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DEFENCE R&D DÉFENSE

Cambodian Maghemite Bearing Lateritic Soil

Benbrack Limited

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Defence Research Establishment Suffield

DEFENCE RESEARCH ESTABLISHMENT SUFFIELD

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An Acquisition Project for Continued Research
Performed by the Canadian Centre for Mine Action Technology (CCMAT)
Department of National Defence
Defence Research Establishment Suffield (DRES)
Ralston, Alberta

Contract No.: W7702-9-0154/001/CAL

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ABSTRACT

The Defence Research and Development Branch (DRDB) of the Department of National Defence (DND) conduct demining research. Defence Research Establishment Suffield (DRES), a component of DRBD, is the lead agency for research of this kind. DRES has, since its inception, developed expertise regarding testing and evaluation of metal detectors for their ability to meet certain requirements. For example, the following detector parameters are critically assessed: detection sensitivity, electronic stability, susceptibility to moisture, mineralized soils, and other environmental factors. This work is critical to allow for objective decision-making regarding acquisition of equipment for the DND.

Further, a Ministry of the Kingdom of Cambodia – Cambodian Mine Action Centre (CMAC), and the United Nations Mine Action Centre (UNMAC), called upon this expertise in 1996. The purpose of this request was to evaluate various currently available detectors in order to recommend to CMAC the best detector suited for the Cambodian environmental condition – hard to detect antipersonnel mines in wet conditions and mineralized soils.

Testing and evaluation of current detector technology continues. DRES issued in 1999, through Public Works and Government Services Canada, a Request for Proposal (RFP) regarding the acquisition of sixty cubic metres of maghemite bearing lateritic soil from the Kingdom of Cambodia to be delivered to a predefined site located at CFB Suffield. The purpose for obtaining this soil is for the continued testing and evaluation of detectors – specifically in difficult environmental conditions such as mineralized soils. It is therefore critical that the maghemite bearing lateritic soil obtained reduces the sensitivity of an Schiebel AN19/2 metal detector.

INTRODUCTION

Defining Laterite

Most of the wide belts of grass-covered and tree-covered savanna that lie adjacent to the rain forests are underlain by tough to thoroughly indurated yellow and red-brown soils called laterites (from later, the Latin word for brick). The characteristic upper dark red-brown layers of laterites dry to a brick-like consistency and are sometimes used for building materials. This thereby indicates a product that has reached virtual equilibrium with its environment. Thus the arched roofs of Angkor in Cambodia, built of laterite, stand nearly intact after seven centuries of neglect.

Laterites vary widely in composition, but most contain aluminum hydroxides and iron hydroxides and oxides, mixed with a little residual quartz. In most laterites, practically all the silicon of the original silicates has been dissolved away by rainwater, along with the easily soluble sodium and potassium, and the acid-soluble calcium and magnesium.

Residual laterite soils are characterized by a pale zone of leaching just above the parent rock, and a dark-brown concretionary zone at or near the surface (Figure 1). Each zone is usually a few decimeters to a few metres thick, but in places it may thicken to tens of metres. The concretionary zone is a concrete-like mass, composed chiefly of either dark brown "limonite" or of many limonite nodules (concretions), of pea or marble size, cemented into a sold mass. The uppermost part of some lateritic soils retains enough unaltered quartz to make it crumbly or even sandy.

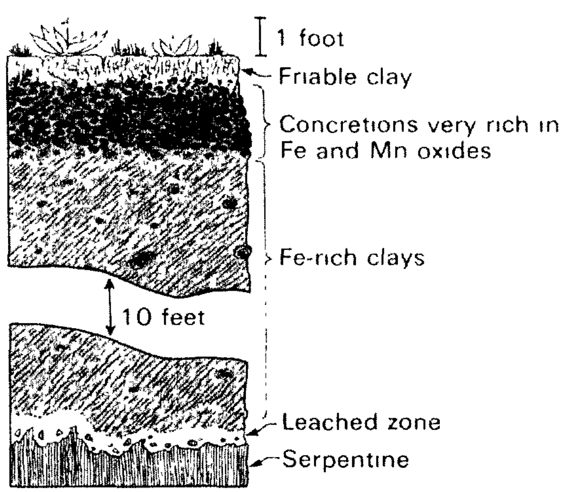

Figure 1. *Profile of Cuban laterite. The concentration of iron in these soils is so great that they are mined as iron ore (J. Gilluly, A.C. Waters and A.O. Woodford, 1968).*

