	" 2 audio
61.25	350	" 3 video
63.0	0.5	——
65.75		Channel 3 audio
67.25	1600	" 4 video
67-74	12	" 4 TV
71.75	3200	" 4 audio
75.0	8	Aeronautical beacon
76.5	0.5	Aeronautical
77.25	0.75	Channel 5 video
77.5	0.15	——
78.5	0.1	——
79.0	0.1	——
81.75	4.5	Channel 5 audio
83.25	20	" 6 video
87.75	19	" 6 audio
89.5	0.2	FM Broadcast
91	1.7	" "
92.5	0.2	" "
93.5	17	" "
94.0	450	" "
95.5	7.0	" "
96.0	0.8	" "
96.5	0.15	" "
97.5	1.0	" "
98.0	1.1	" "
99.0	1.4	" "
99.5	1.0	" "
100	0.8	" "
101	0.8	" "
102.5	0.4	" "
103.5	900	" "
105	0.9	" "
105.5	120	" "

Table X (continued)

FREQUENCY (mc/s)	FIELD STRENGTH (μV/M)	REMARKS
169	0.5	Mobile
175.25	20	Channel 7 video
179.75	10	" 7 audio
181.25	1.3	" 8 video
187.25	2800	" 9 video
191.75	2500	" 9 audio
193.25	2.2	" 10 video
197.75	2.0	" 10 audio
198	0.6	——
199.25	3.0	Channel 11 video
201	0.5	——
202	9.0	——
203	0.2	——
203.75	1.7	Channel 11 audio
205.25	6.0	" 12 video
209	1.0	——
209.75	4.0	Channel 12 audio
211.25	20	" 13 video
215	9	——
215.75	9	Channel 13 audio
217	14	——
231	1.5	——
255	1.8	——
1645	25	Radar
2710	8.5	"
2800	1200	"
2930	15+	"

CONCLUSIONS

No site has been discovered in Eastern Canada which is free from radar interference. None of the sites investigated in Ontario compared in suitability with the best of the British Columbia sites. Three possible sites have been discovered in Ontario. They are, in order of preference: McGarry Flats, Lake Traverse, and Montgomery Lake. McGarry Flats meets nearly all the requirements for size, location, accessibility, etc., but suffers from L-band radar interference. The remaining two sites are much less accessible and would require considerable development. All three sites are much superior to the present site at Goth Hill.

The probability of discovering a suitable site in the western area of Algonquin Park is considered small. There is a possibility that a site may be found in the Laurentian Hills, north of Des Joachims and this area might be investigated. The remaining areas of possible interest are the Eastern Townships and the Gaspe penninsula of Quebec. However, a preliminary map search of these regions has not indicated any promising areas.

It is, therefore, concluded that any site in eastern Canada suitable for the purpose will be subject to a certain amount of radar interference, and that if an observatory were established this interference would have to be tolerated.

RECOMMENDATIONS

It is recommended that a committee whose members would be Dr. D.W.R. McKinley, Dr. G.A. Miller, A.E. Covington, C.F. Pattenson, and N.W. Broten visit the most promising sites in Ontario and that further search be postponed until the committee has expressed an opinion on the suitability of sites discovered to date and on the need for further search.

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3. R.H. Dicke, "The Measurement of Thermal Radiation at Microwave Frequencies". Rev. Sci. Instr. 17, 268-75, 1946
4. J.E. Gibson, "Comparison-Type Receivers for White Noise Radiation at 0.86 cm Wavelength". NRL Report 4864, December 1956
5. "Plan for a Radio Astronomy Observatory." Associated Universities, Incorporated, New York, N.Y., August 1956
6. "Report on Field Strength Surveys for a Radio Astronomy Facility under Contract Number N-173s-21787." Jansky and Bailey, Incorporated, October 1955

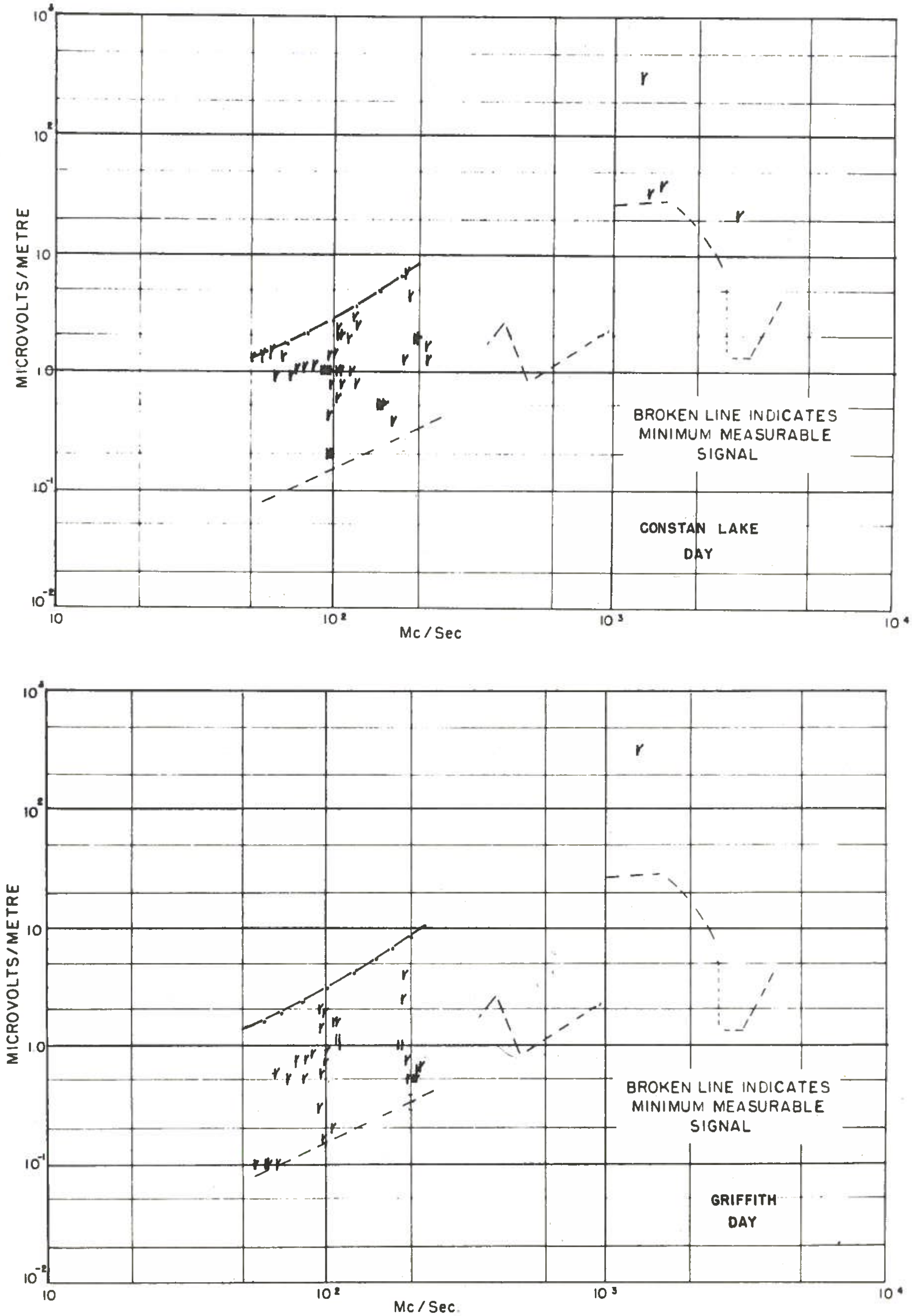
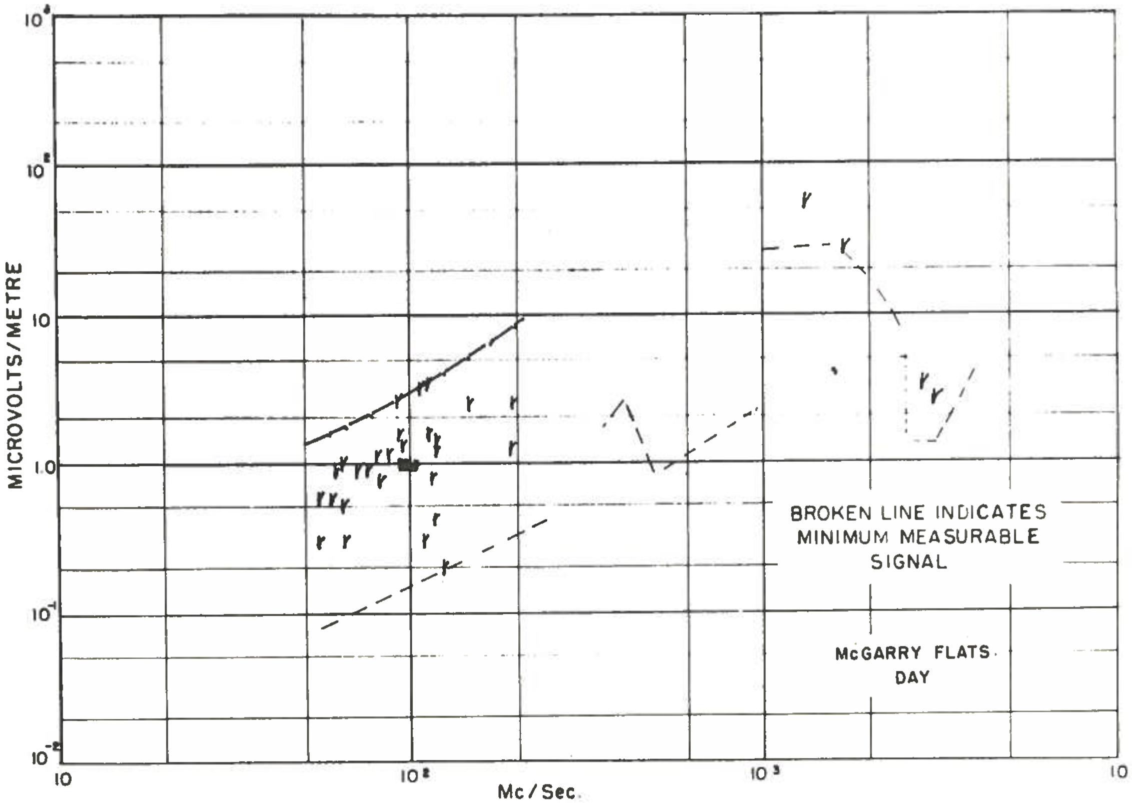


