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EPA **Project Summary**

Microwave System for Locating Faults in Hazardous Material Dikes

Robert M. Koerner and Arthur E. Lord, Jr.

Failure or rupture of impoundments containing hazardous material is one of the causes of release of hazardous materials to the environment. Another area of concern is the integrity of hazardous material pond liners and of liners or diking-grouting systems for secured waste sites. This project identified and assessed two nondestructive test methods for investigating the subsurface of impoundments containing hazardous materials: 1) the continuous wave microwave system and 2) the pulsed radio frequency systems (also termed ground-penetrating radar or GPR). The primary focus of the project was to conduct a technological assessment of these two systems for identifying dike failure characteristics (seepage, formation of soil stratigraphic discontinuity, voids, grouting breakthrough). During the project, these two systems were also evaluated for their potential to detect related subsurface objects such as waste drums.

This exploratory study developed or modified current systems, surveyed the literature, verified laboratory and field experiments, and defined the applicability of each technique for determining subsurface phenomena.

Continuous wave microwaves successfully located subsurface water zones and the tops of rock surfaces, but they had difficulty in detecting containers, voids, and soil stratigraphy. Upgrading of the system by an electronics manufacturing firm should improve performance.

The ground-penetrating radar (GPR) method is a limited tool for environmental monitoring. (Future more extensive work might alter this conclusion.) A highlight of the GPR testing was its successful use in monitoring chemical grout. The most significant feature of the system is the realtime printout of the subsurface detail to the limit of the signal's penetrability. This feature is an advantage when observing a cylindrical drum in shallow sand, but under other circumstances, the system records too much information and

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Introduction

Failures of earthen dikes containing reservoirs of hazardous materials have been attributed to structural defects, hydraulic problems, and to other, seemingly unrelated, factors. Dike conditions and subsurface integrity beneath the soil surface in the foundation, reservoir, and embankment areas need to be determined. The range of conditions and variety of situations is extremely wide.

The traditional method for investigating the subsurface is to test material removed from soil borings and test pits. However, this approach presents a number of potential problems: data, soil disturbances, danger to personnel and elevated costs. To avoid such potential problems, this project investigated nondestructive test (NDT) methods.

Laboratory and Field Test Results.

Two NDT methods, the continuous wave microwave system and the pulsed radio frequency (also called ground-penetrating radar, or GPR), were addressed in this project. Both use electromagnetic waves. The continuous wave microwave system was designed and manufactured by the authors under the auspices of this project. This system sweeps through a range of frequencies and displays alternating constructive and destructive interference peaks. Knowing these peaks and counting their frequency, measures the depth to the interface. The interface seen is actually a material with dielectric properties differing from the one above it. To evaluate the adequacy of the continuous wave microwave system, a series of laboratory and field experiments were undertaken. Table 1 lists these tests and presents a qualitative assessment of the results. The technique used shows promise in a number of

Table 1. *Summary of Continuous Wave Microwave Tests Conducted During This Project*

Test No.	*Objective*	*Results in Terms of Stated Objectives*	*Comments*
Lab. 1	*Water location*	*Excellent*	*Depth ranged from 0 to 18". Spatial location very good. Requires sharp boundary.*
Lab. 2	*Soil interface detection*	*Poor*	*Frequency peaks not distinguishable. Requires soil layers to have different moisture contents. Amplitude distinction possible but difficult.*
Lab. 3	*Void detection*	*Doubtful*	*Frequency peaks not sharp enough. Amplitude distinction possible. Needs good area to contrast against void area for relative assessment.*
Field 1	*Steel plate detection*	*Possible*	*Depends on nature of backfill soil — dry granular soil is good; wet, cohesive soil is poor.*
Field 2	*Water table detection*	*Good*	*Has worked to 60" depth. Must be sharp and distinct.*
Field 3	*Top of rock detection*	*Good*	*Rock probed to 12' with good correlation to predicted values.*
Field 4	*Void detection*	*Possible*	*Thorough tunnel survey conducted, but no verification determined.*

areas although it is not applicable to all subsurface problems. It works best when the differences between the dielectric properties of the soil and the anomaly are the greatest; e.g., dry soil to saturated soil or soil to rock can be distinguished, but the boundary between two different soil types cannot be easily identified.

