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Radar profiling of Newton Airfield in Jackman, Maine

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During April 1987 ground-penetrating radar was used to observe subsurface conditions of Newton Field, an airfield in Jackman, Maine. It was constructed in 1986, with insulation used as part of its subgrade. A road near the airfield that was constructed in the same fashion, except without the insulation, was also profiled for comparison. The survey was to document conditions of nonuniform frost heaving and, if possible, frost depth. Radar data, collected with a 900-MHz antenna, showed that the insulation beneath the runway apparently varied in depth from approximately 5 to 24 in. Frost depth, however, could not be determined with the 900-MHz antenna.

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PREFACE

This report was prepared by Carl R. Martinson, Engineering Technician, Ice Engineering Research Branch, Experimental Engineering Division, U.S. Army Cold Regions Research and Engineering Laboratory. The work was funded under DA Project 4A762730AT42, *Design, Construction and Operations Technology for Cold Regions*; Task BS, *Base Support*; Work Unit 036, *Validated Design Criteria for Pavements in Cold Regions*.

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Multiply	*By*	*To obtain*
inch	25.4	millimeter
foot	0.3048	meter
foot/nanosecond	0.3048	meter/nanosecond
mile/hour	0.4470	meter/second
mile	1609.347	meter

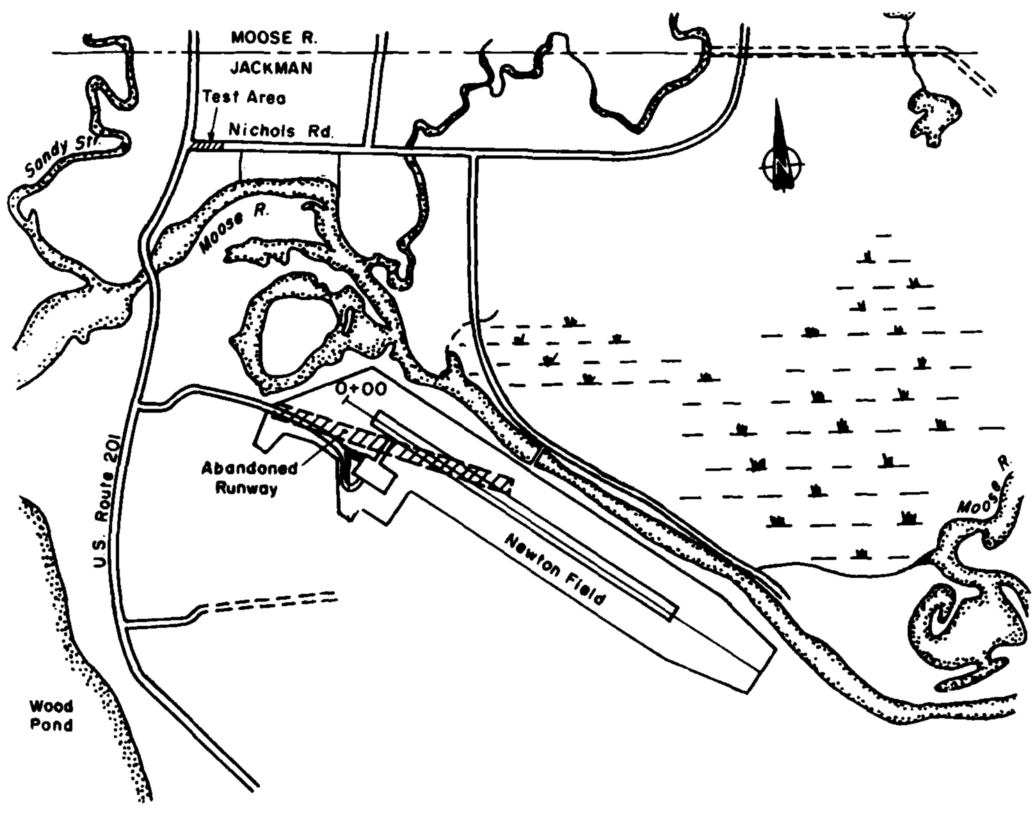
Radar Profiling of Newton Airfield in Jackman, Maine