FIG. 1. NOISE MEASUREMENT AT CONSTAN LAKE AND GRIFFITH



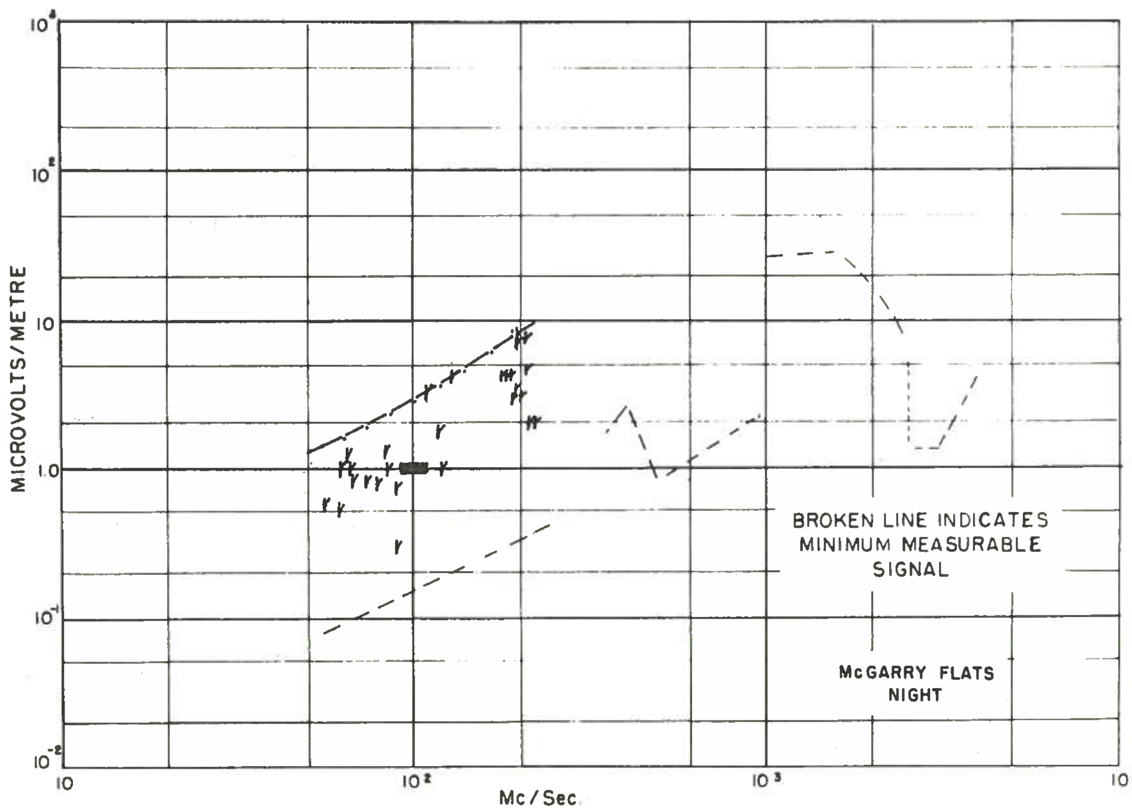
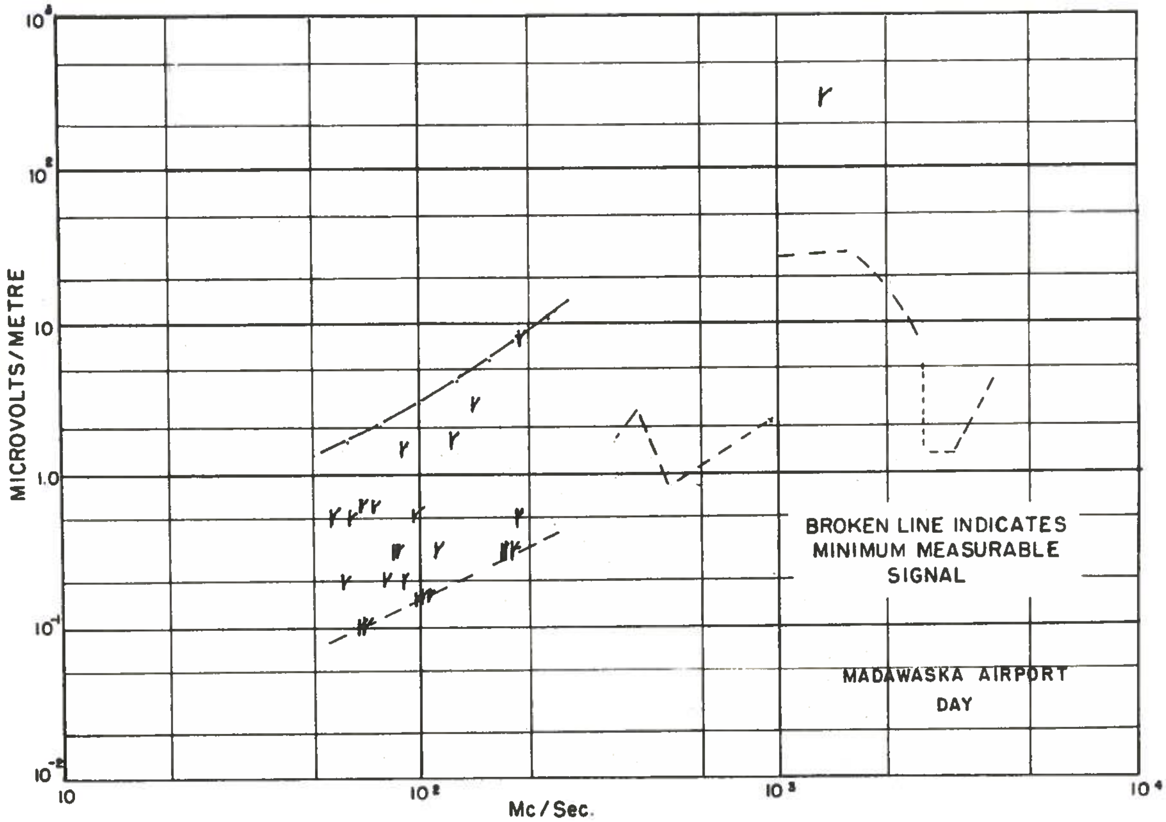


FIG. 2. NOISE MEASUREMENT AT MCGARRY FLATS, DAY AND NIGHT



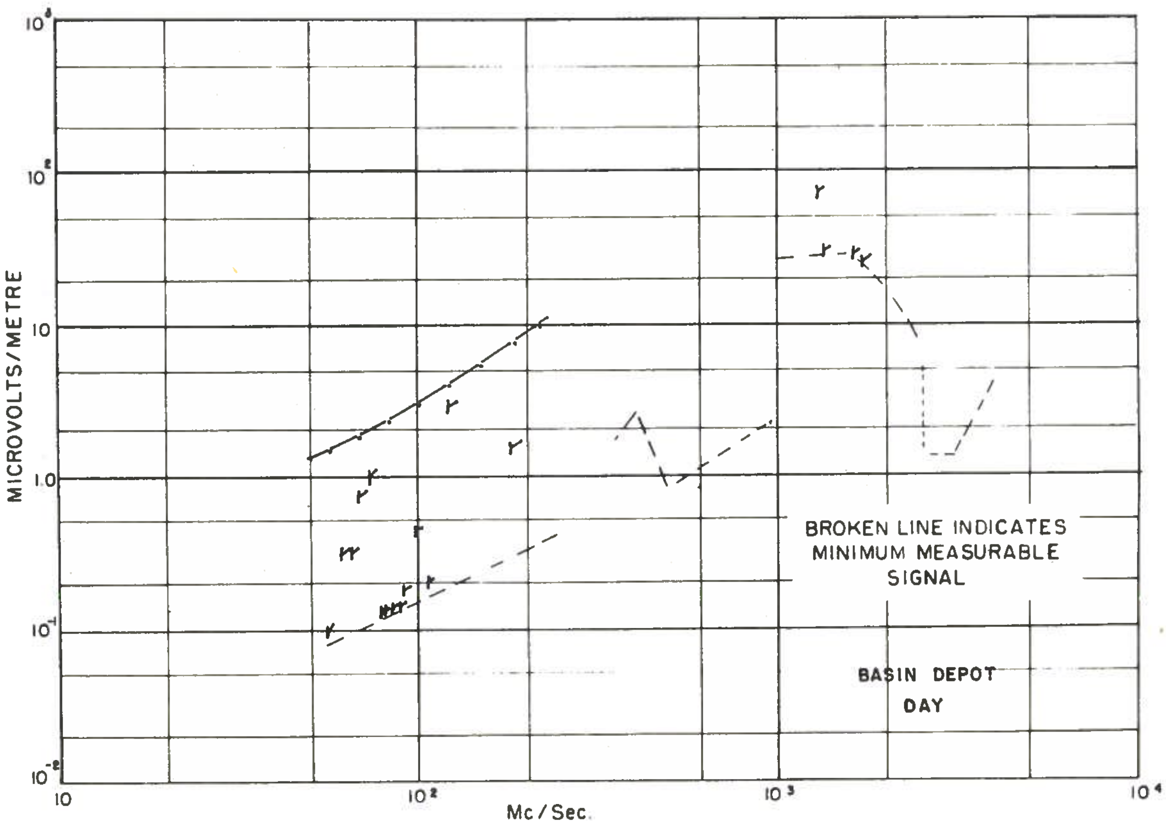
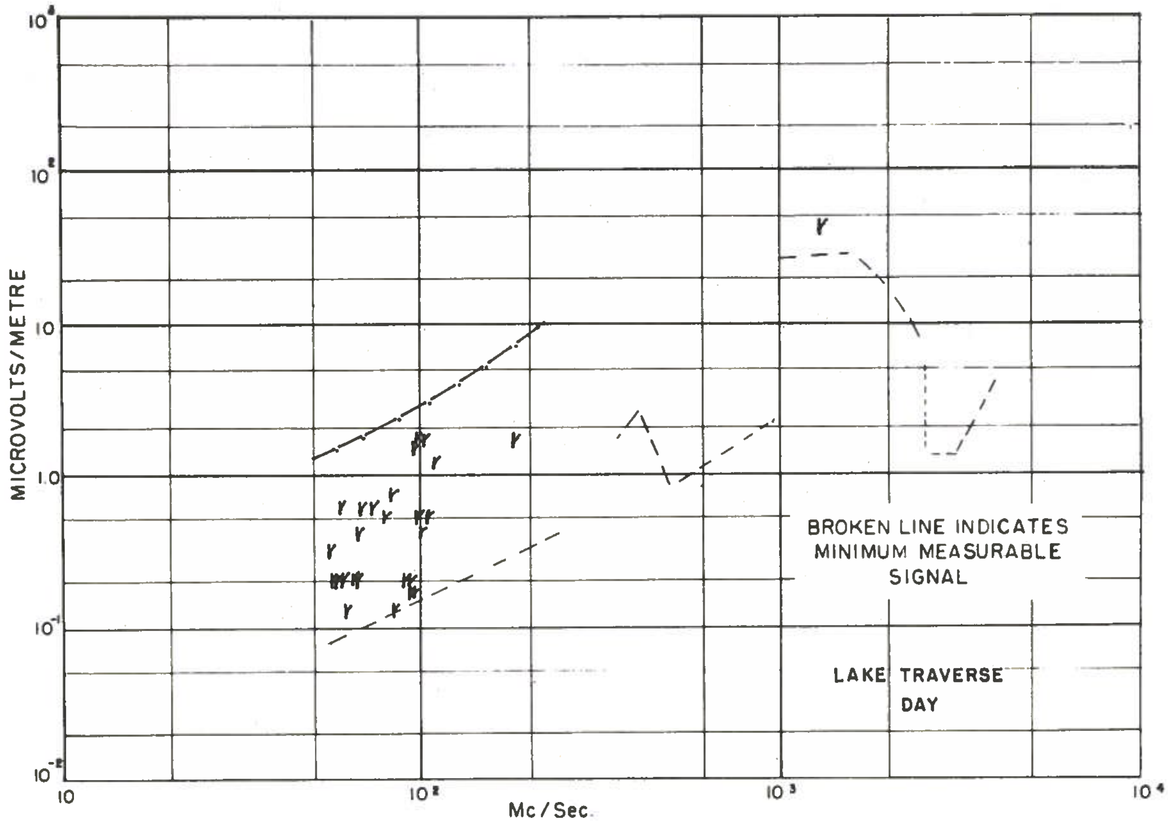