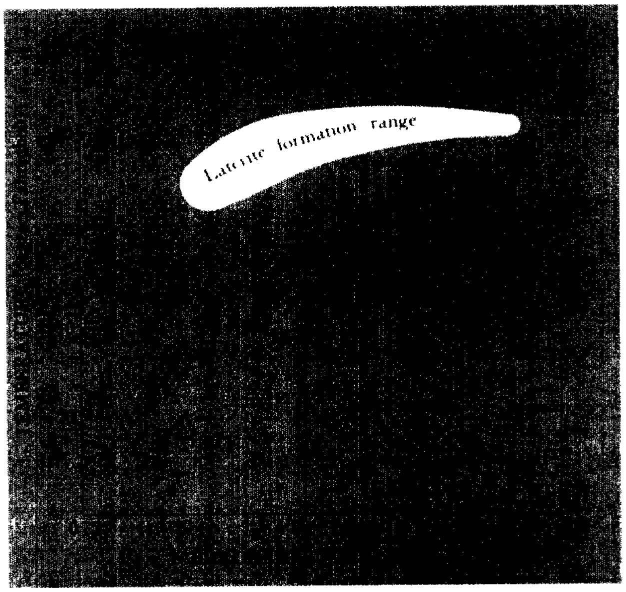

Figure 2. *Optimum range of temperature and precipitation conditions for the formation of laterite (B.S. Persons, 1970).*

This type of soil development is particularly prevalent in the regions of well-defined wet and dry seasons (Figure 2), and is enhanced in flat areas in which iron leached from upper layers moves downward instead of being carried away. Laterites being formed *in situ* from the weathering of rocks include soil types in which iron, aluminum, or silica is concentrated. These soils form residual deposits in tropical and subtropical latitudes (Figure 3).