CARL R. MARTINSON

INTRODUCTION

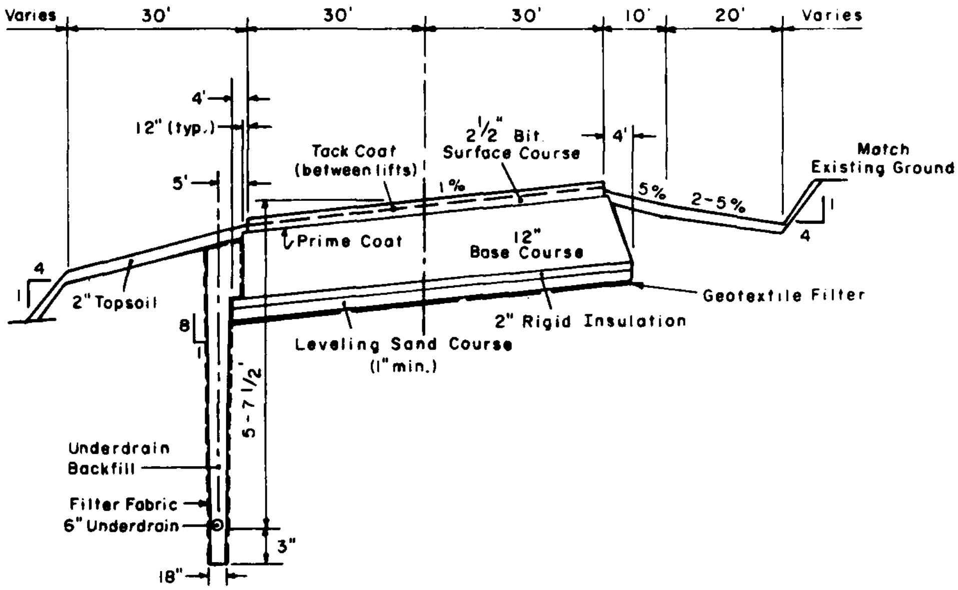
On 25 and 26 April 1987 ground-penetrating radar was used to observe subsurface conditions of Newton Field, an airfield in Jackman, Maine. The layout and a typical cross section of the runway, constructed in August through October 1986, are shown in Figure 1. The surface was paved with 1.5 in. of asphalt. Below that is 12 in., average depth, of clean bank run gravel. Next is a 2-in. layer of extruded polystyrene supported by 1 to 3 in. of a sand leveling course. Under the sand is a geotextile fabric and beneath that is the natural subgrade of silty sand. Subsurface temperatures measured during the 1986–87 winter season with a thermocouple assembly placed in the southwest end of the runway indicated a discontinuity in the thermal regime immediately below the insulation. This situation, along with nonuniform frost heaving along the runway, suggested inadequacies in the subsurface conditions (related to the uniformity of frost penetration) that a radar profile might be able to document.

Approximately one-half mile from Newton Field is Nichols Road. A portion of Nichols Road was reconstructed in 1986 as the runway would have been if the insulation had not been used;



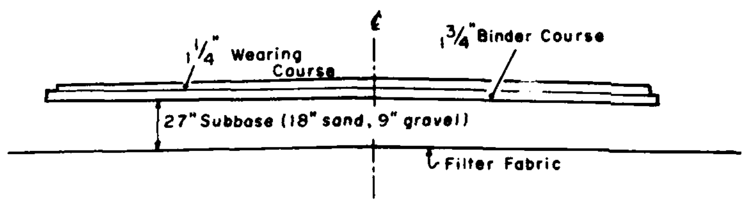
a. Layout of airfield with Nichols Road test section shown.

Figure 1. Newton Field, Jackman, Maine.

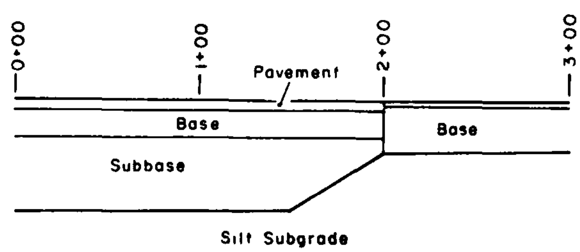


b. Cross section of airfield.

Figure 1 (cont'd). Newton Field, Jackman, Maine.



a. Cross section of first 150 ft, station 2+00 to 0+60, the end of the radar survey.



b. Longitudinal cross section.

Figure 2. Nichols Road, Jackman, Maine.

Figure 2a shows a typical cross section of the reconstructed part of Nichols Road. Part of this road was included in the survey for comparison. A longitudinal cross section, from the plans for the road reconstruction, is shown in Figure 2b.

