RADAR SOUNDING OF BEDROCK AND WATER TABLE AT CHALK RIVER

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INTRODUCTION

When a spill of radioactive waste occurs, one of the main concerns is the flow pattern of ground water in the area of the spill. The study of ground water distribution and flow requires detailed information of the surficial geology and the local water table. Ground probing radar is a relatively new geophysical technique which can provide high resolution data on the surficial geology and water distribution. In this report we present the results of some preliminary radar experiments conducted at Chalk River Nuclear Laboratories (CRNL) of the Atomic Energy of Canada Limited (AECL), Chalk River, Ontario.

While most people are aware of what radar is, not many are familiar with its use for sounding in the ground. The objective of this report is to introduce this new method and demonstrate the information which can be obtained quickly and easily.

BASIC PRINCIPLES, FIELD METHODS AND DATA DISPLAY

Figure 1 illustrates the general principles of ground probing radar. More details can be found in References [1] and [2]. One antenna transmits a radio frequency pulse while the other receives the signal which is transmitted to it directly from the transmitter and from reflectors in the ground. Two general types of soundings are generally employed. In one mode, the two antennas are fixed with respect to one another and towed behind a moving vehicle over the ground.

In the other mode, the antennas are moved with respect to one another on a section of ground where reflectors are detected. The first mode is called the profiling mode and is used to map the lateral extent of reflectors. The second type of sounding is used to map the electromagnetic wave velocity versus depth. Velocity versus depth must be known in order to interpret the profile data.

Subsurface radar reflections are generated when abrupt changes in electrical properties occur in the ground. Changes of electrical properties occur in the ground when there are changes in material and soil water content. At each interface part of the signal is reflected and part of the signal continues on. The amplitude of the reflected signal depends on the magnitude of the electrical contrast and the size of the reflector relative to the wavelength of the signal in the ground.

Figure 2 shows a typical fixed antenna configuration employed for profiling. The particular antennas shown have a centre frequency of 100 MHz and a bandwidth of 80 MHz. The frequency of the antenna system is tailored to the particular geological environment to be studied. As a general rule higher resolution is obtained by increasing the centre frequency while maintaining a constant centre frequency to bandwidth ratio. Deeper penetration is obtained by decreasing the centre frequency while maintaining a constant centre frequency to bandwidth ratio.

The data is displayed on a grey scale record on which antenna position is the horizontal axis and radar signal travel time is the vertical axis. The radar signal itself appears as a shade of grey which is proportional to the signal amplitude. Figure 3 shows a typical radar trace accompanied by a graphic recorder record comprised of several tens of similar traces from adjacent positions. Each trace is obtained in about a tenth of a second.

SOME FIELD RESULTS

Two radar sections obtained in the Chalk River area are used to demonstrate the utility of the radar. Figure 4 shows a sketch map of the Perch Lake site with the radar profile indicated. Figure 5 shows a map of the Upper and Lower Bass Lakes area with radar profiles indicated.

Figure 6 shows a radar section obtained from the ice surface of Perch Lake. Two reflectors are observed. Figure 7 shows a preliminary interpretation of the radar record. The ice thickness was determined using an alternate higher frequency antenna system (see Reference [3]).

The position of the events below the gyttja are accurate to ±10 percent of the depth. The interpretation of what the reflections are actually from may need revising when the drilling data becomes available but it should be made clear that there are reflections from the ranges shown to within the accuracy given above.

Figure 8 shows a radar section obtained on the road which leads to the gravel pit near Upper Bass Lake. The interpretation of the water table and bedrock depths accompanies the data. Numerous other events appear on the record. These reflections are from fine structures (changes in grain size and permeability) in the geologic section. Some of these reflections could arise from perched water tables associated with this geologic horizon. More detailed radar soundings as well as drilling control are required to unscramble the geologic structure coherently.

The interpretation of the radar records require knowledge of the velocity versus depth profile. The Perch Lake profile velocity section used the known ice velocity of 0.167 m/ns and water velocity of 0.033 m/ns. The gyttja velocity was estimated to be 0.043 m/ns. The velocity section used for the pit road profile was obtained from radar common depth point (CDP) soundings. Common depth point soundings are one type of sounding where the antenna separation is varied. The velocities determined in this way were 0.15 m/ns for the unsaturated soil and 0.06 m/ns for the saturated soil.