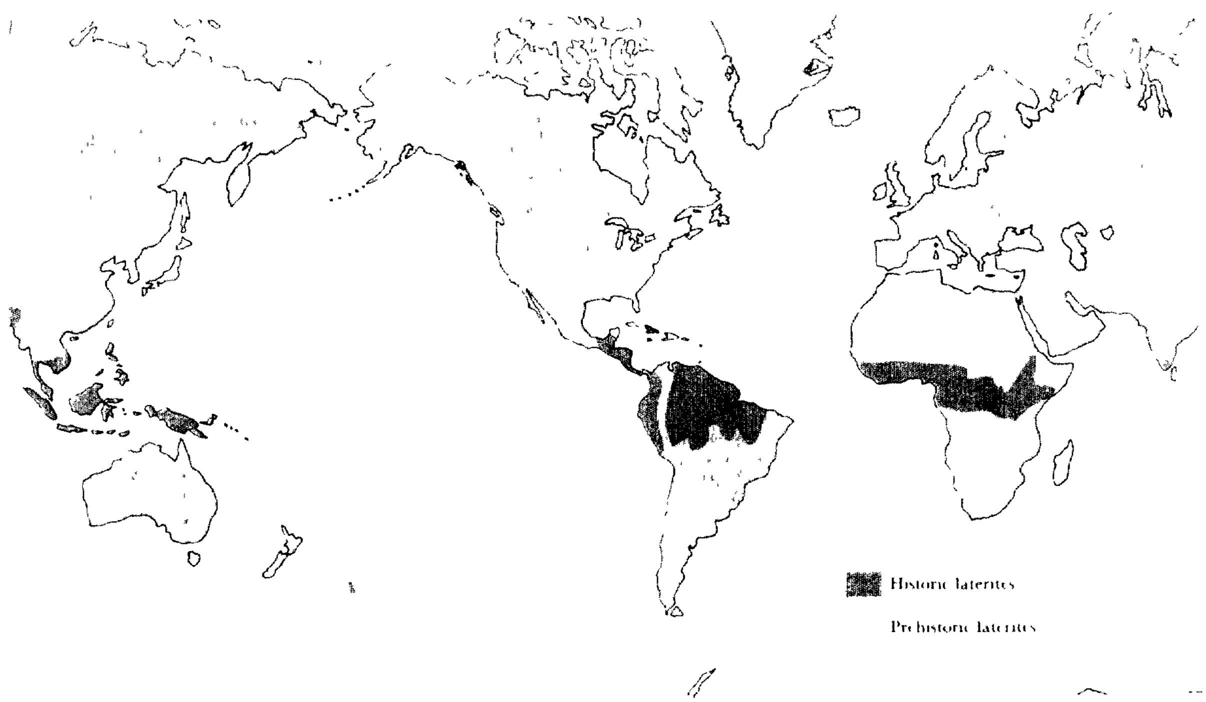

Figure 3. *World distribution map of past and present laterite deposits (B.S. Persons, 1970).*

Objectives

Environmental conditions coupled with mineralized soils ensure that, not only demining exercises, but also everyday existence in the Kingdom of Cambodia is both difficult and dangerous. Additionally, antipersonnel mine concentration found in the Kingdom of Cambodia is estimated to be in the millions, and almost all mine fields are unmapped. With only these factors taken into consideration, the risk of exposure to the general population and deminers is very high. Mines are indiscriminate in terms of target and time. They go on killing and maiming - soldiers and civilians, men and women, adults and children alike - decades after the fighting has ended.

Humanitarian mine clearance may be a relatively new discipline, no more than 15 years old, but some aspects of its work are already well known through decades of experience in development and emergency work. Challenges to combat the global landmine crisis vary from technical questions of detecting and destroying various mines and munitions to managerial, developmental, social, and financial aspects of implementing large programs in a broad variety of scenarios. It is crucial to acknowledge the complexity of the issue, rather than looking for a single, global solution.

Benbrack Limited recognizes:

(1) The far-reaching effects landmines have on countries attempting to rebuild after conflicts;
(2) That landmines affect countries such as Cambodia on every level of development (politically, economically, and culturally);
(3) Landmines have grave effects on the environment, and consequences include the loss of arable land, pollution, and maiming of endangered species;
(4) Access to farmland, irrigation channels, power plants and roads is barred by the scattering of millions of landmines;
(5) There is a direct impact on families with casualties and fatalities. Millions of people have to choose between farming in fear, going hungry, or leaving their homes.

As an endeavor to participate with humanitarian demining, Benbrack Limited responded to the posted RFP in such a manner as to provide a cost-effective procedure to acquire the necessary maghemite bearing laterite soil allowing DRES to continue with testing and evaluation in a safe, controlled environment. By bringing Cambodian maghemite bearing laterite soil to DRES, research and development associated with testing and evaluation can be conducted in Canada, as opposed to exposing research scientists to possible risk with soil *in situ*.

MATERIALS AND METHODS

Human Resources

Two representatives from Benbrack Limited were designated to conduct all business transactions, acquire all information required to complete the task of trans-shipping 60 cubic meters of maghemite bearing laterite soil from Cambodia, and complete all logistically planning to complete this project.

To assist Benbrack Limited representatives, a demining consultant with foreign affair experience was retained from International Demining Consultants Canada Limited.

Laterite Transportation

Prior to engaging a transportation agent, an approximate mass per cubic meter needed to be determined. A representative from DBC Construction was contacted regarding the average mass per cubic meter of typical Alberta clay soil. As there is a gross limit per container, this information would then further be used to calculate the number of polywoven sacks and containers required for trans-shipment of sixty cubic meters of maghemite bearing laterite soil.