The primary value of the radar survey is that it documents what is apparently the unevenness of the insulation beneath the airfield pavement.

EQUIPMENT AND METHODS

Equipment

The radar used for this survey is a Geophysical Survey System Incorporated (GSSI) SIR System 8. It consists of a model 4000 mainframe, model 800 control unit, a Hewlett-Packard model 3964A tape recorder and an EPC graphic recorder. The antenna used with the system was a GSSI model 101C (900 MHz); a 600-MHz model gave noisy and inconsistent results. The operation of this type of system has been described by Annan and Davis (1976) and Morey (1974). Briefly, the system uses timing electronics that clock a pulse generator and sampling head. The generator sends a voltage pulse to the antenna, which transforms the pulse into a wavelet and radiates it into the ground. Part of the signal is reflected back to a separate receive antenna when it encounters changes in the dielectric properties of the surveyed material. A sampling head at the receive antenna transforms the UHF signal into the audio range of magnetic tape recording and playback. The travel time for the signal to complete the round trip to a subsurface interface and back to the antenna can be measured in nanoseconds. The depth can then be determined if one knows the dielectric constant of the media, or the wavelet travel time for a given depth in the media being

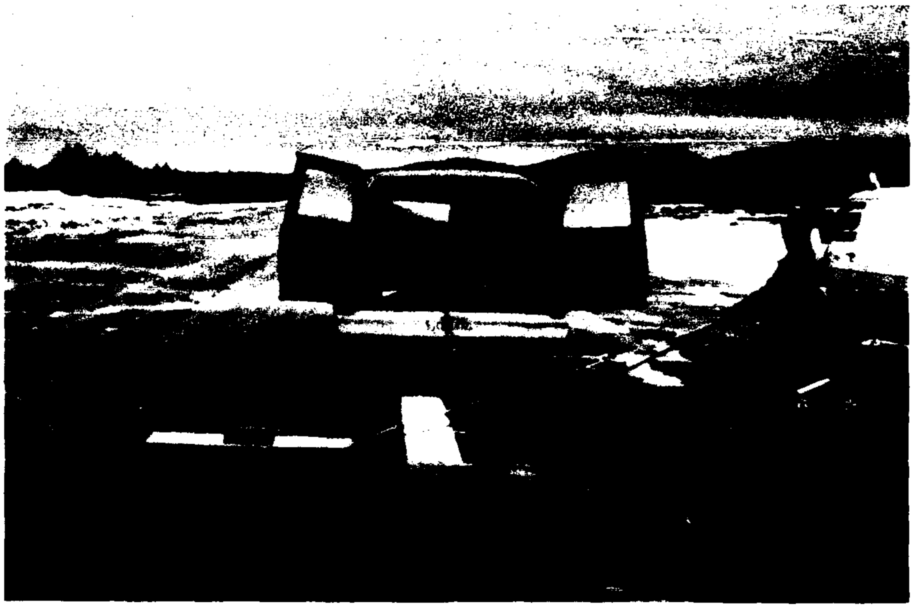


Figure 3. Antenna being towed manually for a cross section line (equipment van behind antenna).

surveyed. With this information the system can be calibrated to produce meaningful results.

Survey methods

The survey was done by installing the equipment in the back of a four-wheel-drive carry-all van (Fig. 3). The antenna was mounted on a sheet of plywood and tethered to the rear of the vehicle at a distance of approximately 15 ft. The van was driven at a constant speed of 2 to 3 mi/hr while towing the antenna on the ground. Two lines were surveyed along the length of the runway: the first along the centerline and the second approximately 10 ft south of it. Event marks were imprinted on the record at 100-ft intervals during this portion of the survey.