SUMMARY AND CONCLUSIONS

The Chalk River area appears to be ideal for radar soundings. The quaternary geology is comprised primarily of coarse grained soils which are very transparent to radar signals. Water table depth was mapped and bedrock was delineated to depths exceeding 20 m. A great deal of graphic information can be extracted quickly and inexpensively with the radar method. The time required for the individual radar profiles shown in this report was about 20 minutes each. The pit road was profiled three times with different antenna configurations in less than two hours.

The results presented here are the product of a quick set of tests conducted in the Chalk River area. The original interest in the area stems from work on the radioactive waste disposal program and the test drilling conducted for this purpose. A more comprehensive radar program accompanied by drilling control may prove to be of immense value to the general hydrogeology studies in the Perch Lake area.

REFERENCES

[1] ANNAN, A.P. and J.L. DAVIS. 1976. Impulse radar sounding in permafrost. *Radio Science* 11(4): 383-394.

[2] DAVIS, J.L., W.J. SCOTT, R.M. MOREY and A.P. ANNAN. 1976. Impulse radar experiments on permafrost near Tuktoyaktuk, Northwest Territories. *Can. J. Earth Sciences* 13(11): 1584-1590.

[3] ANNAN, A.P. and J.L. DAVIS. 1977. Impulse radar applied to ice thickness measurements and fresh water bathymetry. Geological Survey of Canada, Report of Activities, Part B, Paper 77-1B. Energy, Mines & Resources, Ottawa, Ontario.

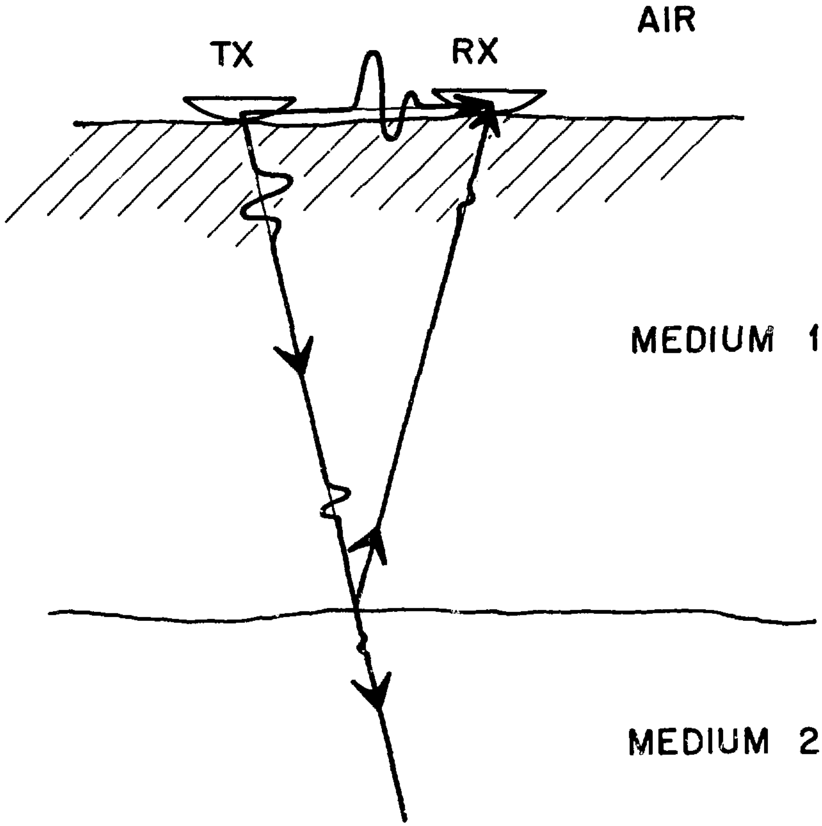

Figure 1. Sketch of ground probing radar principles.