Based on calculated data, ITN International Corp. was contracted to facilitate transportation of sixty cubic meters of maghemite bearing laterite soil in 1,500 polywoven 3.75 cubic foot sacks using four forty foot sea containers. ITN International Corp. further provided Benbrack Limited with a Cambodia-based transport company that would supply Benbrack Limited with the required containers and the means to transport the containers.

To ensure the success of this project, much documentation was required. The following documentation steps were followed:

1) Liaise with CMAC regarding site location of maghemite bearing laterite that meets with the requirements of this project;
2) Obtain the support of CMAC for the export of sixty cubic meters of maghemite bearing laterite;
3) Liaise with the Cambodian Ministry of Economy and Finance, Customs and Excise Department regarding the export of sixty cubic meters of maghemite bearing laterite;
4) Obtain approval and documentation for the export of sixty cubic meters of maghemite bearing laterite;

5) Purchase sixty cubic meters of maghemite bearing laterite from a land holder near Kampong Chhnang;
6) Transportation documentation for the relocation of four forty foot sea containers holding sixty cubic meters of maghemite bearing laterite from site of origin to Sihanoukville;
7) Obtain Sea Port clearance for shipment;
8) Obtain Sea Port Cambodian Customs and Excise clearance for shipment;
9) Obtain clearance from the office of the ComController for shipment;
10) Present paper work to Hanjin Shipping to allow for all four containers to be loaded as trans-shipment freight;
11) Upon the containers' arrival to Canada obtain Canada Customs Clearance;
12) Have all four containers fumigated as per required by Agriculture Canada, and obtain a fumigation certificate.

Experimental Data

The following procedures, as determined by DRES, were followed to gather scientific data from the soil extraction point:

1. *General Test Procedure*

(a) Divide the area to be excavated into 1 meter squares using non-metallic markers. Include a meter fringe around the site that will be tested, but not excavated.

(b) Perform and record the following tests for each square. The tests using the same equipment are not to be consecutive.

(c) All distance measurements should be made using a wooden or plastic rule that is metal free.

(d) Make sure the area is away from power lines, fences, etc.

2. *The Schiebel AN19/2 Metal Detector*

(a) Check battery. Connect coil and headphone according to instruction. Make sure no metal on your person san get close to coil when operating detector (remove watches, rings, etc).

(b) Hold coil up in the air (1-2m over the ground). Adjust the volume control to a comfortable level. Adjust the sensitivity until a regular tick is heard (between silence and squeal).

(c) Check that supplied test pin is detectable at about 9-10cm from the coil (held in air). This ensures that the detector is working at normal sensitivity. Note position of sensitivity knob (e.g. clock position).

(d) Choose a bare spot or one with as little vegetation as possible. Slowly lower the coil head towards a patch on the ground. On non-neutral ground the detector should squeal when the head is lowered to a distance "d" above the soil. Note the height "d". Make sure there are no buried metal objects under the test spot. Check by using another detector or by moving to a different spot and recheck.

(e) Next lower the coil head to the ground surface. Adjust sensitivity until the squealing becomes ticks (as before). Now the detector is balanced to the ground.

(f) Determine the minimum size target that can be detected lying on the ground under these conditions by using a number of washers held within a film canister (or other suitable container). Remove washers until the target is undetectable. Note the number of washers and the position of sensitivity knob.

3. *The Bartington MS2D Susceptibility Meter*

(a) Familiarize yourself with basic operation of the meter (just the basics) and make sure battery checks out okay (a long charge time is needed).

(b) Connect the MS21) probe per instructions.

(c) Turn on by switching the knob from "OFF". Set to "SI" units.

(d) Turn knob to "BATT" and green light should come on if battery okay. Select the 1.0 scale.

(e) Hold the coil up in air and press " Z" button (making sure no metal is near the head) to zero the unit. The display should read 0000.

