

THE FOURTH INTERNATIONAL SYMPOSIUM

"MECHANICAL DEMINING"

BOOK OF PAPERS

"HUMANITARIAN DEMINING 2007"

24 – 27 April 2007

Šibenik, CROATIA

“HUMANITARIAN DEMINING 2007”
International Symposium 24 – 27 April 2007, Šibenik, Croatia

Editor-in Chief
Oto Jungwirth

Editorial Board
Mirko Ivanušić, Nikola Gambiroža, Davor Laura,
Neven Karas, Miljenko Vahtarić

Editor
Nikola Pavković

Published by
CROMAC – Center for testing, Development and Training Ltd.
Sortina 1D, 10 020 Zagreb, Croatia
Tel ++385 (0) 650 0020, Fax. ++385 (0) 652 0301

NOTE:

The material submitted by authors has not been revised.
All terms, definitions and texts are the original constructions of the authors.

CIP zapis dostupan u računalnom katalogu Nacionalne i sveučilišne knjižnice
u Zagrebu pod brojem 660105

ISBN 978-953-99879-3-8

CONTENTS

<i>Oto Jungwirth, Director of CROMAC</i> Use of Demining Machines in Reduction of Suspected Area.....	5
<i>Dinko Mikulic Vjekoslav Stojkovic Vladimir Koroman Ivan Steker</i> Evaluation of Using Demining Machines in Relation to Soil Trafficability	13
<i>Ivica Raguz</i> Advantages of Use of the Hand-Held Magnets and Rakes in Combined Demining Method.....	19
<i>Kaj Hörberg, Tim Lardner</i> Personal Protective Equipment for use in Humanitarian Mine Action	23
<i>Szymon Kostrzewski, Rusiru Dasantha Apputhanthri¹⁴, Jawad Masood, Emanuela Elisa Cepolina</i> Portable Mechatronic System for Demining Applications: Control Unit Design and Development	27
<i>Lois Carter Fay</i> MAIC Survivor Assistance Projects.....	31
<i>Christoph Frehsee</i> HCR-CTRO Evaluates Mini MineWolf for Humanitarian Demining Operations in Croatia	33
<i>Nikola Gambiroža, Ivan Šteker</i> Annual Verification of Demining Machine Characteristics Used in Humanitarian Demining Operations	37
<i>Dr Robert Keeley</i> Measuring Productivity and Cost Effectiveness of Machines for Humanitarian Demining	47
<i>René JOECKLE and Bernard GAUTIER</i> Effectiveness of the DEMICHAIN Concept	51
<i>Roman Turšić</i> International Trust Fund For Demining and Mine Victims Assistance.....	55
<i>Geoff Coley</i> Machine Demonstration Analysis and Preliminary Results.....	57
Summary Remarks	79

Use of Demining Machines in Reduction of Suspected Area

Oto Jungwirth¹, Director of CROMAC

Introduction

In line with rules and regulations that regulate humanitarian demining problem area (Law on Humanitarian Demining, a number of sub-acts passed by proper authorities), demining operations in the Republic of Croatia are conducted following the market principle. In practice, it means that demining is executed by accredited demining companies, that the works are awarded by conducting various forms of procurement in which public procurement is dominant but also that project documentation development, quality control over the operations in progress and after the completion of operations are executed by the institution designated by Law – Croatian Mine Action Centre. Apart from 28 currently accredited commercial companies, out of which one is state-owned and others are private, demining operations are also conducted by non-governmental organization Norwegian People's Aid which does not take part in the market but is financed by donor funds they secure themselves. In order to make sure that demining companies ensure the fulfilment of basic requirements the market sets for them, relating primarily to efficacy, economical quality and safety-quality, considerable capital is invested into procurement of basic means and training of people conducting the operations. It is estimated that ca. 30 million euros have been invested into equipping the companies with means and equipment required. Biggest part of funds invested is related to the procurement of modern demining machines as the engagement of good-quality demining machines in particular increases the efficacy and economical quality of demining process.

¹ Croatian Mine Action Centre, Ante Kovačića 10, 44 000 Sisak, Croatia, E-mail: oto.jungwirth@hcr.hr

1. Available capacities and demining machine capabilities

Modern mechanical demining method in the Republic of Croatia is conducted by demining machines of different types (Table 1) equipped by different working tools (Figure 1).

Table 1. Type and number of accredited demining machines

MACHINE TYPE	PIECES
HEAVY	6
MEDIUM	12
LIGHT	23
EXCAVATORS FLAILS	11
EXCAVATORS CUTTERS	2
	54

What we can see from the Table 1 is that the accredited demining companies currently dispose of 54 demining machines including the excavators, out of which the biggest number accounts for light demining machines. Lately, there has been a trend of procurement of medium and heavy demining machines whose efficacy is considerably bigger than the efficacy of light machines.

