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Detecting buried human remains using near-surface geophysical instruments

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ABSTRACT

To improve the recovery rate of unlocated buried human remains in forensic investigations, there is scope to evaluate and develop techniques that are applicable to the Australian environment. I established controlled gravesites (comprising shallow buried kangaroos, pigs, and human cadavers) in South Australia, to allow the methodical testing of remote sensing equipment for the purpose of grave detection in forensic investigations. Eight-month-old pig graves are shown to provide more distinct identifying results using ground-penetrating radar when compared to four-year-old kangaroo graves. Two further aspects of this research are presented: information (obtained from a survey) relating to the police use of geophysical instruments for locating buried human remains, and the use of electrical resistivity for locating human remains buried in a coffin.

The survey of Australian police jurisdictions, covering the period 1995–2000, showed that police searches for unlocated bodies have not successfully located human remains using any geophysical instruments (such as ground-penetrating radar, magnetometers, or electrical resistivity).

Lower resistivity readings were found coincident with the 150-year-old single historical burial in a heavily excavated field, in a situation where its exact location was previously unknown.

INTRODUCTION

Since the 1990s, the search for buried human remains has increasingly been approached by applying geophysical technology to the subsurface (Bevan, 1991; France at al., 1992; Davenport, 2001; Miller, 1996; Nobes, 2000; Owsley, 1995). Although this trend has contributed to a growing body of case-based documentation on the location of graves, there is no reliable technique that may be used to validate the non-presence or presence of human remains. The current status within the field is that "*...there is no remote sensing method that will consistently find a body or physical evidence*" (Davenport, 2001). Objects that are identified by remote sensing cannot be definitively equated with buried human remains with current technology.

Further scientific research is required to examine and refine the application of geophysical techniques to the detection of clandestine graves because the equipment that is being used was not developed for this purpose. One important aspect is that the physical properties of gravesites have not been identified. The results of research in one country cannot be held to apply to another because of varying soil and climatic conditions.

The most permanent remains of a body are the bones of the skeleton. As there is no "bone detecting instrument", the detection of graves has employed techniques adopted by archaeologists (McManamon, 1984) and has focused on "secondary indicators", such as soil disturbance, or the detection of objects other than the body itself, such as a coffin, or metal artefacts, such as keys, belt buckles, or jewellery. If remote sensing instruments are to detect buried human remains there must be measurable contrasts, and these will depend on the sensitivity of the sensing instrument used (Davenport, 2001). Factors that must be considered are the electrical conductivity of the soil, soil type and soil horizons, chemical and mineral content, water content, porosity, and estimated depth of burial. Further, natural subsurface geological changes, resulting in varying soil types, large rocks, or tree roots can present as scattered signals in a ground-penetrating radar (GPR) survey (Davis et al., 2000).

Testing of geophysical instruments for the purpose of grave location has often taken place in cemeteries (Bevan, 1991; Davis et al., 2000; Unterberger, 1992). Cemetery graves may differ from forensic investigations, in which there may be no coffin and burial depth is usually considerably shallower than a regulatory six feet depth. Where there is no coffin, there may be no voids; the target area is likely to be relatively small and shallow (up to 1 m in depth); the search area itself may be considerably larger than a cemetery search; and there may be no artefacts. Additionally, the use of a backhoe, the usual method of burial in a cemetery, will produce a clear demarcation between disturbed and undisturbed earth (Unterberger, 1992). When a grave is dug by shovel, there is a less stark contrast between undisturbed and disturbed earth. Geophysical instruments are being applied to a situation for which they were not specifically designed.

Searches for human remains take place in varied environments, limiting the capacity to generalize the application of successful methods used in particular case studies. Crime scenes are characterized by the necessity of having to work as quickly and expediently as possible, and to some extent a trial and error approach has been taken to searches. The value of using geophysical instruments in a crime scene, however, is their potential capacity to detect a body without disturbing the site before all evidence is identified in situ.

Organisations in the United Kingdom (Forensic Search Advisory Group) and the United States (Necrosearch International) have been formed to assist police searches for human remains using multidisciplinary techniques, including geophysical instruments, and especially, ground-penetrating radar. There are no such groups existing in Australia, and the application of such technology has not been researched here scientifically, although instruments have been used in actual searches (Thomas, 1999).