FIG. 3. NOISE MEASUREMENT AT MADAWASKA AIRPORT AND BASIN DEPOT



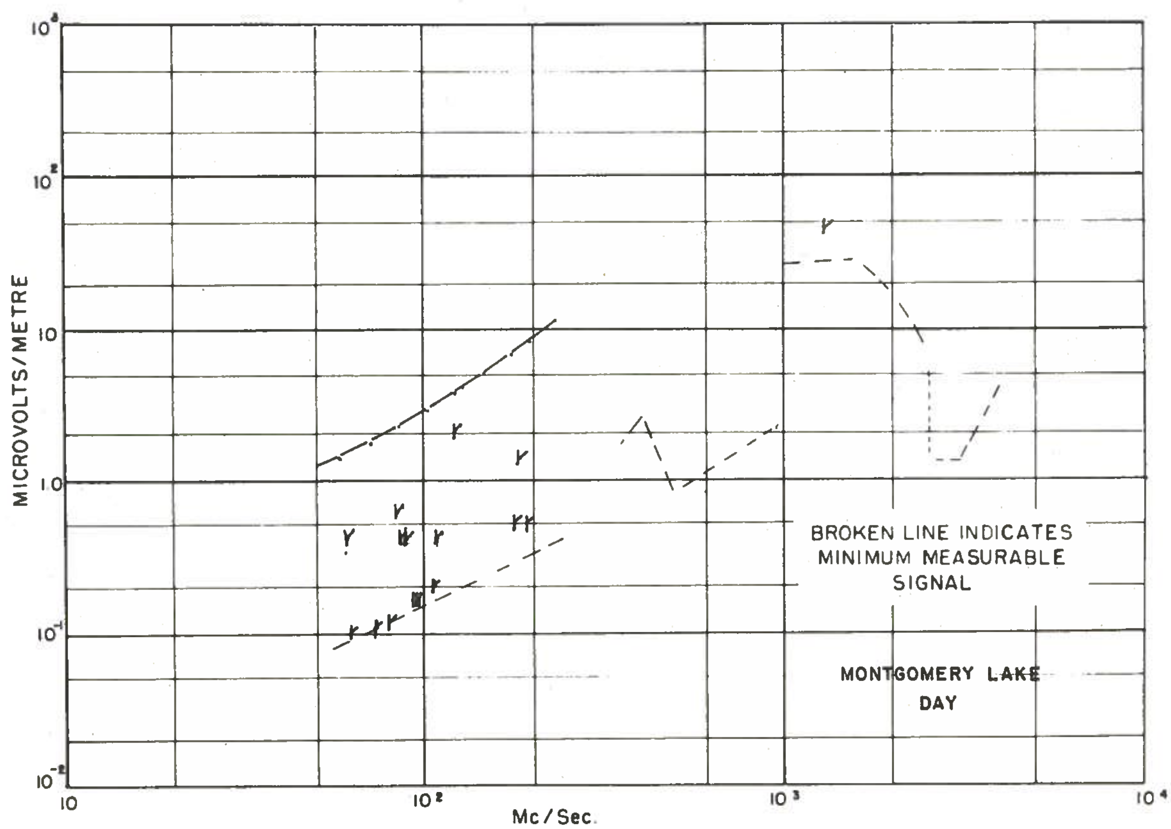
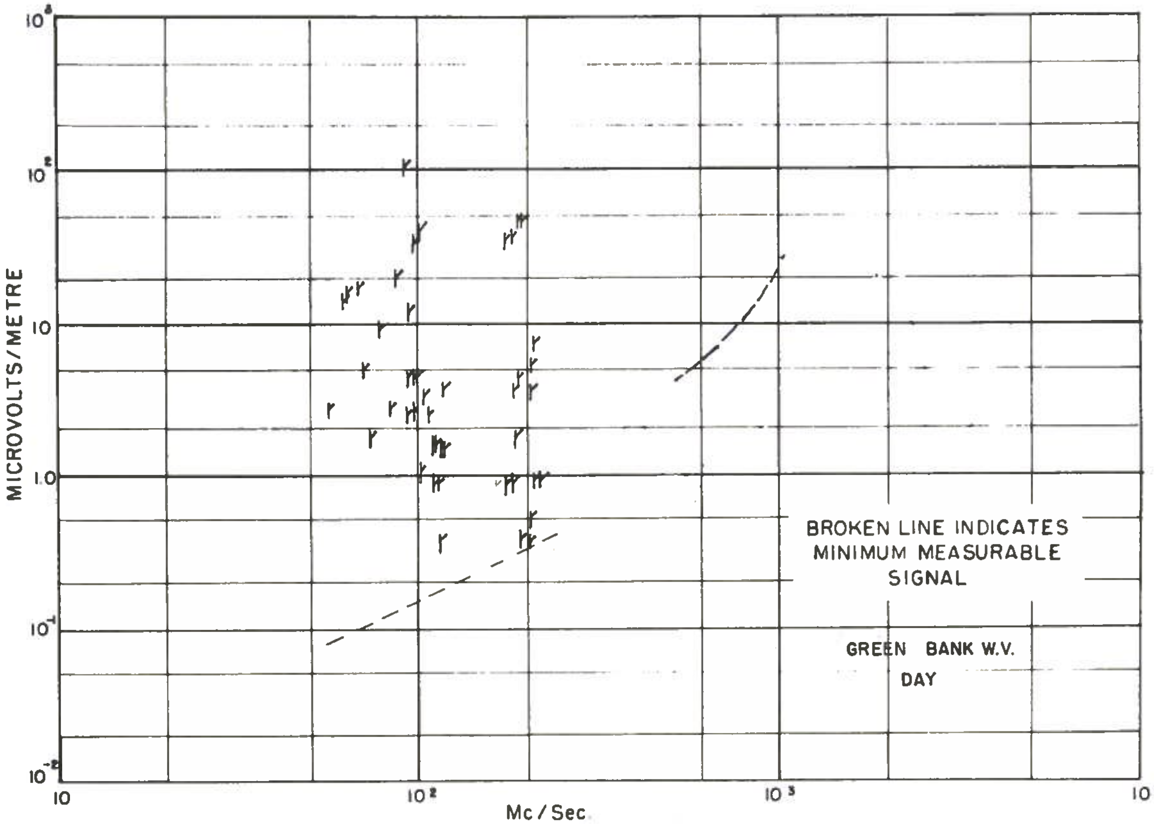