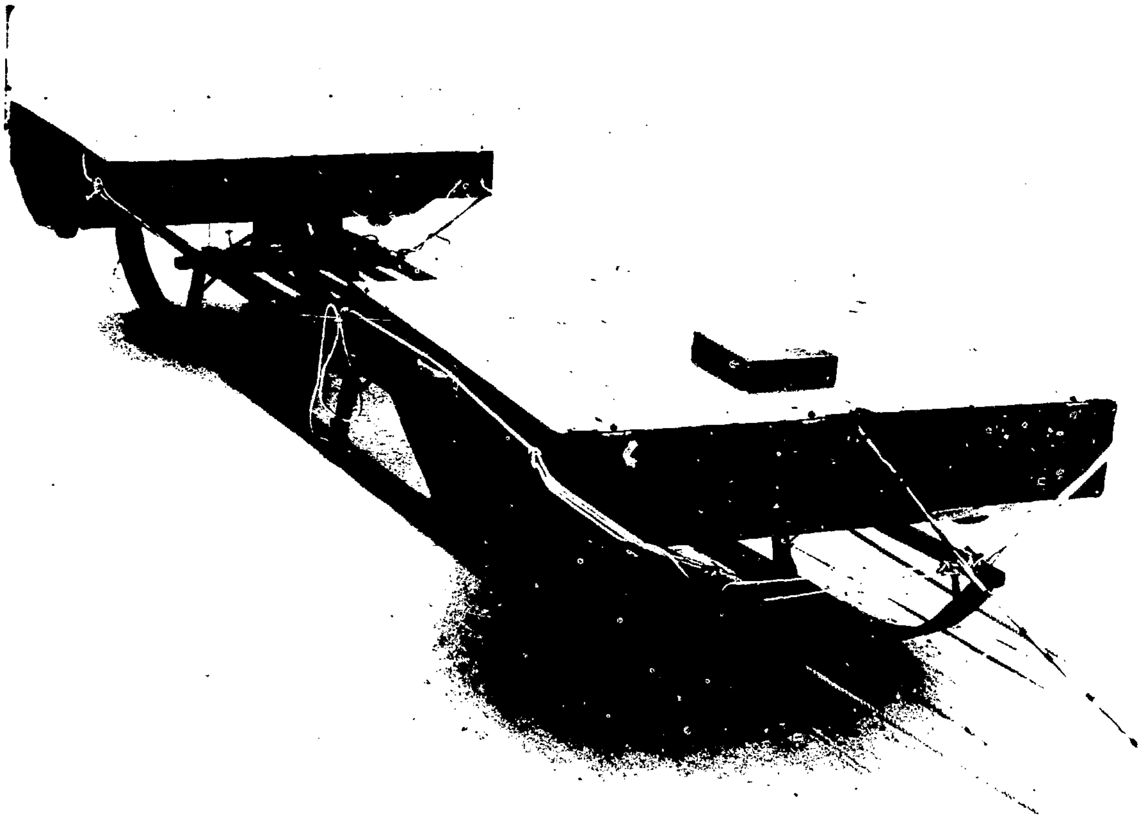

Figure 2. Photograph of antenna configuration used for profiling. Antenna boxes are 1.3 m square and 0.4 m deep.