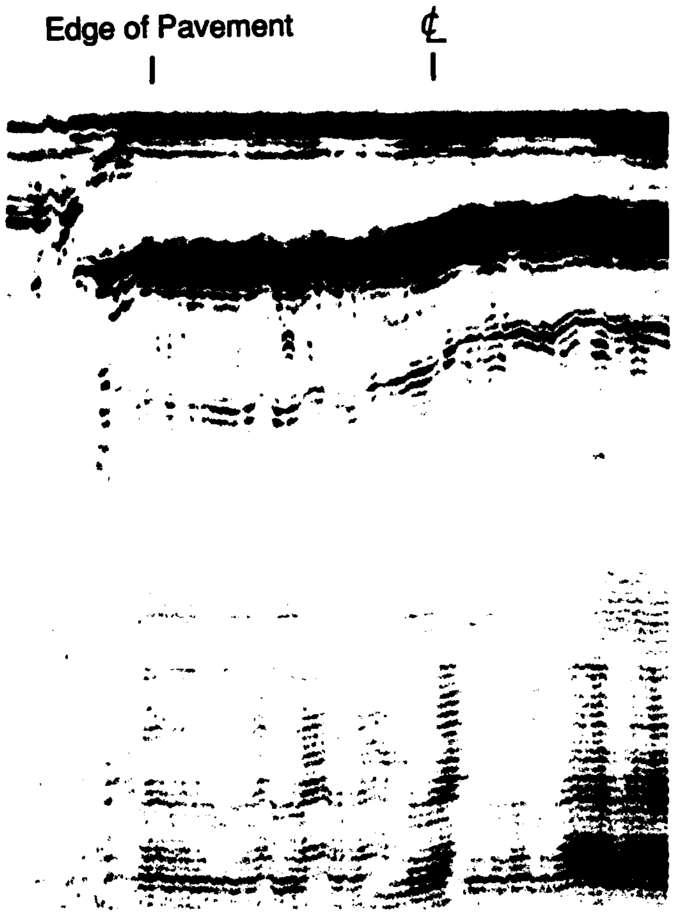
The ground-penetrating radar survey at Nichols Road was done in the same fashion, except only one line was surveyed along the north side of the road, and event marks are at 20-ft intervals. At the airstrip several lines were surveyed across the runway from north to south. These were done with the vehicle parked and the antenna towed manually at a very slow walk (Fig. 3).

RESULTS AND DISCUSSION

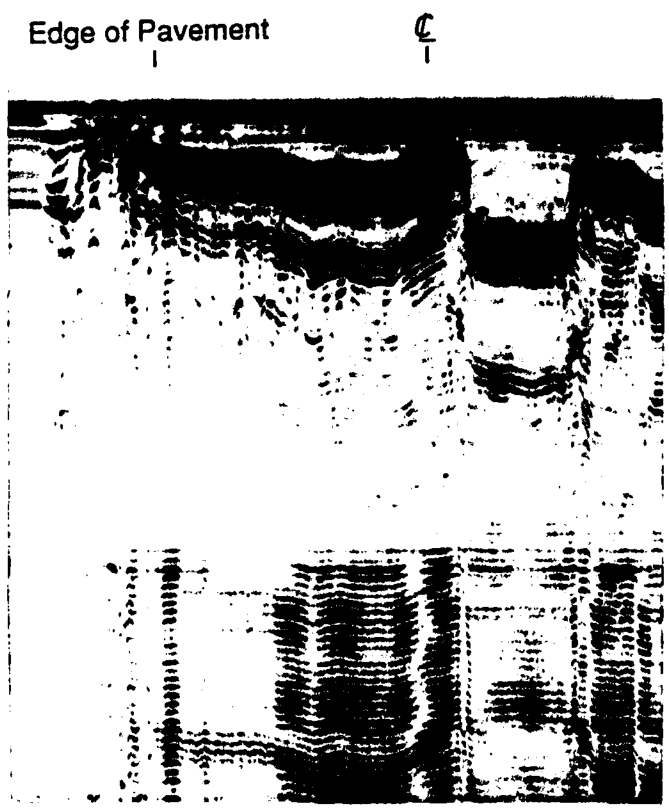
In all the photographs of the graphic record in this report, there are event marks with notations at the top of the print. The first set of bands below that is the antenna direct coupling. Next is the series of bands that represent the apparent gravel/insulation/sand interface. This is closely followed by a second set of bands that is a multiple of the first interface. Unfortunately, there are no definite returns from beneath this interface. In some of the photos the multiple is also present at the bottom of the print.

Core samples of the runway were not taken to obtain layer thicknesses. However, the insulation extends beyond the pavement edge for a few feet at the same depth as the insulation below the paved portion of the runway. To calibrate the system the antenna was placed on the ground next to the airstrip and towed from the unpaved area to the pavement and across it while data were recorded. The unpaved portion was then excavated to the insulation and the depth measured. This was done at three locations and provides the basis for determining the time of signal propagation to the insulation for the entire runway survey.