For the *pulsed radio frequency* system (GPR), several commercial systems are available. For this project, a system was purchased and somewhat modified for a specific site situation. The modifications included new transceiver carriages for rough terrain, and construction of two narrow torpedo antennae, a transmitter, and a receiver for downhole monitoring. The GPR system is basically a microwave reflection system in which a short pulse is transmitted into the ground, reflecting off a dielectric anomaly, and returning to the ground surface. Travel time is measured, and depth can be calculated from the propagation velocity of the electromagnetic waves in the soil. The GPR system provides a continuous printout as the transceiver antenna is moved across the ground surface. The stronger the dielectric difference is between the soil and the anomaly, the stronger will be the return signal, and the sharper will be the recorder trace. These systems are extremely sensitive to all subsurface anomalies, and numerous data are always received. Their sensitivity requires frequent tuning to assure accurate visual interpretation.

To evaluate the adequacy of the GPR system, a series of laboratory and field experiments were conducted. Table 2 lists these tests and qualitatively assesses the results. Although the table may seem to imply that the technique is not viable, the reader should note that most of these very challenging tests had never been attempted before and there have been suc-

Table 2. *Summary of Pulsed Radio Frequency Tests Conducted During This Project*

Test No.	*Objective*	*Results in Terms of Stated Objectives*	*Comments*
Lab. 1	*Sensitivity study*		*A dielectric constant difference of less than 1 results in a detectable signal.*
Lab. 2	*Polluted water detection*	*Poor*	*Salt saturation was difficult to quantify.* *Salt boundary not observable.* *Acetone was not responsive.*
Lab. 3	*Small void detection*	*Possible*	*Steel pipe easily detected.* *Smooth hole reasonable.* *Roughened hole marginal.*
Field 1(a)	*Defining water table*	*Possible*	*Good in granular soil.* *No good in fine-grained soil.*
Field 1(b)	*Defining soil stratigraphy*	*Good*	*Soils in different categories (sands, silts, clays) are distinguishable.* *Vertical boundaries are detectable.*
Field 2	*Buried container location*	*Excellent* *Poor*	*Metal drums in granular soil.* *Metal drums in fine-grained soil.*
Field 3	*Void detection*	*Poor*	*Insufficient dielectric contrast unless void is water-filled.*
Field 4	*Chemical grout monitoring*	*Possible*	*Qualitative tool at present.* *Perhaps quantifiable.* *Tremendous potential if additional work is successful.*

cesses. When a sharp dielectric difference existed between upper and lower materials, test results were most accurate; i.e., buried containers were easily detected, but polluted water and small voids in dry soils were not easily defined.

Conclusions and Recommendations

The continuous wave microwave system used in this project was built by the authors. The system successfully located subsurface water zones and the tops of rock surfaces. Containers, voids, and soil stratigraphy were seldom located. To improve the system's performance in the latter area would require further electronic development. The current experimental system requires a microprocessor-based minicomputer to count oscillloscope wave cycles and calculate depths to the reflecting anomalies. To greatly improve the system a real-time printout should be developed to provide continuous operation. For field use, the current power pack should be made more mobile with a built-in 110-volt electrical system. In general, the entire system needs further development, using more sophisticated laboratory and field tests to refine procedures.

The GPR method can be used for environmental monitoring, but has limitations, as noted in the full report. The highlight of the experimentation using the GPR system was its use in monitoring the chemical grout commonly used to halt seepage in leaking earth dikes. Two adjacent boreholes with transmitting and receiving antennae provide travel time printouts. Comparing traces before and after grouting allows instantaneous assessment of the completeness and uniformity of the grouting operation. When an unsatisfactory area is repaired, the GPR system can be used for actual control of the field operation. Also there were preliminary successes in using the technique to detect metal drums. This work should definitely be followed up.

A very significant feature of the equipment is the real-time printout of the subsurface detail to the limit of the signal's penetrability. Although this feature is excellent for observing a cylindrical drum buried at a shallow depth in dry sand, it often makes interpretation difficult in less than ideal circumstances. Often the system records too much information, and at times the background is overwhelming, completely obscuring the desired trace. Signal enchancement techniques are definitely needed to solve this problem. Two approaches are possible: One is a computer-aided system, and the other is empirical comparisons. Both approaches should be pursued to achieve the full advantage of a GPR system.

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Robert M. Koerner and Arthur E. Lord, Jr., are with Drexel University, Philadelphia, PA 19104.
***John E. Brugger** is the EPA Project Officer (see below).*
The complete report, entitled "Microwave System for Locating Faults in Hazardous Material Dikes," (Order No. PB 85-173 821/AS; Cost: $14.50, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
Releases Control Branch
Hazardous Wastes Engineering Research Laboratory
U.S. Environmental Protection Agency
Edison, NJ 08837