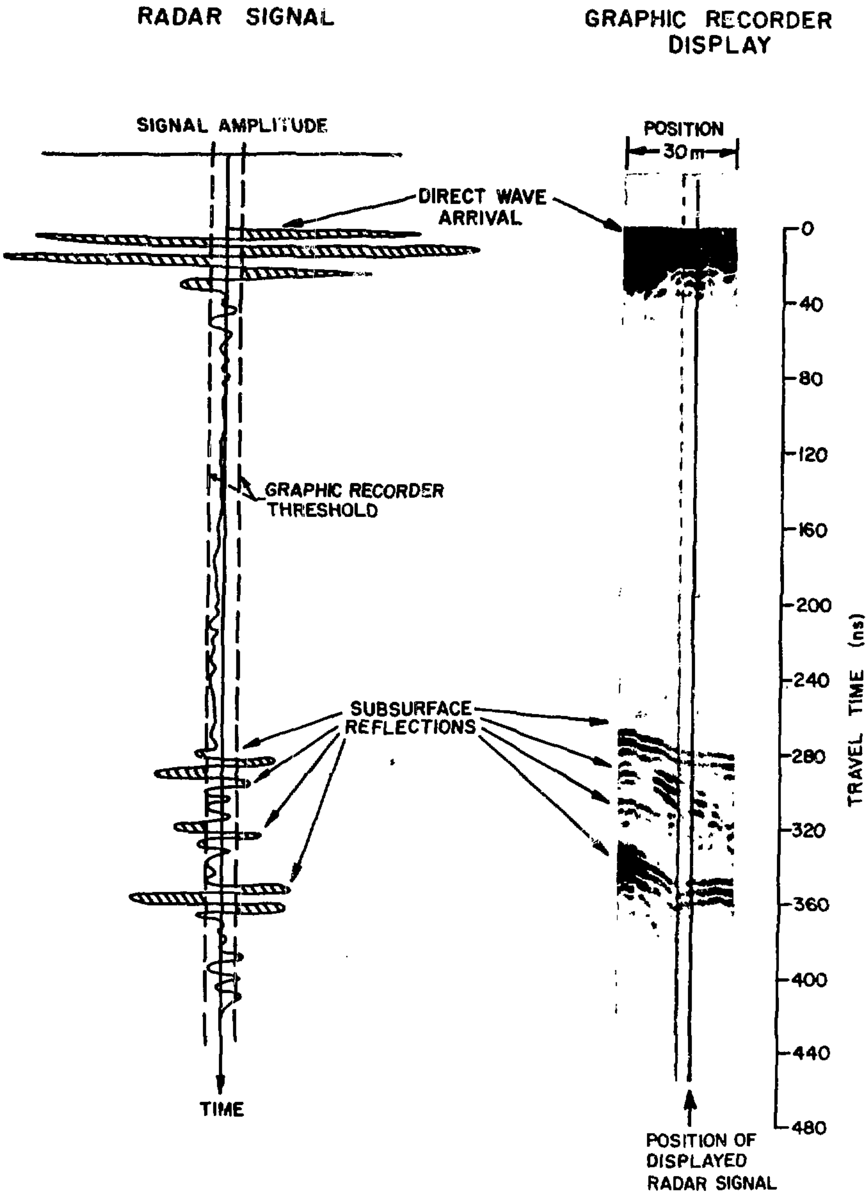

Figure 3. Radar record accompanied by graphic recorder display of several tens of similar records.

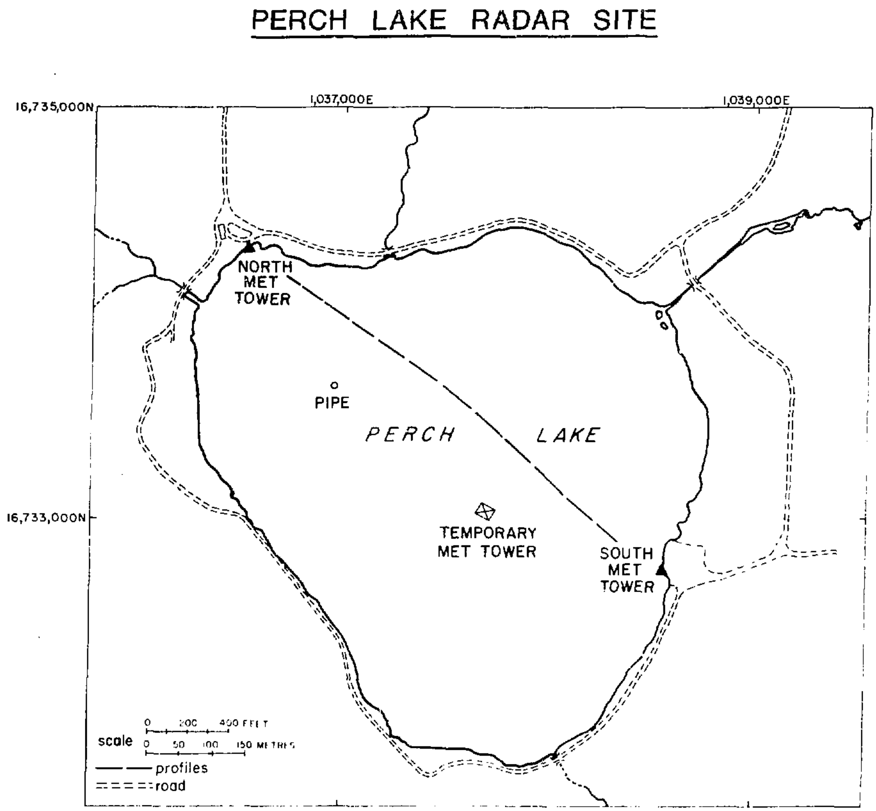

Figure 4. Sketch map of Perch Lake area at Chalk River.