(f) Lower the coil onto the soil - choose a bare spot if possible. Press "M" and note the reading. Make sure no metal around. Large metal objects may result in negative numbers (trouble). If the numbers are very high, then you should suspect that metal is present.

(g) Conduct this measurement at least once in each grid. Repeat the procedure if time permits (i.e. balance in air and measure).

(h) Note location and reading by hand. It is also possible to use the data logger (PC).

(i) Take samples if possible at each grid square using a 35mm film canister or other sufficient holder.

4. *The Geonics EM38 Ground Conductivity Meter*

(a) Briefly review the EM38 Operating Manual. The manual is overly complex and difficult to follow. The ground conductivity and susceptibility measurements using this device are optional. Take note of chapter 2 and 3, "Survey Procedures" and "Electrical Interference", especially the comments on the influence of conductive objects and power lines.

(b) Test battery as per manual. Perform the initial In-phase (I/P) nulling. As per the metal detector, insure that metal objects are removed from the area (coins, watches, keys, etc). Set the range switch to 1000 mS/m. Set the mode switch to the I/P position. Lift the instrument to a height of at least 1.5m above the ground and hold in the horizontal position (-) (like an airplane wing). Using the I/P Coarse Zero and I/P Fine Zero Controls, adjust the meter to indicate near zero. Repeat nulling procedure with using the 100 mS/m range setting and insure the readings within +/- 10 mS/m of zero.

(c) Perform the initial quadature phase (Q/P) zeroing. Set the range switch to 100 mS/m and the mode switch to the Q/P position. Lift the instrument to a height of at least 1.5m above the ground and hold in the horizontal position (-) (like an airplane wing). Use your shoulder as a reference, as the height needs to be constant (within +/- 5cm) when adjusting the settings over the nulling process. Using the Q/P Zero Control, adjust the reading to a value of approximately 50 mS/m. Note the meter reading (denoted as H). Rotate the instrument into the vertical orientation (1) (like an airplane fuselage) and note the meter reading (denoted as V). Over highly conductive ground it may be necessary to switch into the 1000 mS/m range. V should be equal to twice H if the Q/P is correctly set.

If 2H does not equal V, calculate C=V-2H. Adjust the meter to read either C+H in the horizontal position or C+V in the vertical position. Repeat step (c) to insure the Q/P zeroing is correctly set. In any case, the final H and V should be recorded before the survey and noted after the survey.

(d) The Q/P zeroing needs to be repeated during the survey if the ground conductivity readings fall from over 1000 mS/m to under 100 mS/m. Also, in some cases, the ground is so resistive that step (c) drives the settings of V=H=O (correctly).

(e) Read section 1.4 "Final In-phase Nulling" of the Operating Manual. It is suggested that the survey of the excavating area be carried out once in the vertical position and once in the horizontal position. Therefore, with the unit on the ground in the vertical position (1) and the mode switched to I/P, the I/P Coarse and Fine Controls are used to null the In-phase component. The survey is then carried out in the vertical position with the mode switch in the Q/P position and the range switch in the most sensitive position as possible (conductivity in mS/m vertical).

If it is observed that the values of conductivity do not repeat from one range switch setting to another, then the susceptibility signal has become too large and the EM38 must be re-nulled, repeating steps (b) to (e).

(f) Repeat the survey in the horizontal position (-) by first placing the unit on the ground and switching the mode to I/P. The I/P Coarse and Fine Controls are used to null the In-phase component. The survey is then carried out in the horizontal position with the mode switch in the Q/P position and the range switch in the most sensitive position as possible (conductivity in mS/m horizontal).

(g) Remember to check and record the V and H components (but do not set) from step (c) after the survey has been completed.

(h) Read chapter 5, "Measuring Soil Magnetic Susceptibility" and measure the magnetic susceptibility of the excavation area.