The graphic record shows that the time delay of signal reflection from the insulation layer does not change abruptly with depth from the unpaved to the paved portions of the surveyed lines (Fig. 4 and 5). It is assumed, therefore, that the signal velocity is the same for the gravel beneath the paved and unpaved portions of the runway. The number of calibration measurements may



a. Cross section at station 7+00.



b. Cross section at station 8+00.

Figure 4. Ground truth profiles for three stations at the pavement edge.

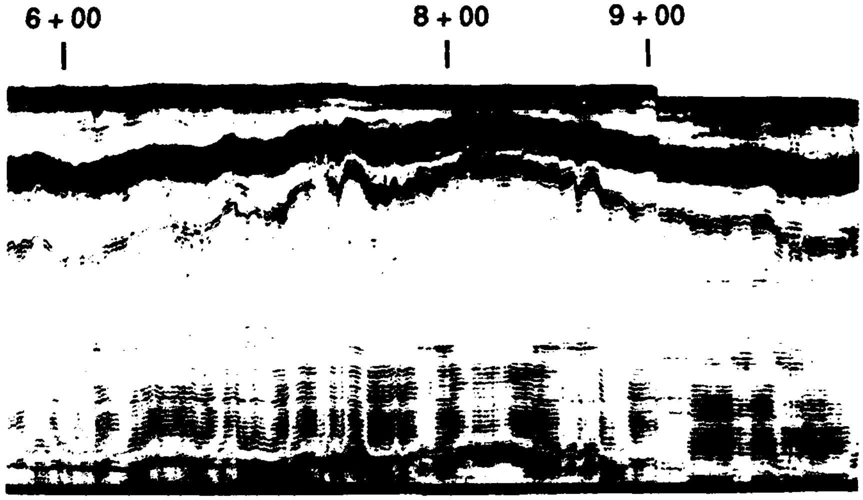


Figure 6. Centerline survey passing through station 8+00 where the insulation appears nearer the surface. The shift at station 9+00 is caused by equipment malfunction.

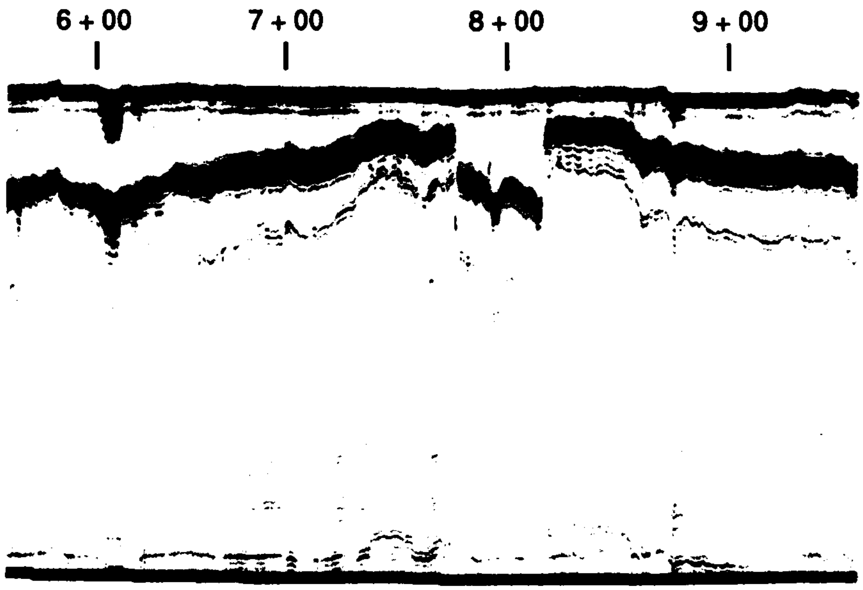
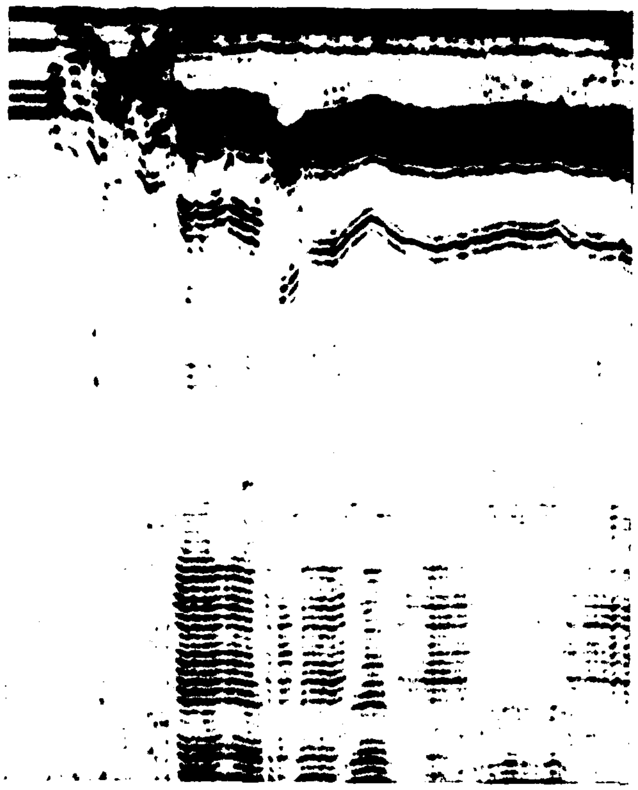