FIG. 4. NOISE MEASUREMENT AT LAKE TRAVERSE AND MONTGOMERY LAKE



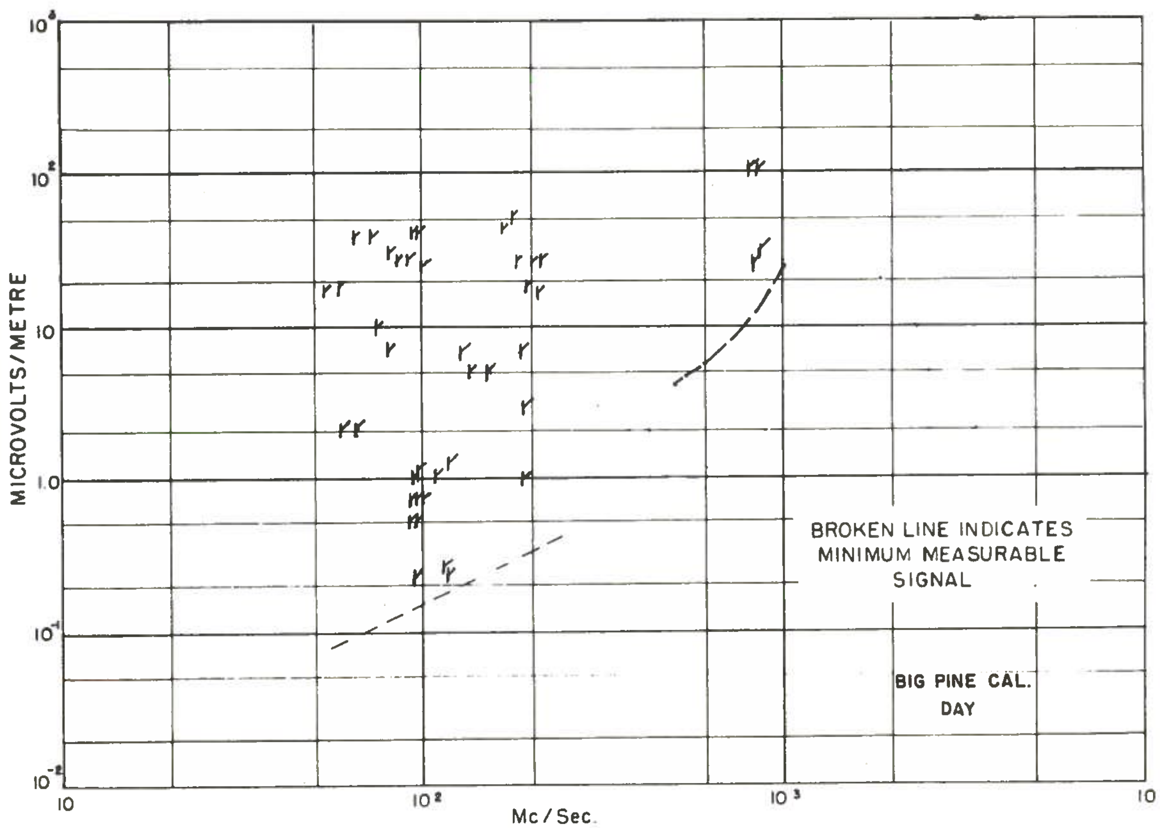


FIG. 5. NOISE MEASUREMENT AT GREEN BANK AND BIG PINE

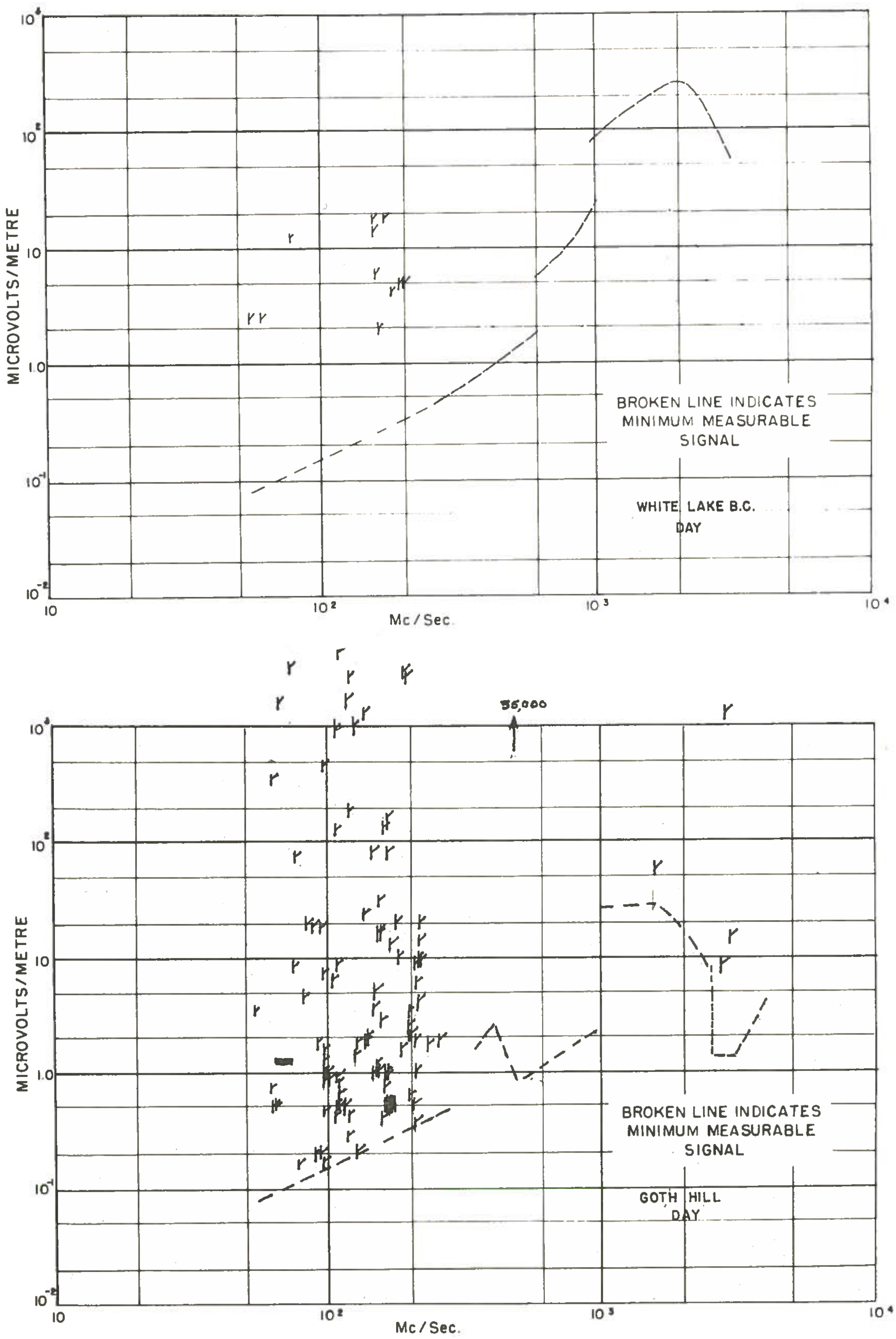
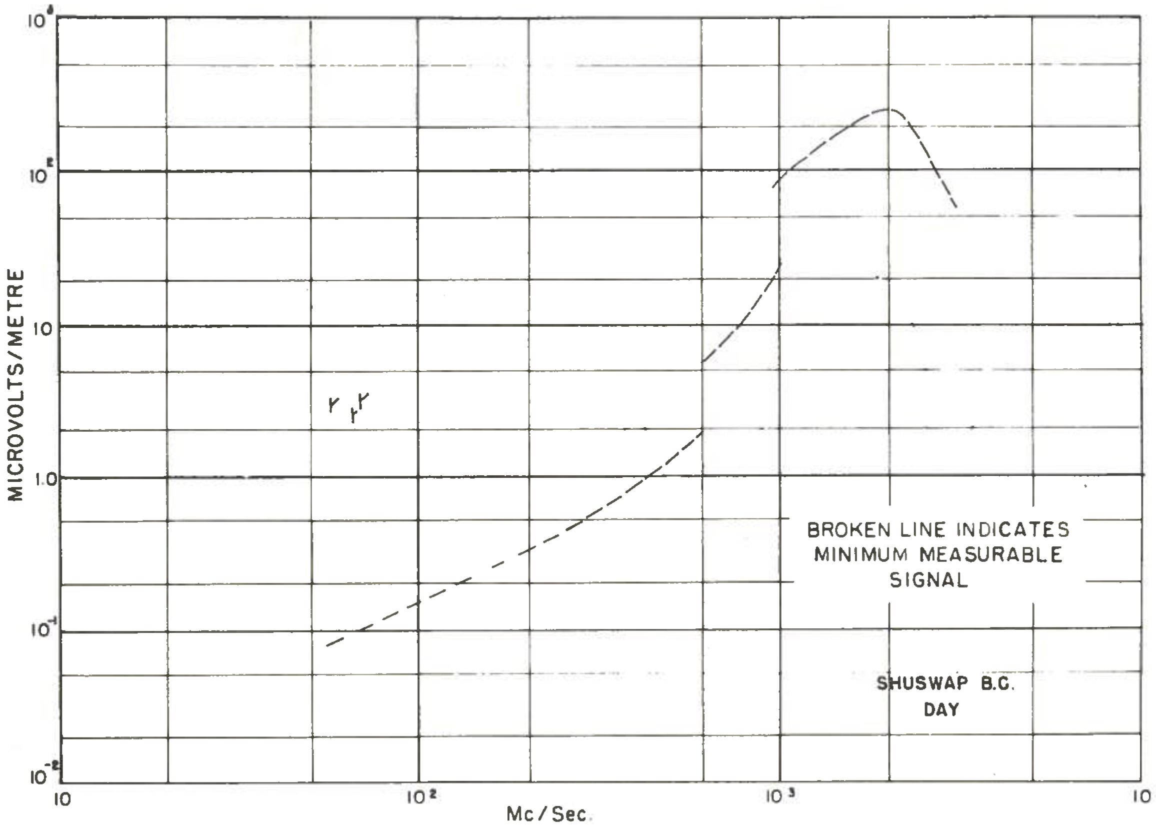