RESULTS

Geographical Location – Laterite Acquisition Area

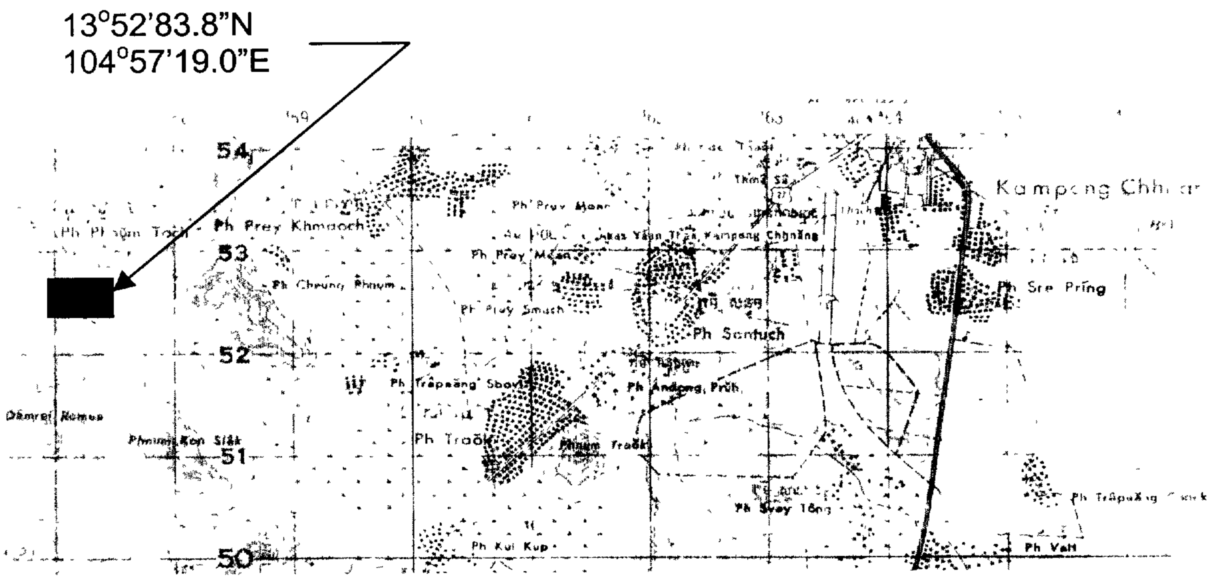

Figure 4. *Location of maghemite bearing laterite acquisition site.*

Figure 5. *Soil profile of maghemite bearing laterite acquisition site (B.J. Baker, 1999)*

Experimental Data

1. *General Test Procedure*

Grid Design:

A1	A2	A3	A4	A5	A6
B1	B2	B3	B4	B5	B6
C1	C2	C3	C4	C5	C6
D1	D2	D3	D4	D5	D6
E1	E2	E3	E4	E5	E6
F1	F2	F3	F4	F5	F6
G1	G2	G3	G4	G5	G6
H1	H2	H3	H4	H5	H6
I1	I2	I3	I4	I5	I6
J1	J2	J3	J4	J5	J6

2. *Schiebel AN19/2 Metal Detector*

Initial Instrument Zeroing Procedure and Observations:

(a) Test pin detectable at approximately 9-10cm from the coil (held in air). Sensitivity knob clock position = 7.
(b) When the coil is moved to the ground the distance "d" the detector begins to squeal = 38cm. This distance was repeated several times in different locations.
(c) Balance the detector to the ground. Sensitivity knob clock position = 1.

Coil Height From Ground (cm)	Detector Squeal	Detector No Squeal	Washers Detected
4	◆		40
4	◆		30
4	◆		20
4	◆		18
4	◆		17
4	◆		16
4		◆	15
4		◆	14
4		◆	13
4		◆	10
4		◆	5

3. *The Bartington MS2D Susceptibility Meter*

Quadrant	Data 1	Data 2
A1	4.47	4.24
A2	3.07	2.88
A3	3.18	2.96
A4	3.45	3.23
A5	3.22	3.00
A6	3.08	2.91