Figure 7. Survey parallel to the centerline and approximately 10 ft south of it, passing through station 8+00 where a discontinuity appears.

During the course of the ground-penetrating survey, we noticed an asphalt patch that began near the centerline of the runway and extended about 10 ft to the south. It was approximately 40 ft long and passed through station 8+00. Figure 6 shows that the insulation interface is apparently closer to the surface near station 8+00 than to either side of it on the centerline survey. Figure 7 shows a discontinuity approximately 40 ft long, with station 8+00 near the center of it. A cross-sectional survey at station 8+17, documented in Figure 5, shows the same discontinuity for a distance of about 10 ft. The subsurface observations correspond closely in size with the

Edge of Pavement ℄



c. Cross section at station 9+00.

Figure 4 (cont'd).

be too few, considering the variation in time delay of the three measurements. Therefore, later calculations of depth should not be considered exact. The average round trip pulse travel time is 5.5 ns/ft. This was determined by calculating travel time to the insulation interface at each of the three calibration points and averaging the results.

Since the depth to the insulation is known at three places, the time calibration can be used to calculate the dielectric constant (ε) of the media as follows:

$$\varepsilon = (tc/2d)^2$$

where t is the round trip time of propagation, c is the speed of light in a vacuum (1 ft/ns) and d is the depth from the surface to the insulation. The three calibration points give an average dielectric constant of 8.1.

It is possible that changes in the media (i.e., dielectric constant) could make the record show an apparent change in depth when, in fact, the depth is constant. It is believed that this is not the case for the majority of the data presented here. The best way to validate the data is to bore holes at various points along the survey line and compare the results with the radar data.

Edge of Pavement ℄

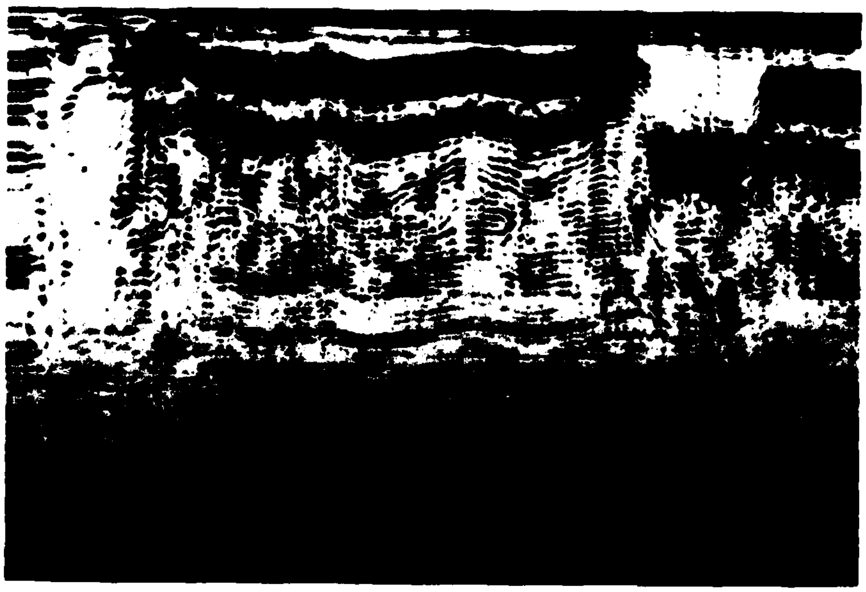


Figure 5. Profile from north to south (left to right) across the runway at station 8+17. The insulation layer can be seen extending beyond the edge of the pavement. At approximately 5 ft south of the centerline is a discontinuity in the interface.