FIG. 6. NOISE MEASUREMENT AT WHITE LAKE AND GOTH HILL



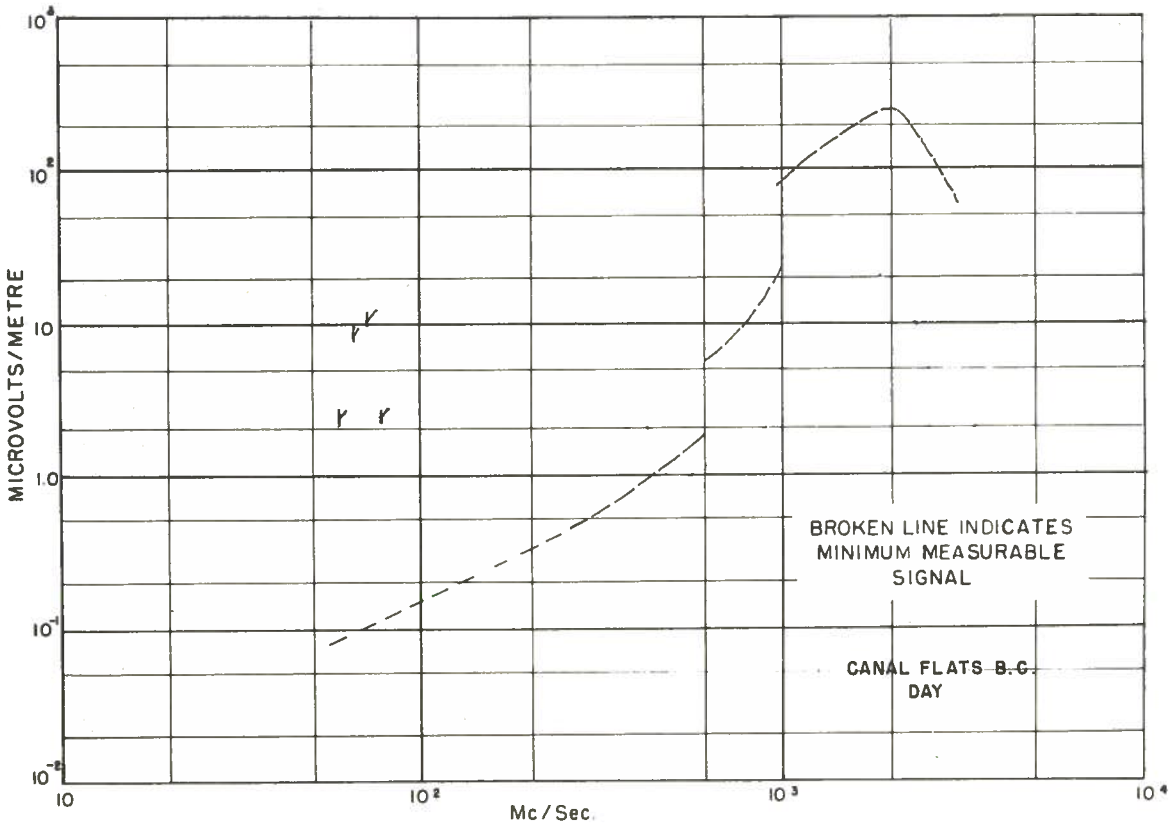
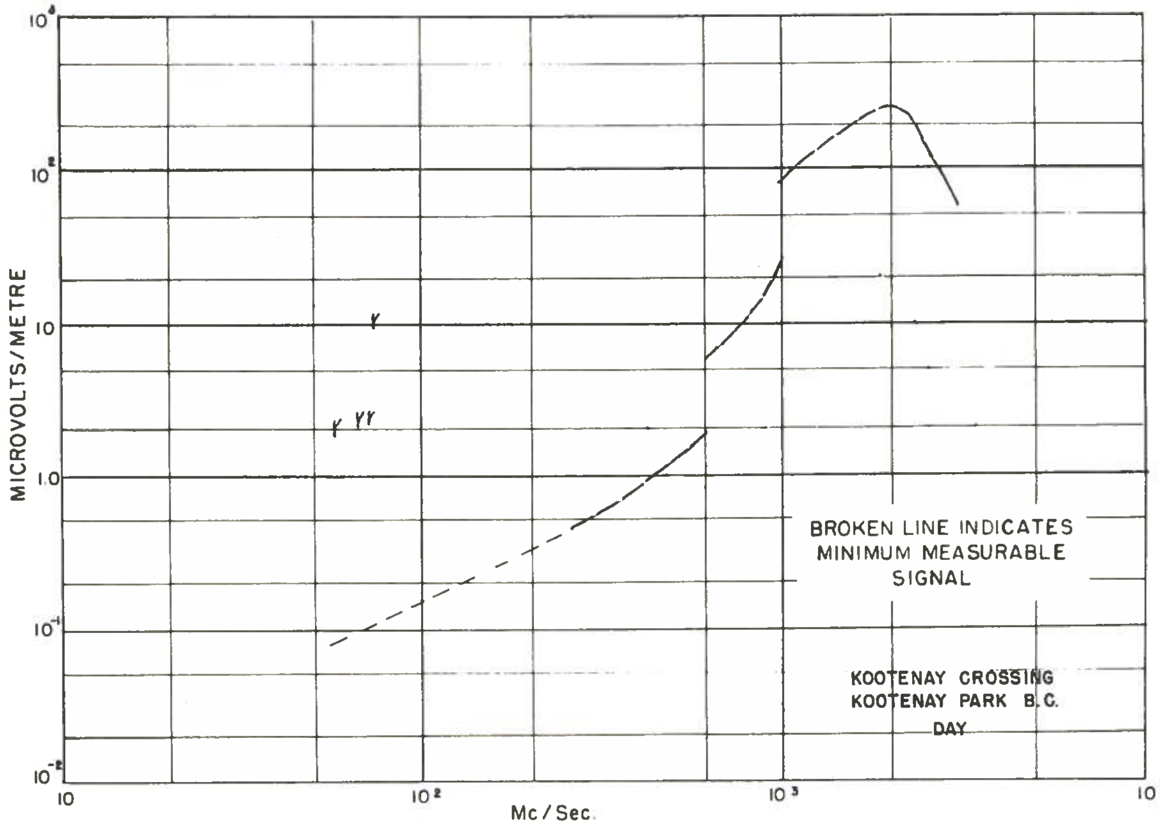