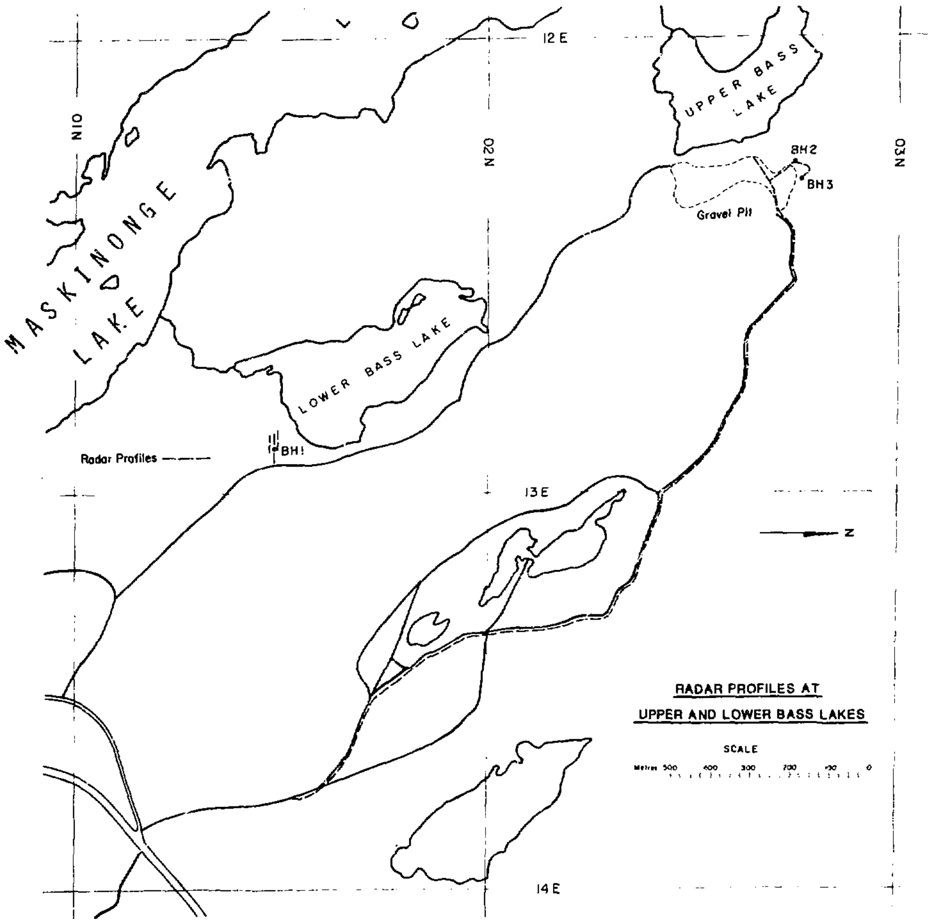

Figure 5. Sketch map of Upper and Lower Bass Lakes at Chalk River.