Table 1. Depth to apparent insulation layer as measured in nanoseconds and corresponding calculated depths in inches.

	Centerline of runway		*10 ft south of centerline*	
Location station	*Measured time (ns)*	*Calculated depth (in.)*	*Measured time (in.)*	*Calculated depth (in.)*
3+00	9	20	9	20
4+00	11	24	9	20
5+00	10	22	9	20
6+00	9	20	9	20
7+00	6	13	5	11
8+00	3.5	8	8	17
8+30	3	7	2.5	5
9+00	5.5	12	5	11
10+00	7	15	6	13
11+00	8	17	7	15
12+00	5	11	5	11
13+00	5	11	7	15
14+00	9	20	7	15
15+00	6	13	5	11
16+00	7	15	7	15
18+00	5.5	12	5.5	12
19+00	6	13	6	13
20+00	6	13	5.5	12
21+00	6	13	7	15
22+00	6	13	6.5	14
23+00	6	13	6.5	14
24+00	7	15	8	17
25+00	7	15	7	15
26+00	5.5	12	7	15
27+00	5	11	6.5	14
28+00	8	17	7.5	16
29+00	6	13	6.5	14
30+00	5	11		
31+00	6	13		
31+50	6	13		

Table 2. Time delays to the apparent insulation layer as measured in nanoseconds and corresponding apparent depths in inches. The location is the distance from the north edge of the runway pavement in feet. The centerline of the runway is at the 30-ft mark.

	Cross section 8+27		*Cross section 8+22*		*Cross section 8+17*	
Location	*Time (ns)*	*Depth (in.)*	*Time (ns)*	*Depth (in.)*	*Time (ns)*	*Depth (in.)*
0	3	7	3	7	3	7
5	3.5	8	3.5	8	3.5	8
10	4	9	3.5	8	3.5	8
15	3.5	8	3	7	3.5	8
20	3	7	3	7	3	7
25	3	7	3	7	3	7
30	2.75	6	2.5	5	3	7
35	2	4	1.75	4	2	4
40	2.5	5	1.5	3	9	20
45	4	5	4	9	9	20
50	4.5	9	4.5	10	4	9

patch seen at the surface. During a subsequent visit to the airport, we were informed that the insulation was too close to the surface in this area and that the area was excavated and the insulation placed at the "correct" level. We were also told that the repair extended to locations where the insulation was in its proper position.

Nonuniformity of the depth of the interface is present throughout the runway survey, although it is not generally as severe as in the area of station 8+00. The returns in Figure 8 are typical, except for the event at station 30+00. At that location a crack extended across the runway. It is speculative to say that the crack and the unusual return are somehow related and it is mentioned only as a possible explanation.

The variation in the depth of the insulation as seen in Figure 8 is also documented in Table 1. The range of depth for the centerline survey is from 7 to 24 in. If the area near station 8+00 is excluded, the range of depth becomes 12 to 24 in. The range for the south line is 5 to 20 in.; including the area near 8+00, the depth range becomes 11 to 20 in. The depth of the insulation appears to be consistently shallower at the east end of the runway for both long surveyed lines.

The cross-sectional data (Fig. 4 and 5 and Table 2) also show some depth variation within a survey line and from cross section to cross section. The insulation at stations 8+00 and 8+17 generally appears closer to the surface than elsewhere in the survey.

There were no ground truth measurements taken to accompany the profile at Nichols Road (Fig. 9); therefore, references to depth are in nanoseconds only. The road was surveyed from station 3+00 to station 0+60. Event marks were imprinted on the record at measured 20-ft intervals. The area from station 2+00 to 1+50 is a transition zone. The area from station 1+50 to 0+00 is the rebuilt road as mentioned in the *Introduction*.