Quadrant	Data 1	Data 2
B1	3.90	3.75
B2	3.83	3.66
B3	3.25	3.04
B4	3.03	2.87
B5	3.36	3.15
B6	3.84	3.64

Quadrant	Data 1	Data 2
C1	3.91	3.75
C2	5.77	5.55
C3	3.51	3.29
C4	3.58	3.32
C5	3.80	3.72
C6	4.44	4.22

Quadrant	Data 1	Data 2
D1	3.63	3.45
D2	4.16	3.98
D3	3.71	3.55
D4	4.06	3.82
D5	3.70	3.56
D6	3.60	3.42

Quadrant	Data 1	Data 2
E1	4.00	3.82
E2	3.45	3.22
E3	3.90	3.72
E4	3.53	3.33
E5	3.88	3.70
E6	2.31	2.15

Quadrant	Data 1	Data 2
F1	3.10	2.92
F2	3.71	3.56
F3	3.77	3.59
F4	3.19	3.02
F5	3.15	2.98
F6	3.06	2.90

Quadrant	Data 1	Data 2
G1	3.03	2.85
G2	3.00	2.82
G3	3.20	3.01
G4	3.10	2.95
G5	2.96	2.80
G6	3.20	3.05

Quadrant	Data 1	Data 2
H1	3.23	3.06
H2	2.91	3.75
H3	2.89	3.72
H4	3.33	3.06
H5	3.29	3.11
H6	3.00	3.82

Quadrant	Data 1	Data 2
I1	3.22	3.02
I2	3.86	3.69
I3	3.13	2.98
I4	2.94	2.78
I5	3.09	2.93
I6	3.23	3.05

Quadrant	Data 1	Data 2
J1	3.31	3.13
J2	3.13	2.97
J3	3.16	3.00
J4	3.03	2.89
J5	3.37	3.22
J6	3.49	3.32

3. *The Geonics EM38 Ground Conductivity Meter*

Instrument Zeroing

Instrument zeroed at a height of 1.5m.

DESCRIPTION	**Instrument Readings at Calibration**				
Variable	H	V	H1	V1	C
Instrument Reading	50	46	-4	-8	-54

Instrument Quadrant Observations

H value before survey = 9
V value before survey = 4.2

H value after survey = 9.2
V value after survey = 4.4

Quadrant	**H**	**V**
A1	5.4	9.9
A2	3.4	13.0
A3	3.8	11.4
A4	14.0	11.4
A5	5.2	12.1
A6	4.5	9.4

Quadrant	**H**	**V**
B1	2.6	11.6
B2	3.2	11.4
B3	4.2	11.1
B4	4.9	10.4
B5	5.0	8.2
B6	4.2	10.7

Quadrant	**H**	**V**
C1	2.9	10.7
3.0	2.9	8.2
C3	3.0	8.3
C4	3.4	8.1
C5	3.4	10.1
C6	3.7	8.8

Quadrant	**H**	**V**
D1	4.2	11.7
D2	5.6	11.8
D3	3.8	11.5
D4	3.4	10.8
D5	5.6	10.8
D6	3.7	10.6

Quadrant	H	V
E1	3.4	11.2
E2	2.5	9.9
E3	2.5	9.8
E4	2.7	9.0
E5	2.5	9.6
E6	2.4	9.4

Quadrant	H	V
F1	3.1	9.9
F2	2.2	9.3
F3	2.6	9.8
F4	2.9	10.0
F5	4.5	10.1
F6	2.1	8.1

Quadrant	H	V
G1	3.8	9.3
G2	3.8	10.0
G3	3.1	10.4
G4	3.1	9.1
G5	2.5	8.3
G6	2.5	6.8

Quadrant	H	V
H1	1.9	7.7
H2	2.8	8.5
H3	3.4	8.6
H4	3.5	7.9
H5	2.6	9.0
H6	2.5	6.9

Quadrant	H	V
I1	2.5	7.9
I2	2.4	6.9
I3	3.0	8.4
I4	3.2	8.4
I5	2.6	9.2
I6	2.0	9.3

Quadrant	H	V
J1	3.0	8.1
J2	3.8	9.3
J3	3.6	9.2
J4	3.4	8.8
J5	3.6	9.1
J6	3.0	8.8

Fumigation Certificate

Abell
Pest Control
Since 1924 Because We Care

CERTIFICATE OF FUMIGATION

This certifies that the following subject has been professionally fumigated, adhering to all guidelines and specifications as set out in the British Columbia Fumigators guidebook.