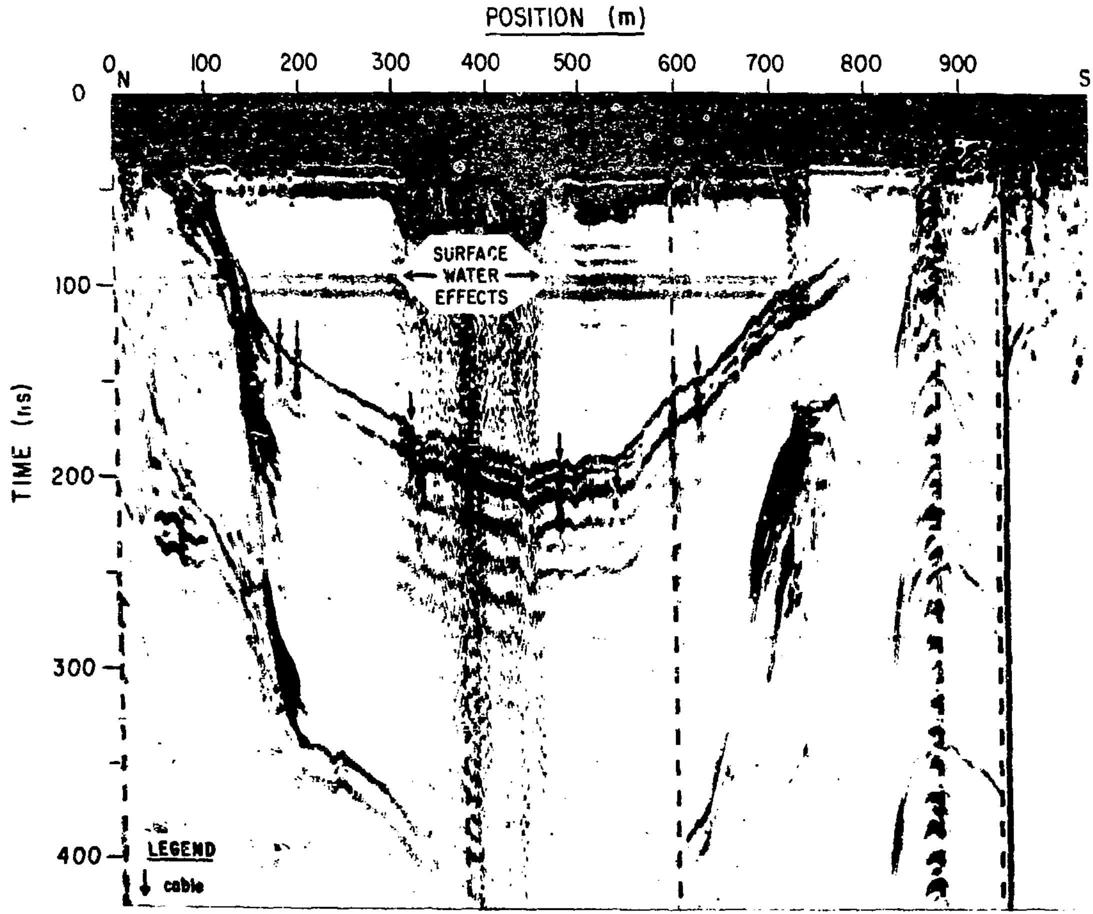

Figure 6. Radar section from ice surface of Perch Lake.