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One of the first published studies to highlight the potential of a multi-disciplinary approach, incorporating geophysical instruments, to detecting graves in a forensic investigation, was based on Project PIG (Pigs In Ground). Commenced in 1986 in Colorado, Project PIG was a response to a problem faced by Colorado law enforcement officials; they were to search for approximately twelve bodies allegedly buried over several years in an area covering several square kilometres. A test area of buried pigs was established on which to test search and recovery techniques. Details of the GPR findings are not presented in the publication, but France et al. (1992) consider the GPR to be the "most useful tool to delineate possible graves" because of the capacity to identify soil changes and/or excavation patterns.

GPR has been the most commonly used geophysical instrument in forensic searches for human remains. Successful locations using GPR have been achieved indirectly through the identification of non-specific radar anomalies (Hammon et al., 2000). Obviously, the indication of soil disturbance or an indication of a buried object does not mean that human remains are present, and it is the aspects of data specifically relating to buried human remains that should be more thoroughly researched.

This was shown when Bevan (1991) conducted nine geophysical surveys over burial sites (historical burial sites and cemeteries) in the United States, using GPR and electromagnetic induction methods. The results had mixed success, with GPR providing results that suggested graves where there were none, but also not detecting known graves. Graves where bones had been re-buried were not detected by GPR. Bevan highlights the fact that formal gravesites such as those in cemeteries are detectable in GPR results from their shape (because coffins are longer in one direction) and predictable depth. However, Bevan found that the same identifying pattern from a GPR survey found at another cemetery was caused by a natural change in the soil strata.

The ambiguity and potential lack of geophysical responses that could occur in a crime scene are highlighted by the published account of a search by Nobes (2000). Nobes applied both GPR and electromagnetic (EM) surveying to search for a body buried (without a coffin) for almost 12 years in a plantation forest in New Zealand. The body had allegedly been buried initially in a shallow grave, and later transferred to a deeper grave, approximately 1.2 m deep. The search was complicated by the fact that at different times tree harvesting and tree stump removal had taken place in the area. GPR was not used to identify the anomaly (later identified as the body); instead, an isolated EM anomaly was found which proved to be coincident with the body. In this example, Nobes (2000) questions whether the GPR would have presented a definitive response due to the complexity of the subsurface of the area surveyed. The sandy ground had the potential to obscure any grave-like excavations.

As forensic investigations are conducted and initiated by police services, I conducted a survey of Australian police jurisdictions to indicate the extent, if any, of the use of geophysical instruments for locating human remains. The responses show that there has been little successful application of scientific instruments to the location of clandestine graves in criminal investigations. These results, as discussed in the next section, indicate the lack of research undertaken in Australia to examine potential ways of improving the recovery rate of unlocated human remains. Geophysical technology, and its potential in this process, should be further explored in the Australian context.

To provide data relating to South Australia on the effectiveness of selected geophysical instruments for locating buried human remains, I have created seven gravesites in which animal and human cadavers are buried. These gravesites are also being monitored to provide data on the physical attributes of gravesites over time. The controlled gravesites simulate those found in criminal investigations and include three kangaroos, three pigs, and one human cadaver, buried in calcareous soil in typical South Australian scrubland outside Gawler, north of metropolitan Adelaide. Burial depth is between 0.5 and 1 m, and burials were carried out between 1998 and 2002. Soil disturbances coincident with the burial sites of the animal graves have been observed in ground-penetrating radar surveys. There are differences between the pig graves and the kangaroo graves, however, in terms of capacity to image buried animal remains, suggesting factors inhibiting detection using GPR as the time between interment and search increases.

Electrical resistivity was used successfully, as part of this research, to determine the location of a 150-year-old burial in Willunga, South Australia. The implications of these results are that continued and repeated research needs to be conducted, using instrumentation that may be focussed on the identifiable properties of gravesites and buried skeletal remains, to answer the questions that have arisen from these studies.

METHODS

Survey of the use of geophysical instruments in police investigations

I designed a questionnaire to ascertain the use, if any, of geophysical instruments by Australian police services to locate buried human remains. For murder cases where the body was not immediately located and searches had been conducted, the survey asked what methods had been employed successfully during 1995–2000. The questionnaire did not ask for data on methods not considered successful in each search. This survey was posted to sections managing forensic investigations in all Australian police jurisdictions.