FIG. 7. NOISE MEASUREMENT AT SHUSWAP AND CANAL FLATS



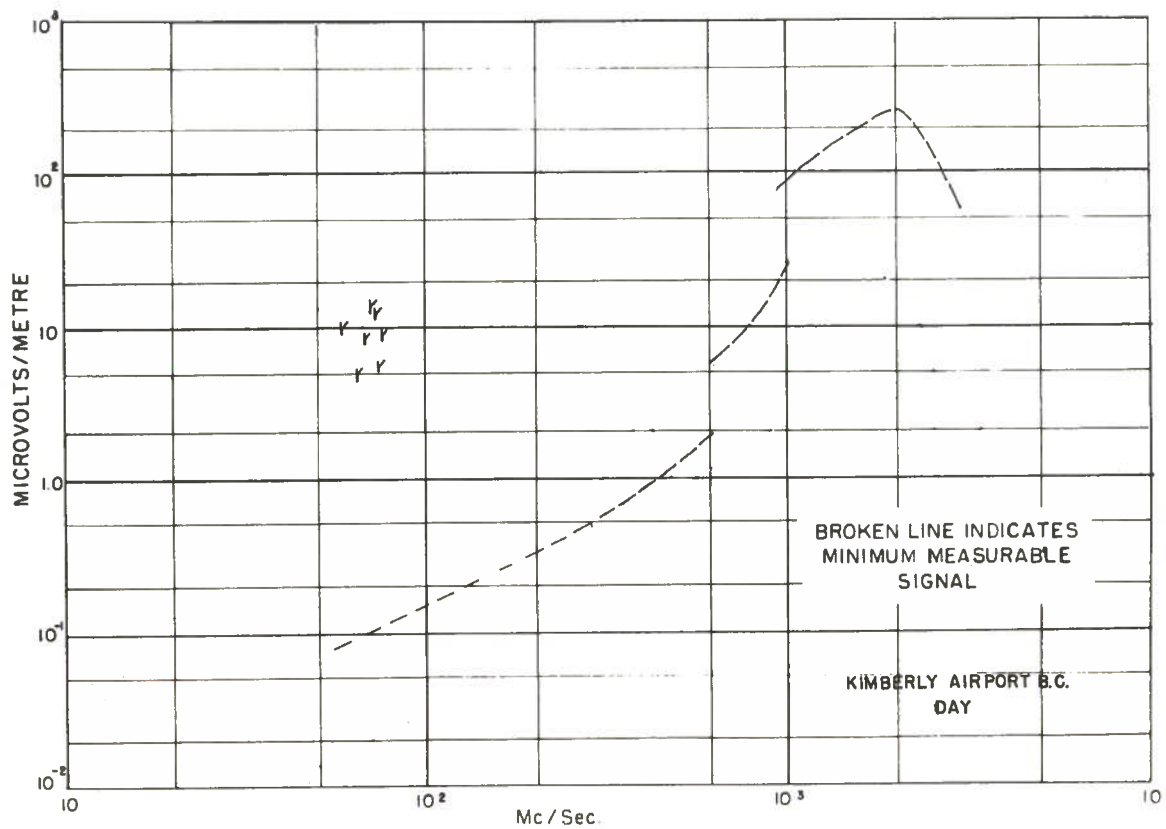


FIG. 8. NOISE MEASUREMENT AT KOOTENAY CROSSING AND KIMBERLY AIRPORT

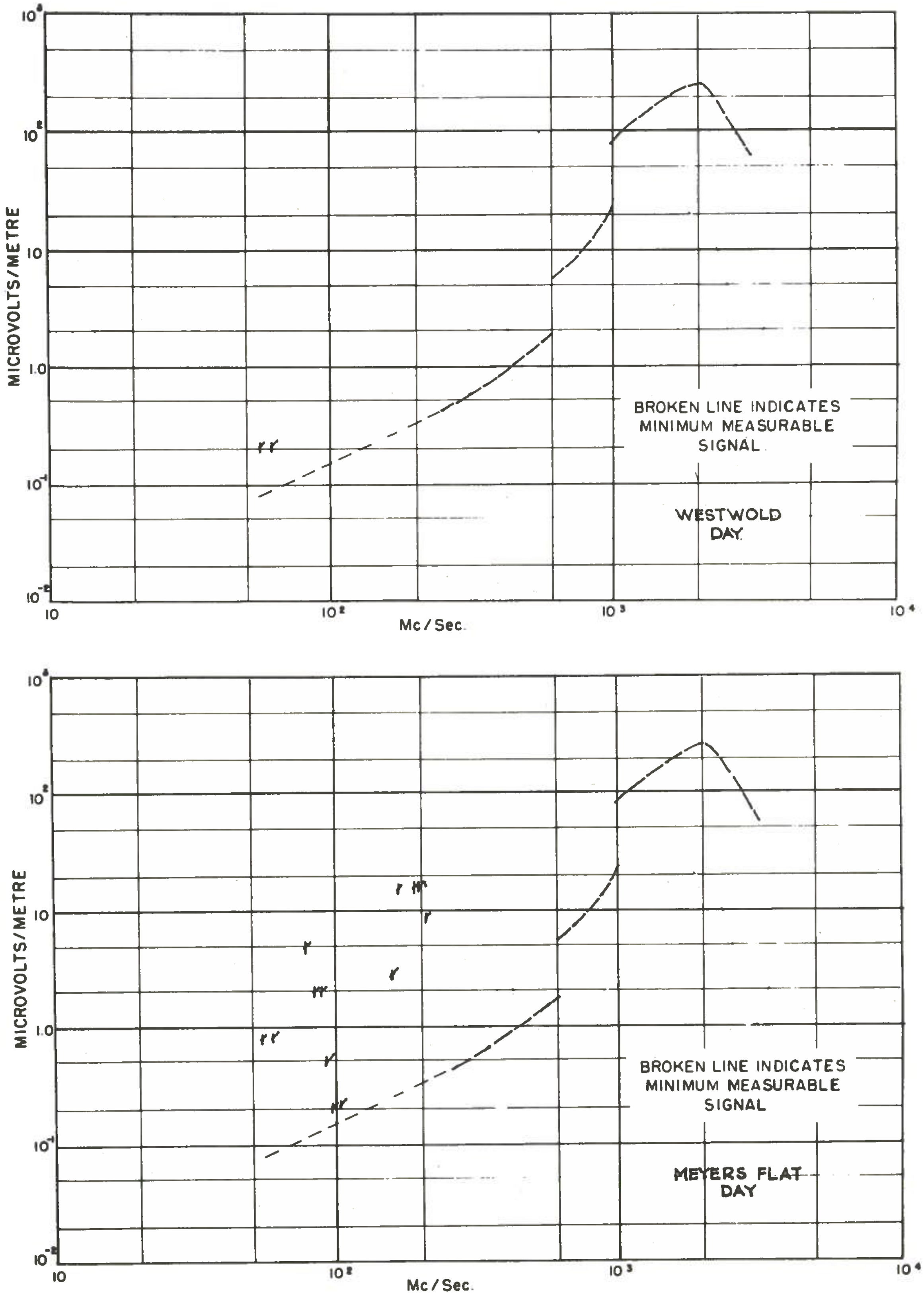


FIG. 9. NOISE MEASUREMENT AT MEYERS FLAT AND WESTWOLD

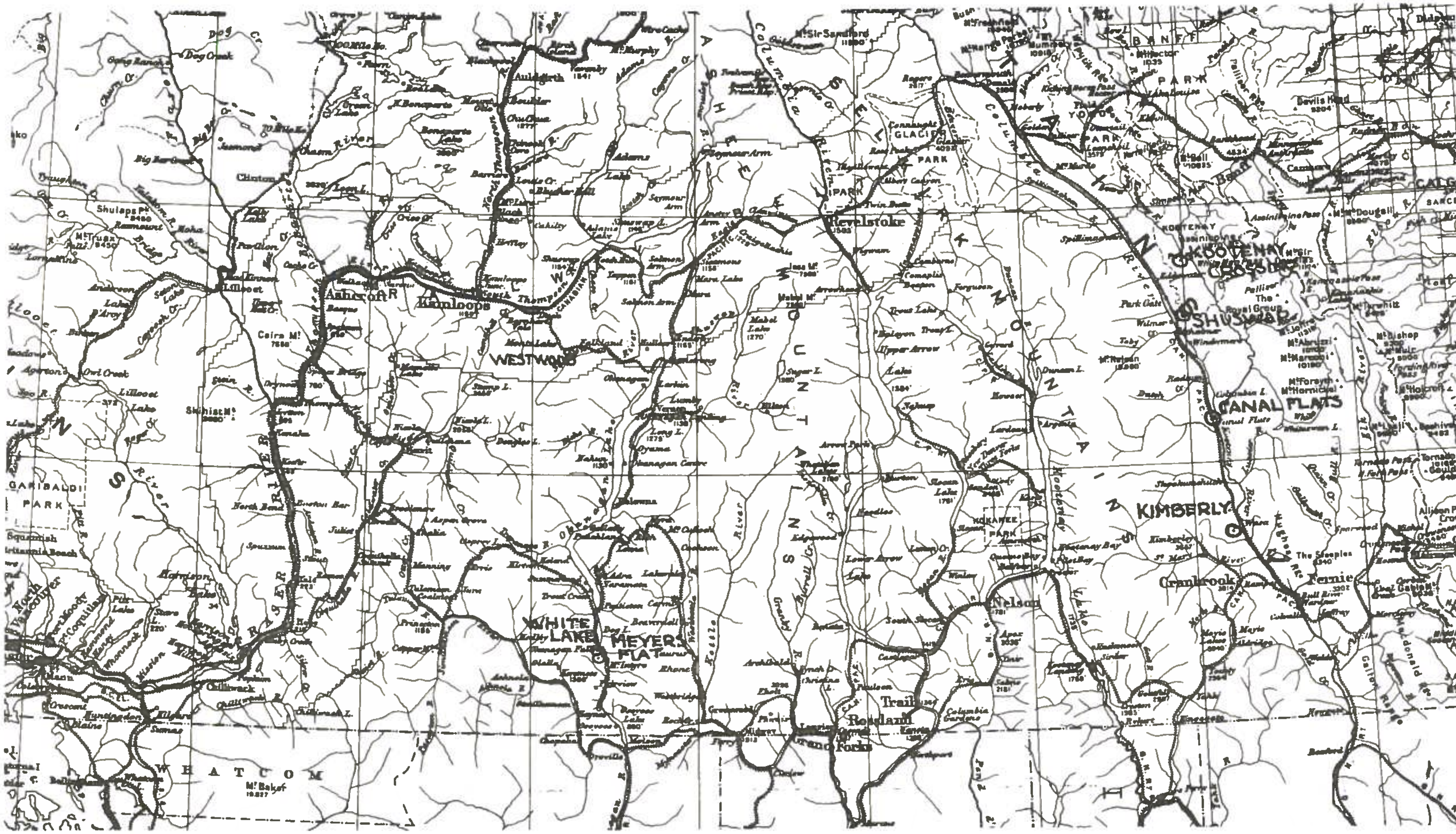


PLATE I BRITISH COLUMBIA SEARCH AREA

PLATE II EASTERN CANADA SEARCH AREA

PLATE III MAP SHOWING LOCATION OF MCGARRY FLATS