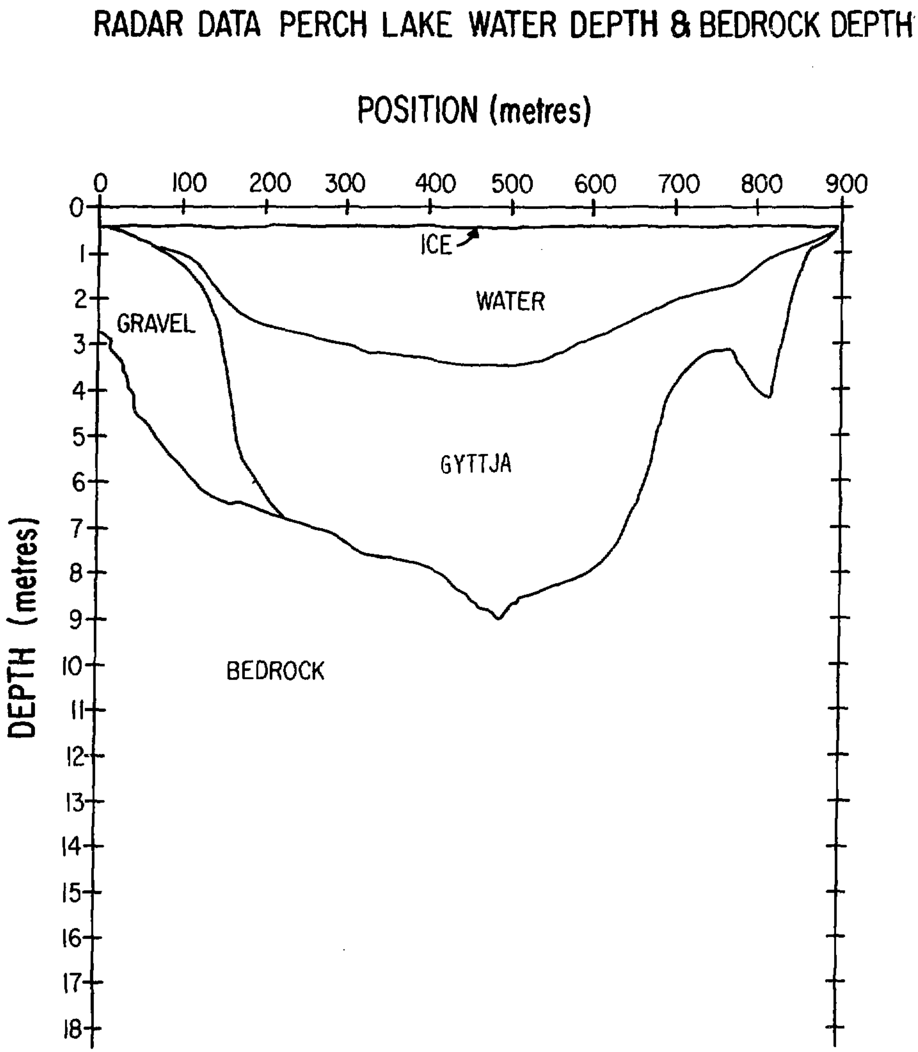

Figure 7. Interpretation of radar section of Perch Lake shown in Figure 6.

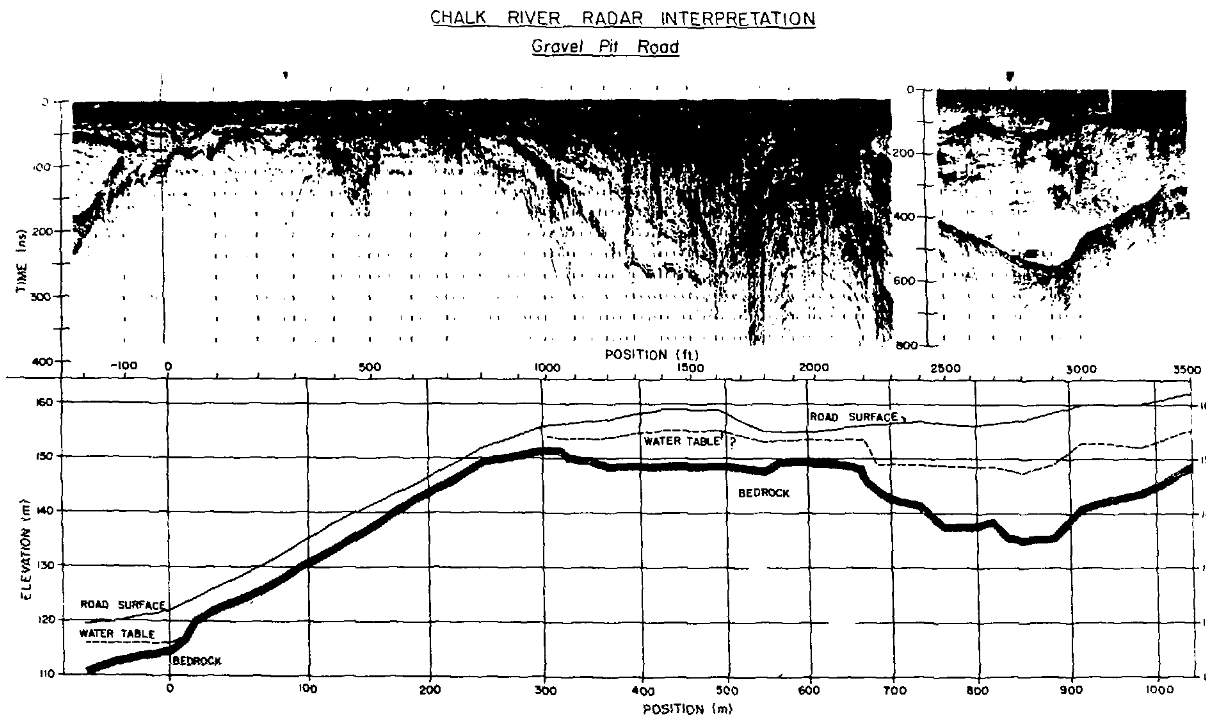

Figure 8. Radar section plus water table and bedrock interpretation of the radar section.