Five States (and one Territory) responded. Under-reporting may have occurred for two reasons: firstly, all States advised that the data had required manual file searches to complete the written questionnaire; and secondly, until a body is found, persons are classified by police as missing, and not a murder victim. Written responses from police jurisdictions to the survey questions were collated by the author. Collectively, the survey responses show that 22 murder victims across five States were not found initially because their place of burial was not known. Prior to 1995, four States report 35 additional unrecovered bodies. Of the 22 victims for whom searches were conducted during 1995-2000, none were successfully located using geophysical instruments (the question asked for the method of detection used to locate the human remains). The means by which they were located was reported as follows: 22 were found by passers-by; 12 by police ground search; nine through verbal information (the total does not equal the number of body searches conducted so it is assumed that there may have been joint methods used). Most of these murder victims (16, or 73%) were found within 6 months (13 or 59% within 3 months).

The questions contained in the survey did not address all methods attempted during searches, only those that had been found to be successful. A follow-up survey covering the period 2000-2002 is currently being completed.

From these results, it may be seen that if appropriate methods and guidelines are developed, there is potential for the systematic application of geophysical technology to the location of gravesites within Australia. This potential application will be dependent upon successful results demonstrated through methodical research, the availability of instruments appropriate to the environmental conditions, and the accompanying expertise in their application for this purpose. However, it is clear that geophysical instruments have not yet been used successfully (whether or not they have been applied to any great extent is a further issue) by Australian police services for the location of buried human remains. The reasons may be several and cannot be extrapolated from this survey, although personal communications with each police jurisdiction revealed that ground search is still the most common search method used because geophysical technology has been little researched in Australia for this purpose.

Controlled gravesites and geophysical surveys

Overseas studies, cited above, advocate the potential of geophysical instruments for use in locating buried human remains. The survey results above suggest that police in Australia are seldom using methods other than traditional search methods. This prompted me to establish a test area to examine the efficacy of technology-based search methods. Three kangaroos, three pigs, and one human cadaver have been buried in scrubland that forms part of the University of Adelaide's Roseworthy campus, north of metropolitan Adelaide. The purpose is to monitor observable physical changes over time; to identify the physical properties of gravesites, and to test the effectiveness of available technology (such as ground-penetrating radar, electromagnetic induction, and electrical resistivity) in detecting buried skeletal remains. The depth of burial ranges from 1 m to 0.5 m, and the graves were dug with shovels and picks for all burials.

A soil profile of a grave showed that in the burial area the strata are uniform. The soil type is classified as calcareous. Horizon A (0.0–0.05 m) is a sandy loam, and could be considered windblown sand. Horizon B (0.1–0.15 m) is calcareous. Horizon C (below 0.15 m) has a nodular unconsolidated texture with roots visible to 0.4 m. The ground was dry at the time of the GPR surveys and water content low as temperatures during the summer period (January, 2001) were around 38°C.

Ground-penetrating radar surveys (200 MHz antennae, Sensors and Software version 1.2 PulseEKKO 100 system) were conducted in 2001 over the animal graves, at which time the kangaroo graves were almost four years old and the pig graves were eight months old. The GPR equipment consisted of ground-coupled dipole antennae, 1000-Volt transmitter, receiver, and a laptop computer to log the data as collected and to display "real-time" data. The penetration using this frequency is approximately 4 m. The transmitting and receiving antennae are stepped along in small increments (between 0.2 to 0.5 m) while maintaining a constant separation.

An orientation survey using the GPR was completed in the same general area as the animal graves, using the same equipment set-up as was used for the grave surveys. From this, the near surface was described as flat-lying with uniform strata, reflecting in-situ soils developed on bedrock. The signal seemed to be almost completely attenuated below approximately 1 metre depth (probably due to the high-clay soils in the area). From the orientation survey, it was expected that disturbances down to 1 metre in depth should be observable in the GPR surveys of the animal graves.

Data processing was undertaken using the PulseEKKO software (version 1.2). It comprised the following stages: (1) averaging of traces in the spatial domain to smooth data over 20-cm intervals from the original 10-cm samples. This filtering has the effect of reducing the influence of near-surface heterogeneities and antennae placement errors during data collection; (2) averaging of the time record to smooth data over two time intervals from the original sample. This has a similar smoothing effect to trace averaging; (3) gain adjustment was applied to accentuate late arrivals; (4) air and ground head waves were removed by clipping the data beyond about 15 ns, to remove the influence of waves travelling directly from transmitter to receiver without penetrating the ground; (5) the profiles are contoured and coloured so that blue and red colours indicate strong reflectors and greys indicate background responses.