Date:	January 10, 2000
Container #:	HSCU 1041286 HSCU 7701772 HSCU 7723977 HSCU 7829629
Location:	1285 Franklin in Vancouver
Dosage:	3lb/1000 cubic foot
Fumigant Used:	Methyl Bromide
Weather Conditions:	10 degrees celsius
Held:	48 hours

Laurence Elzinga
Fumigator
License # 46746 A

CONCLUSION

The Defence Research Establishment Suffield (DRES), a component of DRBD, has, since its inception, developed expertise regarding testing and evaluation of metal detectors for their ability to meet certain requirements. In order to further critical assessments of detection sensitivity, electronic stability, susceptibility to moisture, mineralized soils, and other environmental factors are being pursued. This work is critical to allow for obtaining solutions to current environmental factors posed by a variety of soil conditions as well as objective decision-making regarding future development and acquisition of equipment for the DND. It is therefore critical that a solution to the effects of maghemite bearing lateritic soil that dramatically reduces the sensitivity of the Schiebel AN19/2 metal detector.

Representatives from Benbrack Limited were contracted to obtain 60 cubic meters of maghemite bearing laterite soil from Cambodia with the assistance of the referred demining consultant from International Demining Consultants Canada Limited. Benbrack Limited was requested to perform various tests as specified by DRES, using the *Schiebel AN19/2 Metal Detector,* the *Bartington MS2D Susceptibility Meter* and the *Geonics EM38 Ground Conductivity Meter* on site. After all testing was completed the 60 cubic meters of maghemite bearing laterite soil was then trans-shipped from Cambodia to the Defence Research Establishment Suffield (DRES).

The procedures followed to gather scientific data from the soil extraction point was to firstly divide the test area into one-meter squares using non-metallic markers. Secondly, to perform all testing as specified by representatives of DRES using the *Schiebel AN19/2 Metal Detector,* the *Bartington MS2D Susceptibility Meter* and the *Geonics EM38 Ground Conductivity Meter.* All data was recorded individually for each instrument for each square metre. All initial distance measurements that were made using a plastic rule that was metal free. The test area was located well away from power lines, fences, or any structures that may have resulted in interference of testing results.

The 60 cubic meters of maghemite bearing laterite soil that was obtained from Cambodia was purchased from a landholder near Kampong Chhnang. In order to meet both Customs Canada and Agriculture Canada's guidelines, all of the sixty cubic meters of maghemite bearing laterite soil was hand loaded into 1,500 polywoven 3.75 cubic foot sacks. The 1,500 polywoven sacks were then loaded equally into four, forty-foot sea containers for shipment from the site of origin to Sihanoukvillee and then to the port of entry into Canada. All four containers were fumigated as per required by Agriculture Canada while in the port of entry. The fumigation certificate was obtained and forwarded to both Customs Canada and Agriculture Canada in order to allow release of the containers and shipment to DRES.

Based on the successful completion of this project, Dr. Das and Mr. Russell have discussed further acquisition needs with representatives of Benbrack Limited. Benbrack Limited would be pleased to further explore the opportunity of providing these items to DRES:

Material Description	Assay Required (%)	Quantity Required (cubic metres)	Assay and Quantity Located
Magnetite	20	60	22.7% and 60 cu m
High [Boron} Soil	5	20	12% and 20 cu m
High [Salinity] Soil	-	20	-
High [Organic] Soil	50	30	90% and 30 cu m
High [Iron] Soil	-	-	20% and 60 cu m

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