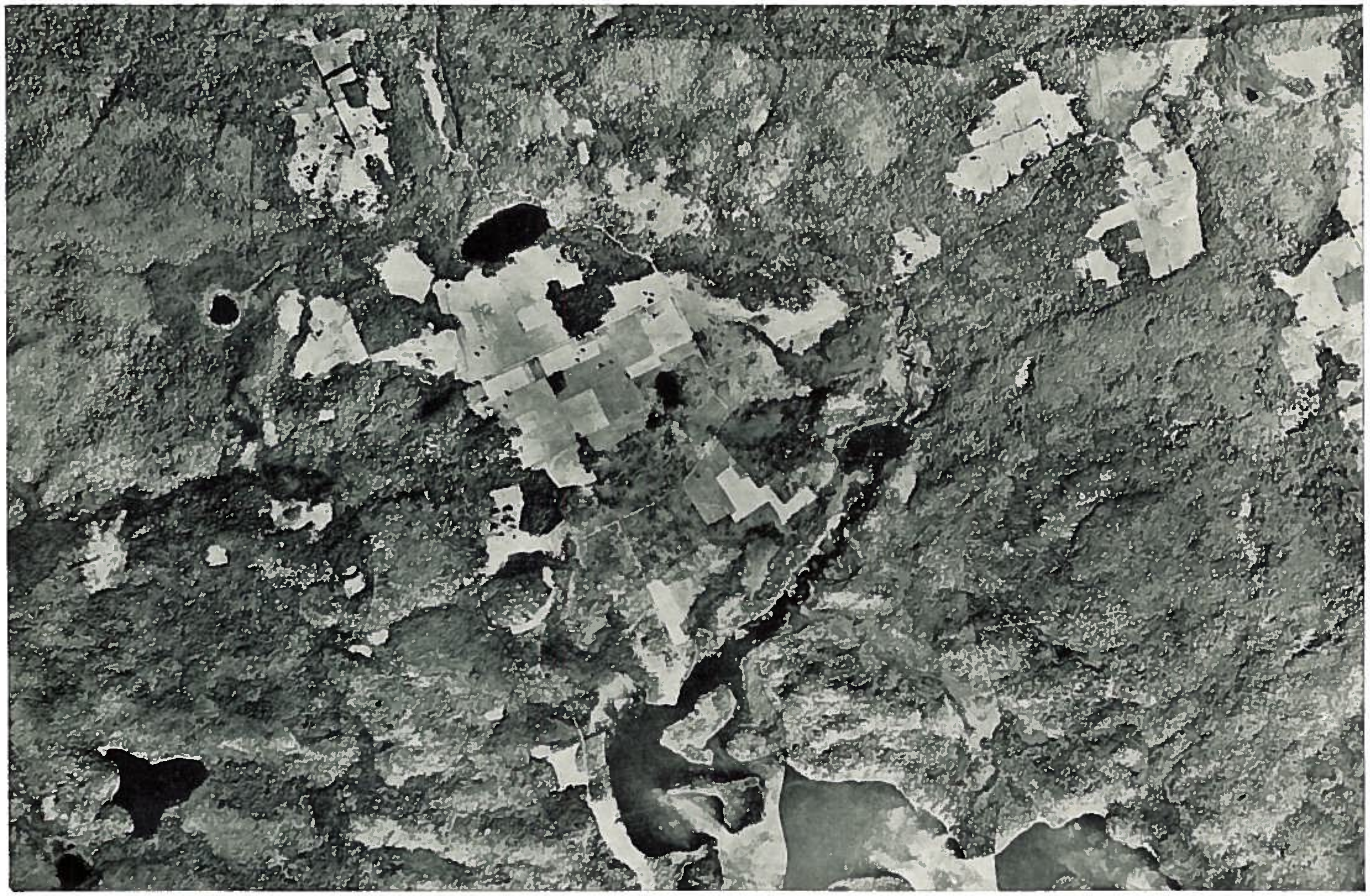


PLATE IV—AERIAL PHOTOGRAPH OF MCGARRY FLATS

RCAF Photo

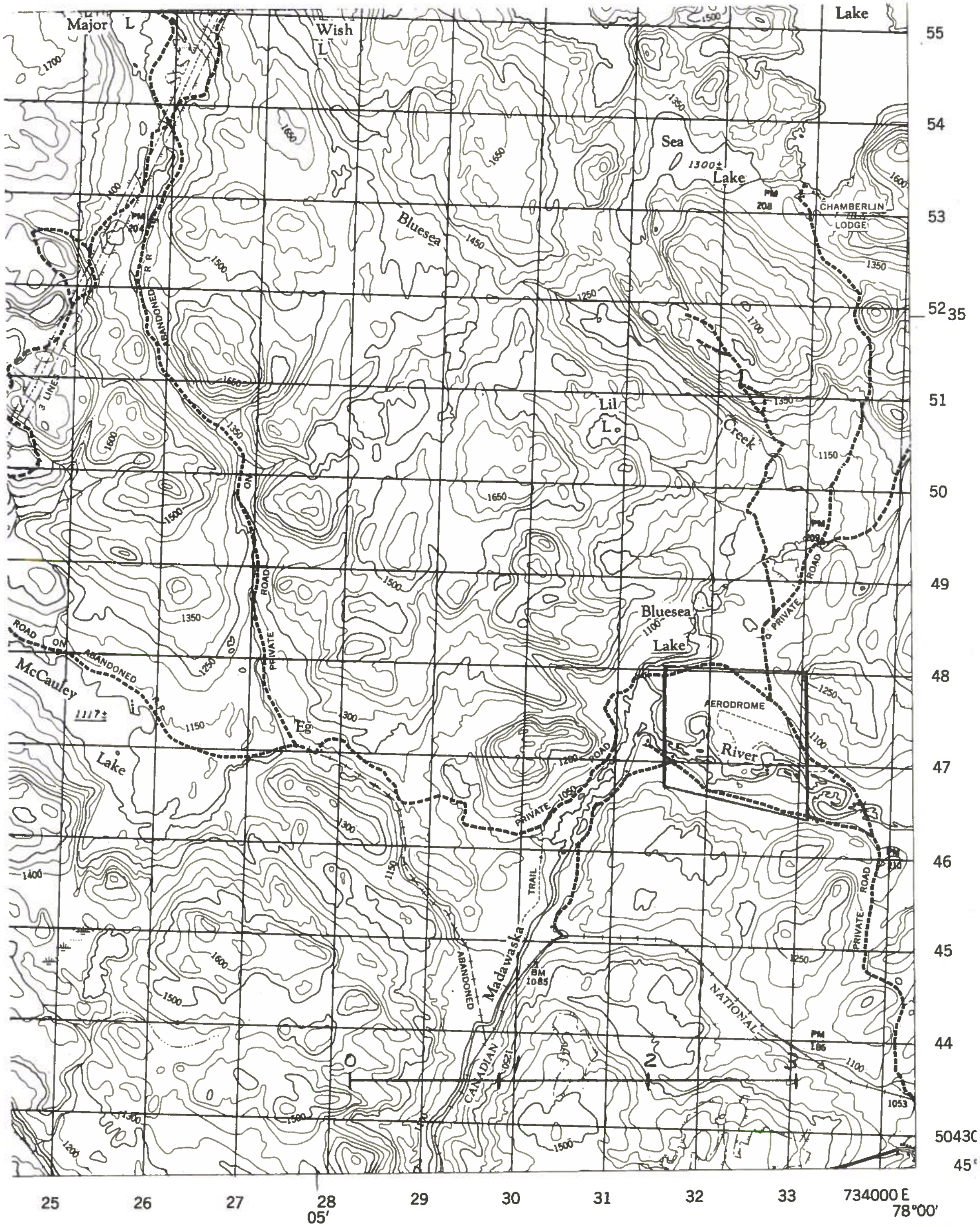


PLATE V MAP SHOWING LOCATION OF MADAWASKA AIRPORT

PLATE VI—AERIAL PHOTOGRAPH OF MADAWASKA AIRPORT

RCAF Photo

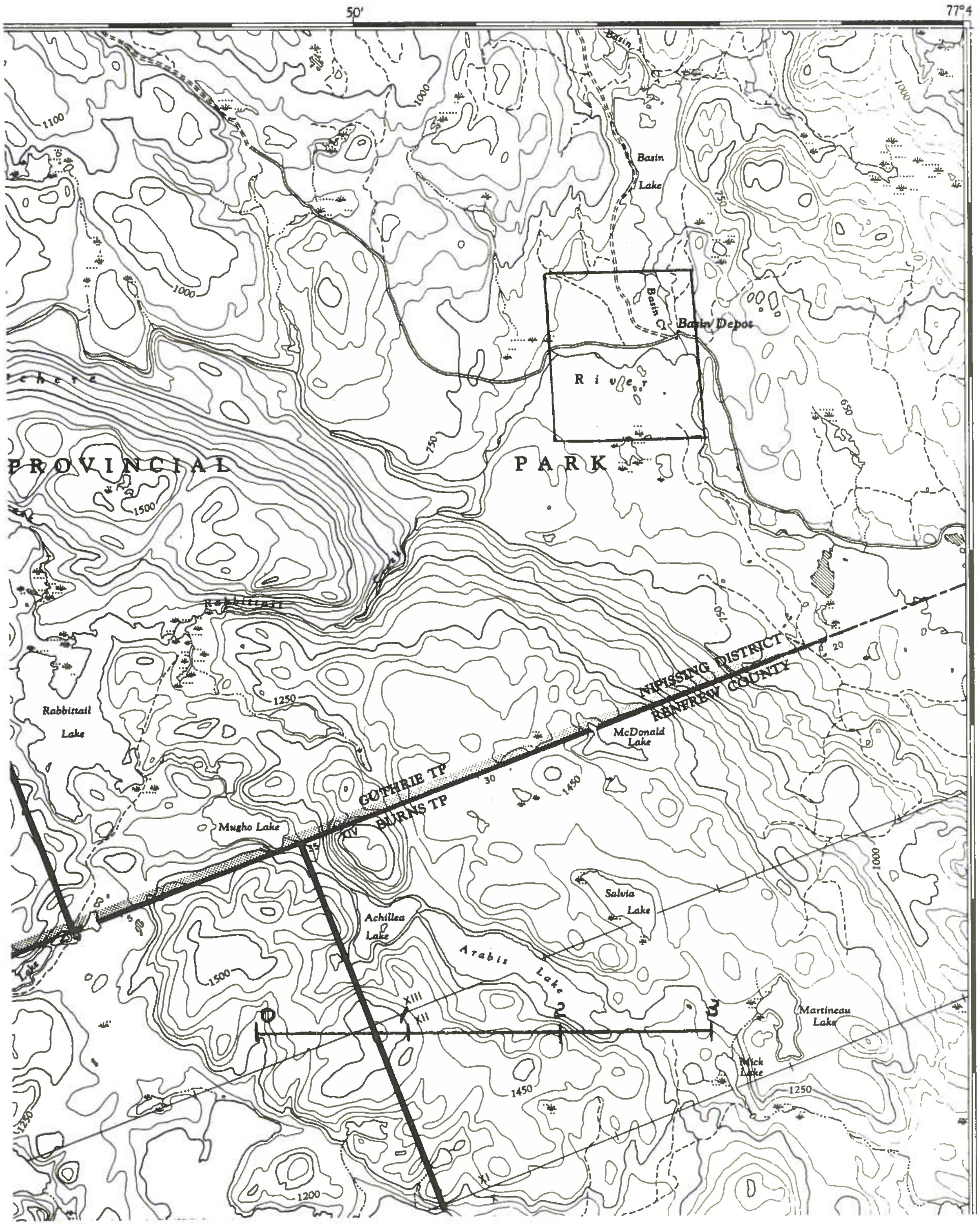


PLATE VII MAP SHOWING LOCATION OF BASIN DEPOT

PLATE VIII—AERIAL PHOTOGRAPH OF BASIN DEPOT