The dimensions of each animal grave are approximately 1 metre square, and the GPR traversed in a straight line across each grave for between 8 and 12 m, with the known graves located at around the 4-metre mark in Figures 1 to 6.

RESULTS

GPR surveys of each grave showed anomalies that could be equated with the known depth and position of the graves, with the pig graves being more marked than the kangaroos. It is indeterminate whether this is related to the age of the burial. Figures 1, 2, and 3 depict the pig graves based on six different lines at right angles, adjacent to, and over the middle of the grave. Strong reflections coincident with and overlapping the grave were found, compared to relatively weak signals on either side of the grave. Figures 4, 5, and 6 show the results for the three kangaroo graves. The kangaroo graves are not as readily identifiable as those of the pigs, and were the graves not known to be there, they may not have been earmarked for further examination in a real search situation on the basis of this GPR survey data.

DISCUSSION

Figures 1 to 6 show disturbances and aberrations at each site. There are clear differences between the data obtained from the kangaroo graves and those of the pigs. One possible reason affecting detection capability is the length of burial time, as soil compaction occurs. The kangaroos were buried deeper than the pigs by approximately 0.5 metre. It was expected that the longer kangaroo bones, compared to the shorter pig bones, might have provided more distinguishable objects, but this has not been demonstrated in the results. The equipment itself, and in particular the antennae selection, may not have been suitable.

The GPR survey information shows anomalies coincident with the animal graves, with clear distinctions between the results of the pig and kangaroo graves. However, these anomalies may also be attributed to other factors, in a real search. The differences between the animal graves suggest that GPR may have application within a certain timeframe after burial, but this is conjecture at this point and further comparison is required.

The anomalies from the GPR survey could also be related to factors other than the presence of the remains, such as the grave itself, disruption to soil layers, nearby tree roots, or boulders. For example, Figures 1 and 6 are the two gravesites that were next to trees, and tree roots could be responsible for indications of anomalies.

Electrical Resistivity Applied to an Historical Burial

A locally owned paddock in Willunga, South Australia was thought to contain a burial that had occurred some 150 years ago. The paddock had been heavily excavated, and consistently ploughed level for the last 50 years. Observable indicators were obscured due to this disturbance of the land over time, although there were several circular areas of green couch grass compared to surrounding areas of dead grass. However, these could equally

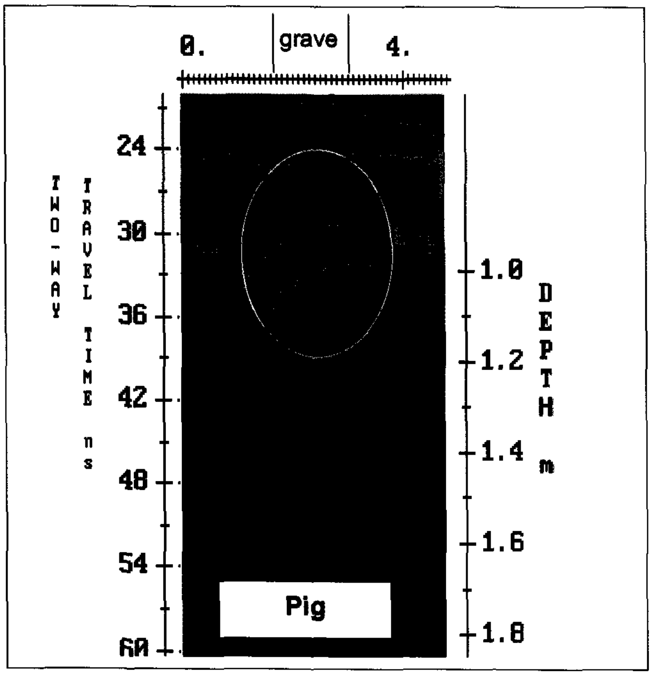

Fig. 1. A pig grave is clearly identified (using ground penetrating radar) eight months after burial at 0.5 m. The pig was buried in cotton clothing only.