There are numerous returns at various depths throughout the survey. At station 2+00 where the transition zone ends there are five distinct bands that continue to the end of the survey. The first three bands are the direct coupling while the other two are part of returns from a shallow interface that can also be seen be-

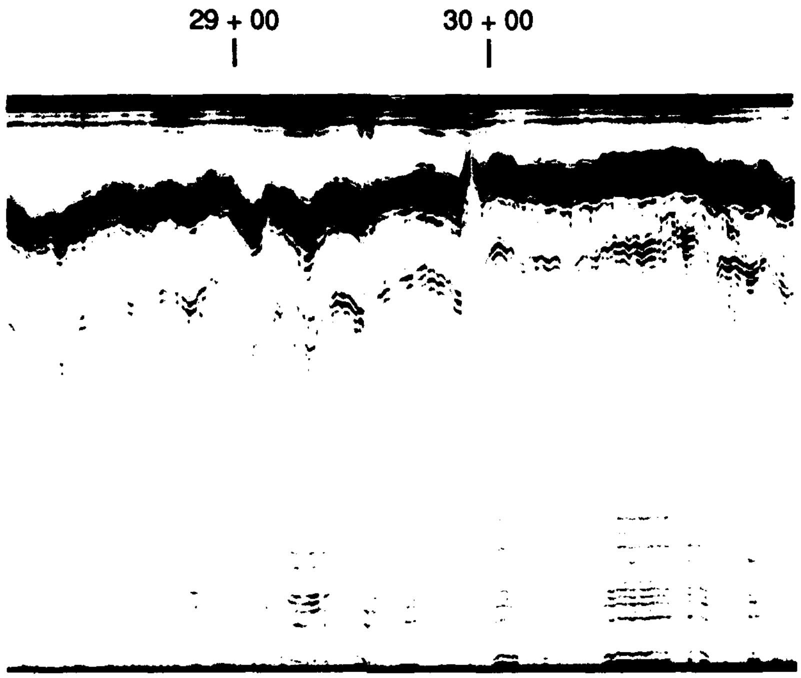


Figure 8. Portion of a typical survey line along the length of the runway. The unusual return at station 30+00 may or may not be related to a crack in the asphalt near that point.

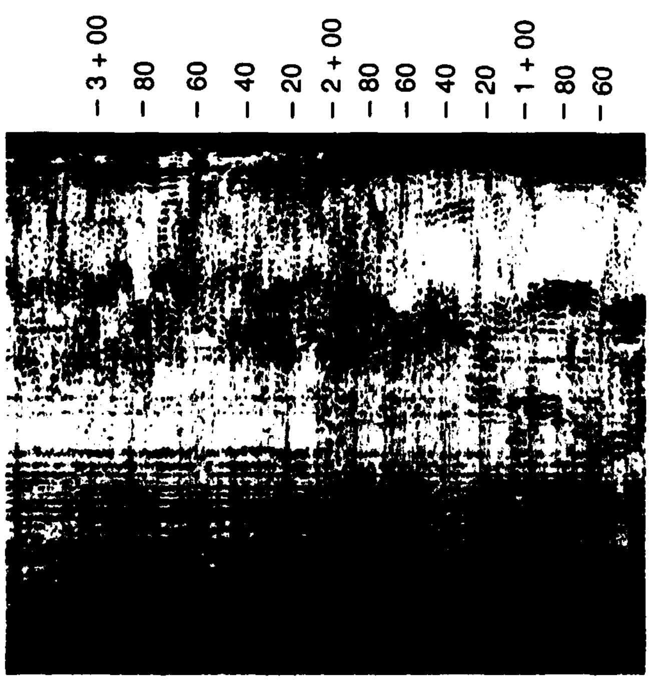


Figure 9. Nichols Road survey. The modified subsurface begins at station 2+00 and continues to the end at station 0+60.

tween stations 3+00 and 2+00. Whatever the cause, there is a distinct change in the graphic record at station 2+00. Another obvious and more important feature is the omission of the return that occurs on the runway survey (Fig. 6) and represents the apparent gravel/insulation/sand interface. Although there are some returns at depths corresponding to 12 to 15 ns, there is nothing as obvious or continuous as that which occurs on the runway survey. The area encompassed by station 1+50 to 0+00 of the road is identical to the runway, except that the insulation is not present. That being the case the Nichols Road survey supports the idea that the strong returns of the runway survey represent the insulation layer.

CONCLUSIONS

Since there are no returns to represent the insulation layer on the Nichols Road survey but clear returns are evident on all runway surveys, ground penetrating radar was successful at locating the buried insulation layer.

Thanks to a repair to install the insulation at the "correct" depth, which showed clearly on the graphic record, it was shown that insulation depth determined is also reliable.

It may be possible to determine frost depth when conditions, such as soil moisture content, are other than they were at this survey site. It may also be possible if other antennas with different characteristics (i.e., frequencies) are used. Whether or not that can be achieved was not determined by this work.

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