RCAF Photo

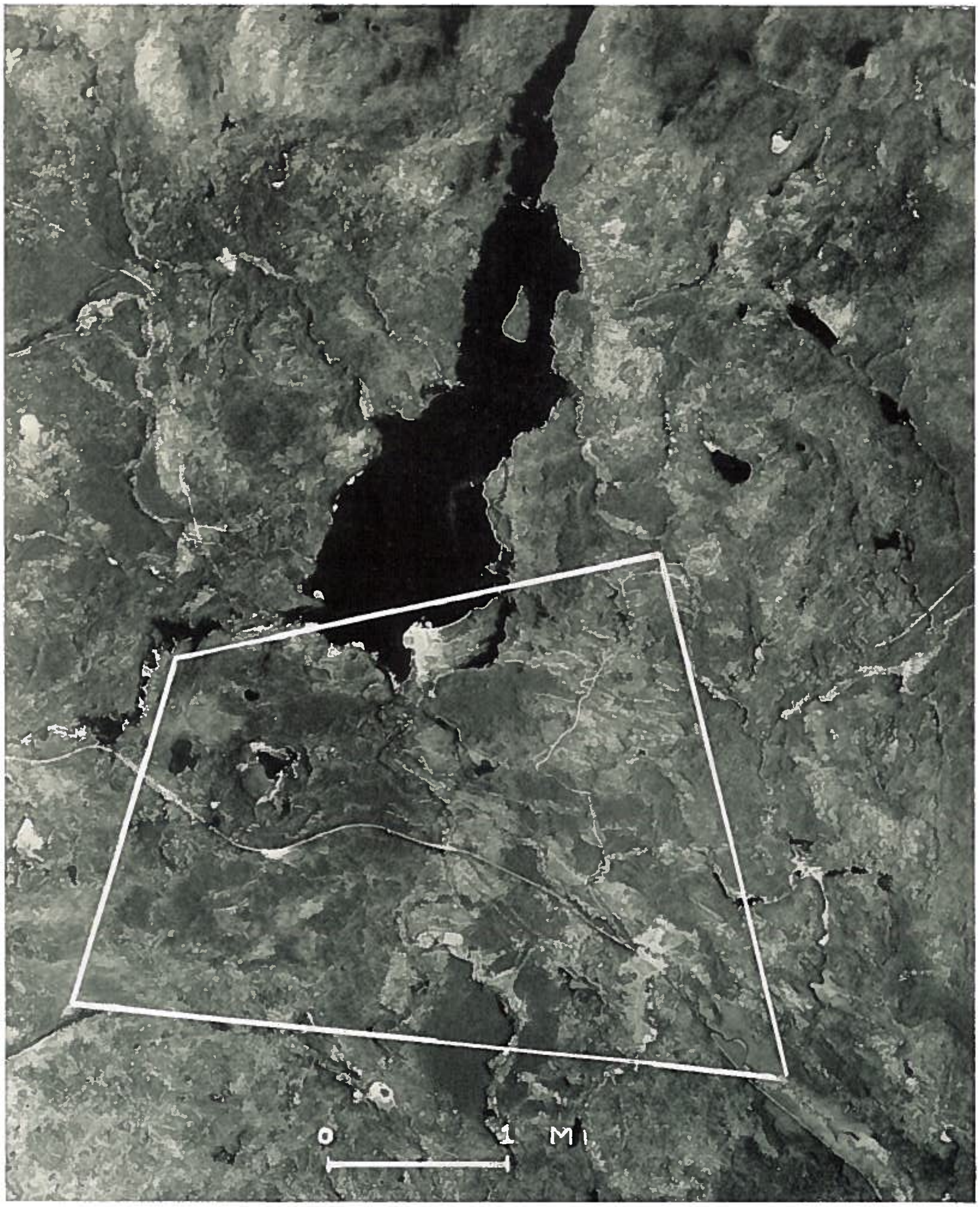


PLATE IX—AERIAL PHOTOGRAPH OF LAKE TRAVERSE

RCAF Photo

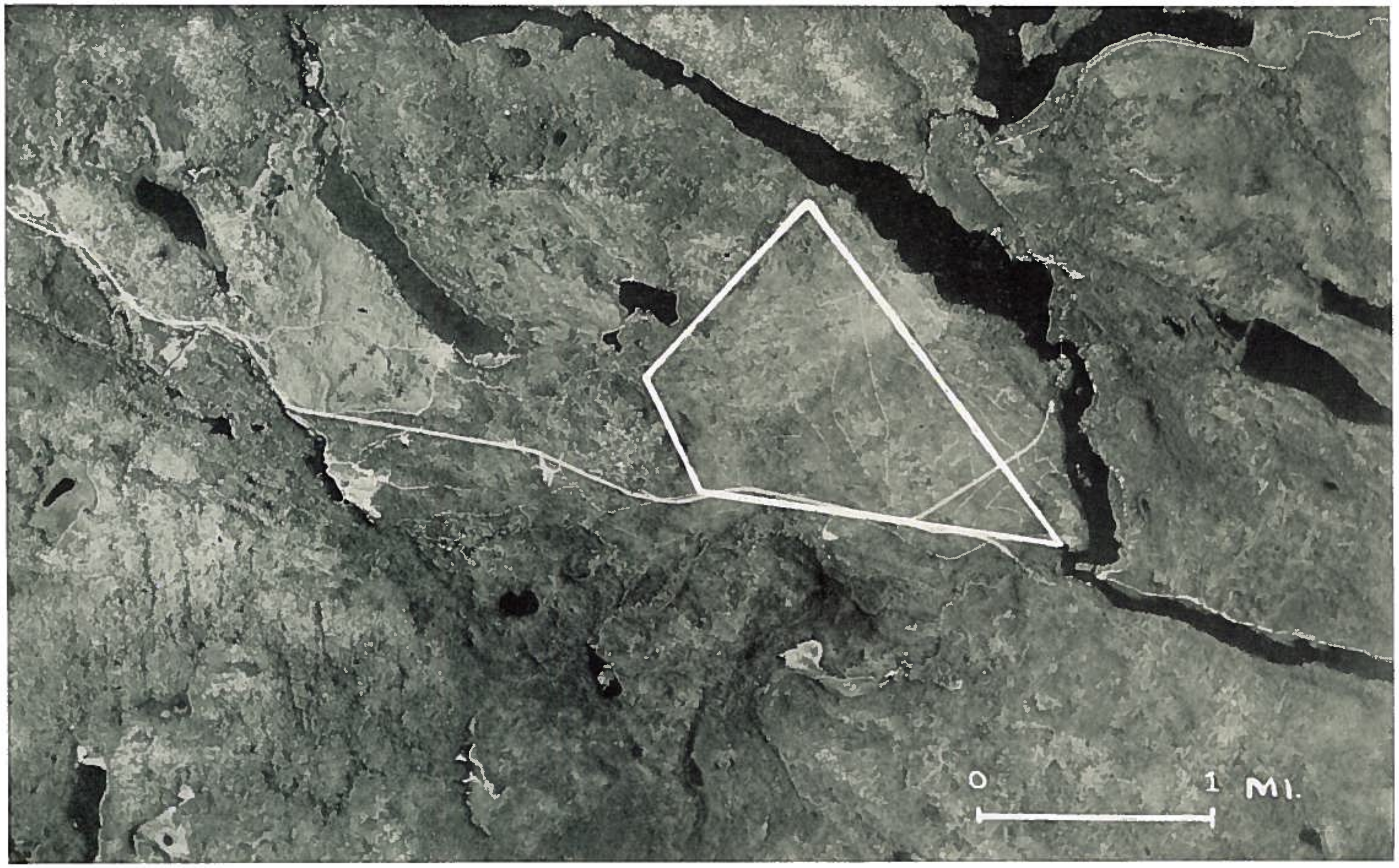


PLATE X—AERIAL PHOTOGRAPH OF MONTGOMERY LAKE

RCAF Photo

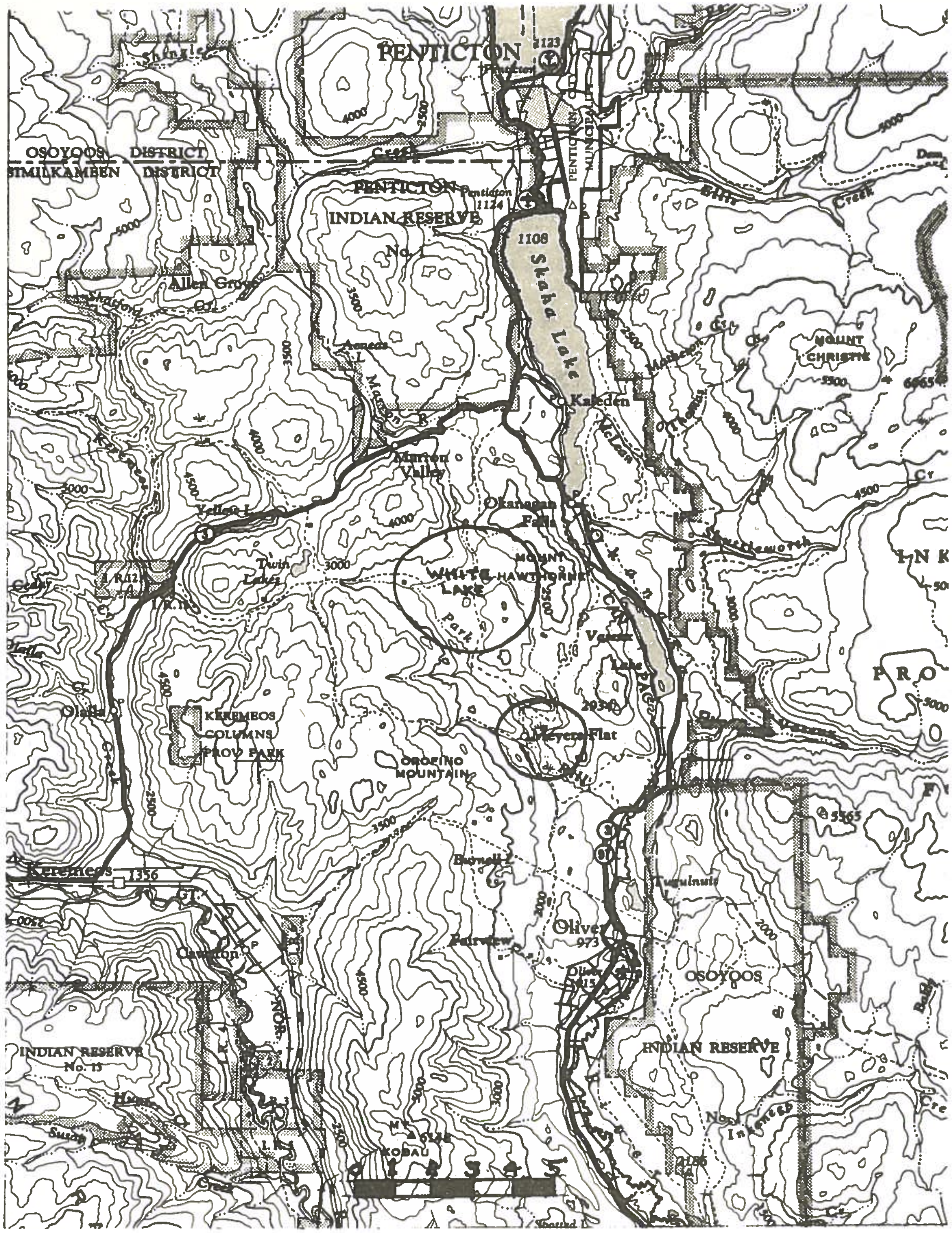


PLATE XI MAP SHOWING LOCATION OF WHITE LAKE AND MEYERS FLAT

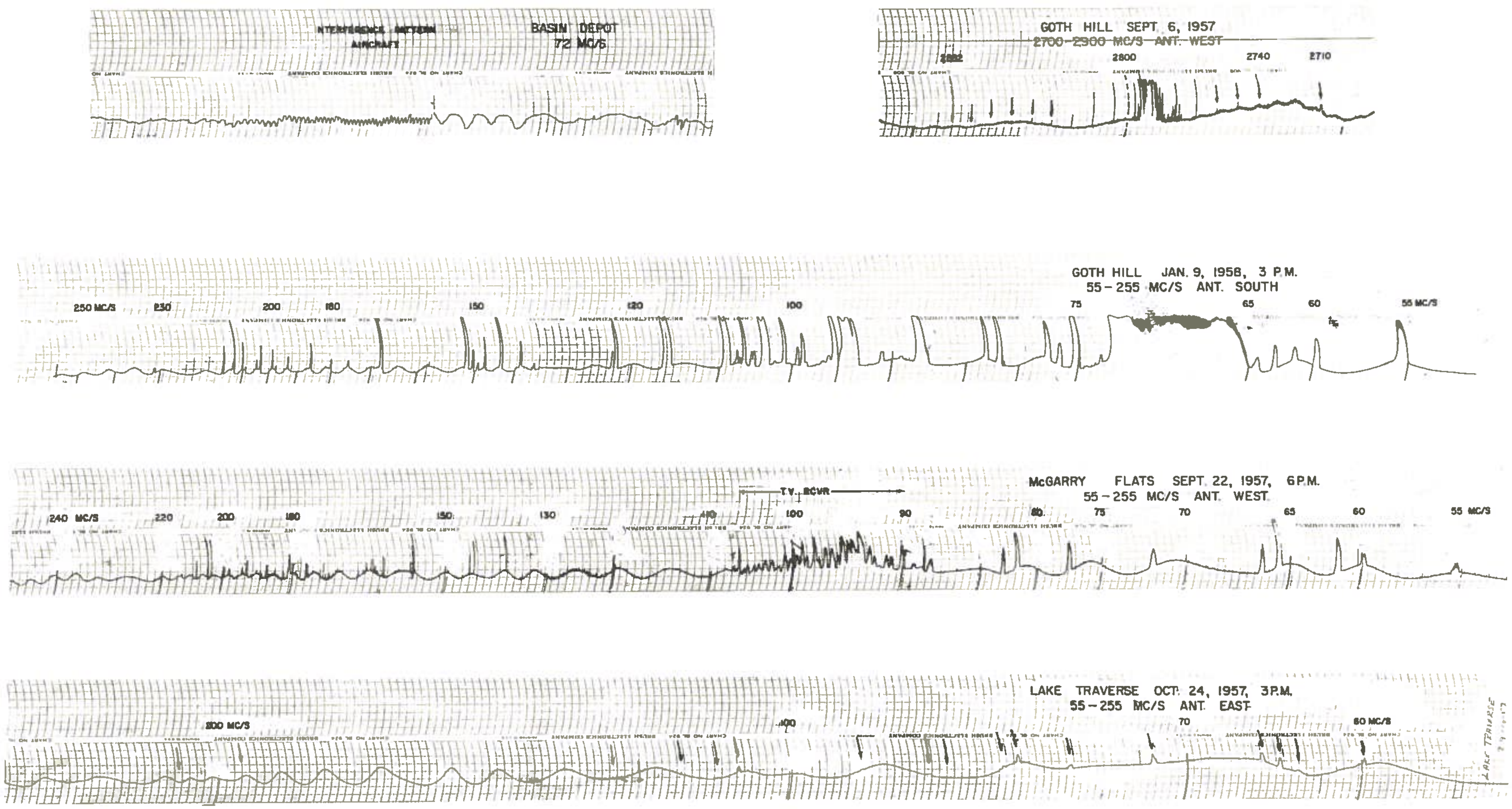


PLATE XII TYPICAL SIGNAL VERSUS FREQUENCY RECORDS