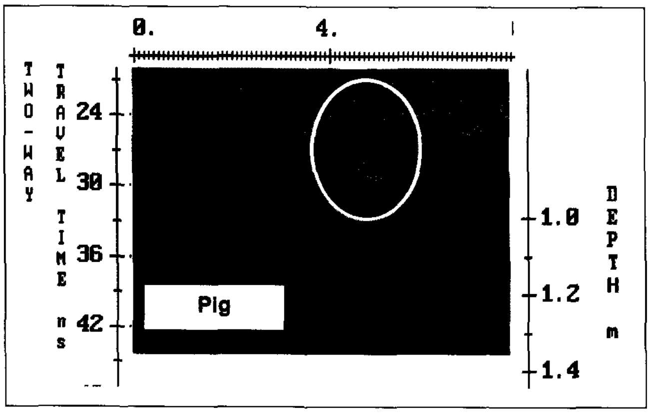

Fig. 2. Another of the pig graves is clearly depicted (using GPR) eight months after burial at 0.4 m. The pig was clothed in cotton and synthetic items, including a metal belt buckle and rubber-soled sandshoes.

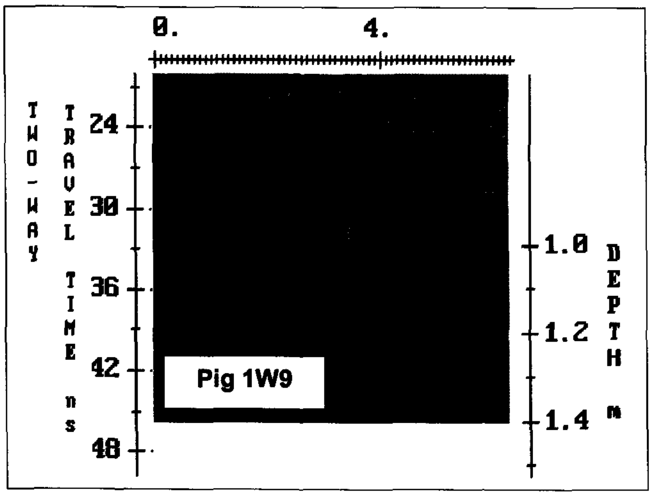

Fig. 3. A third pig grave is clearly depicted (using GPR) eight months after burial at a depth of 0.5 m. This pig was buried in a plastic garbage bag, left unsealed.

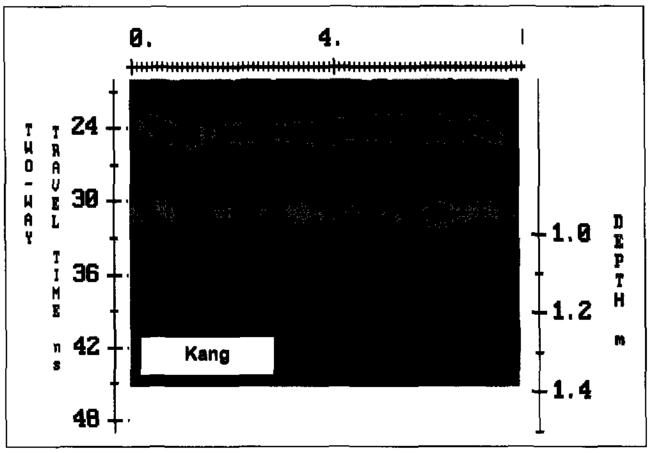

Fig. 4. A kangaroo grave shown using GPR at 0.75 m depth. The grave contained cotton and synthetic clothing, including a belt buckle.

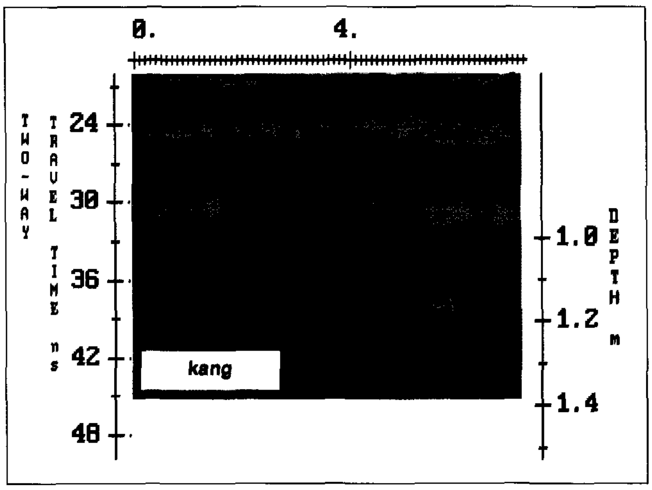

Fig. 5. Another kangaroo grave that is not clearly evident using GPR. The grave is situated at the 4 m mark at approximately 1 metre depth. The grave contained cotton and synthetic clothing, including a belt buckle.

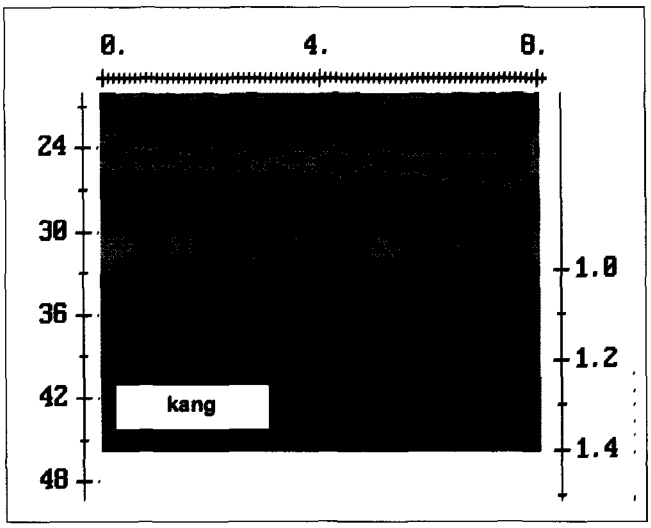

Fig. 6. A third kangaroo grave that is not clearly evident using GPR. The grave is situated at the 4 m mark at approximately 0.5 m depth. This kangaroo was covered in a plastic bag in addition to cotton and synthetic clothing.

have been the sites of buried pets or farm animals. A monument marking the grave had been broken and moved by a plough some 30-50 years before (Mrs B. Fitzpatrick, personal communication, corroborated by local parishioners).

Electrical resistivity (using a STING system) was used to survey several key areas in the paddock, including where the monument remains were scattered. It was not known what to expect from the data collected. The results showed lower resistivity readings, compared to other areas of the paddock, over the area around the remains of the broken monument (Figure 7) and this area was marked to be excavated first. Excavation revealed a timber coffin containing a skeleton embedded in clay buried 1.5 m below the surface, confirming the contrast demonstrated in the information from the resistivity survey. As clay had seeped into the coffin itself, there were no voids inside the coffin.

Electrical resistivity has therefore been found successful in this search in detecting human remains buried in a coffin, with the key indicator being lower electrical resistivity relative to the surrounding area. This was attributed to the likely collection and retention of water in the coffin and body area. The value of the geophysical instrument was its capacity to detect contrast, and the survey did not detect the body itself but secondary factors relating to the physical nature of gravesites. Further research is required to determine whether resistivity would be useful where human remains are buried without a coffin and at a shallower depth.

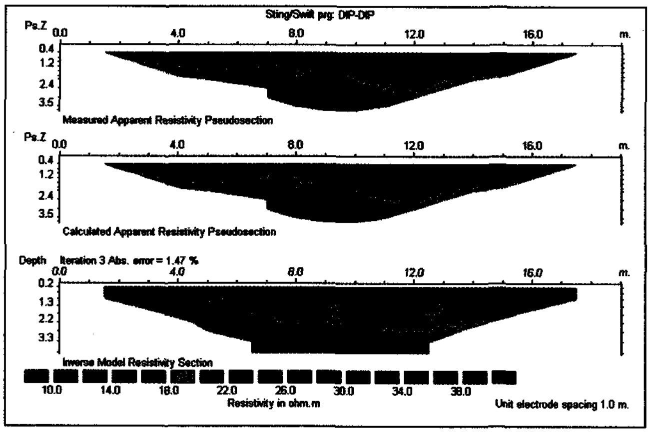

Fig. 7. Electrical resistivity survey, with inversion model (bottom diagram). Note the shallow low-resistivity anomaly between 11 and 12 m along the profile.

CONCLUSIONS

The location of buried bodies requires further research, to refine the application of geophysical methods for this purpose. The controlled gravesites in South Australia have been established to provide an opportunity to conduct scientific tests of geophysical systems. GPR and resistivity surveys demonstrate their application to the detection of buried human or animal remains, although the results are related to the instruments' capacity to detect contrast with the surroundings and not the remains themselves. Further research is required on the environmental properties of gravesites that might be detected by technological means. A broader range of geophysical instrument testing is planned, including the examination of the effect of seasonal variations. Two major difficulties encountered have been the unavailability of appropriate geophysical equipment in South Australia for such tests, and of funding organisations with a commercial interest in recovering human remains.

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