From the aspect of working tool, demining machines dispose of flails characteristic for light demining machines, tillers and combination of flails and tillers characteristic for medium and light demining machines. (Figure 1)

All the machines used in demining process in the Republic of Croatia are subject to detailed testing and their characteristics are verified each year. In the process of annual verification of demining machine characteristics (what is the subject of separate work at the symposium), among other things, the existence of required quality of soil treatment (soil treatment depth and density) and the capacity of each machine presented through m²/h are established.



Figure 1. Type and appearance of working tool the machines dispose of

Table 2. Average soil treatment depths and capacities of each machine category

MACHINE TYPE	PIECES	AVERAGE DEPTH cm	AVERAGE PERFORMANCE m ² /h	AVERAGE PERFORMANCE m ² / 5 h	DAILY AVERAGE m ²
HEAVY	6	26	3.370	16.850	101.100
MEDIUM	12	22	1.276	6.380	76.560
LIGHT	23	20	936	4.680	107.640
			SUM	27.910	285.300

Average soil treatment depth for heavy, medium and light machines reached during the annual verification of characteristics, average capacity of separate machine categories and average daily efficiency on the basis of 5 hour of work are given in the Table 2. What we can see is that in the conditions of full engagement of demining machines and with required quality of their work, stated machines can cover 285.300 m² on the basis of 5 hour work.

2. Methods of suspected area reduction

Mine suspected area in the Republic of Croatia is reduced by applying three methods. These are: general survey, mine search and demining (Figure 2).

2.1. General survey

General survey in the Republic of Croatia is conducted by CROMAC following precisely defined

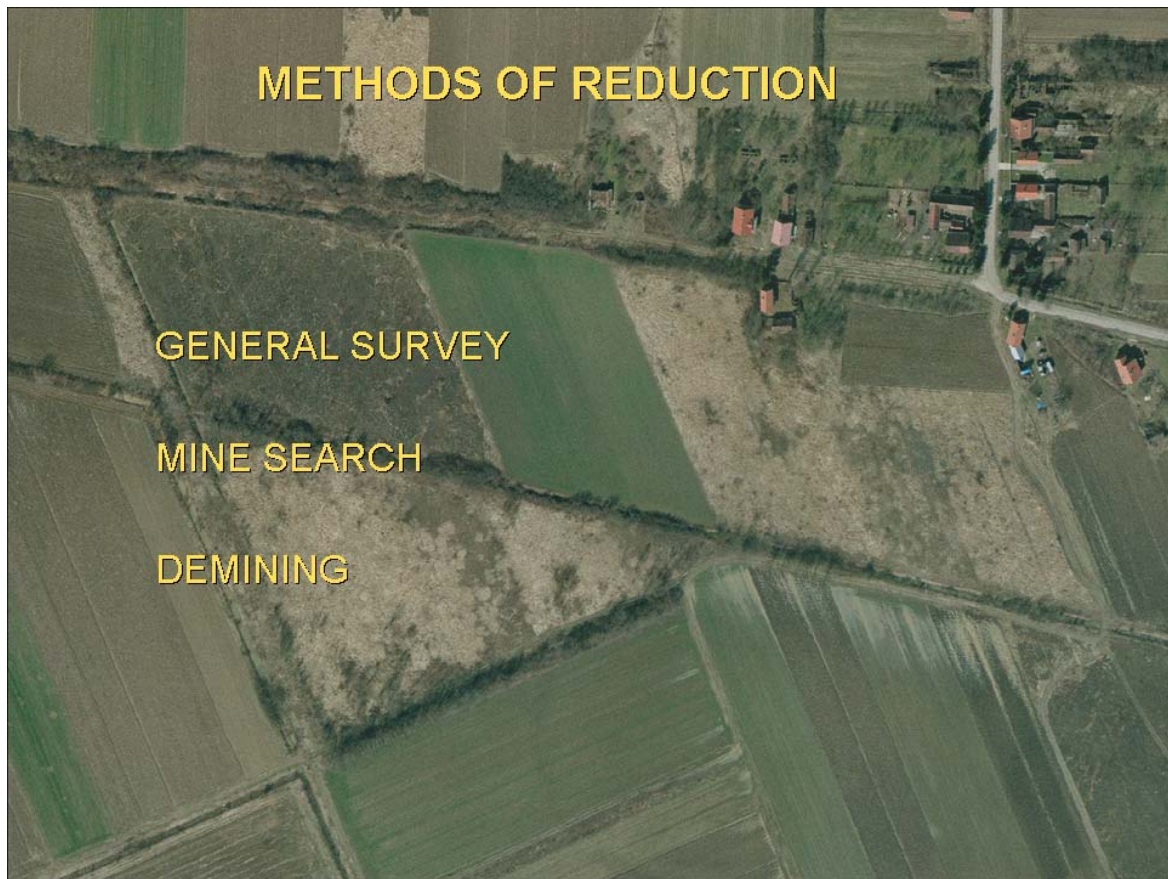


Figure 2 Mine suspected area in DOF-2

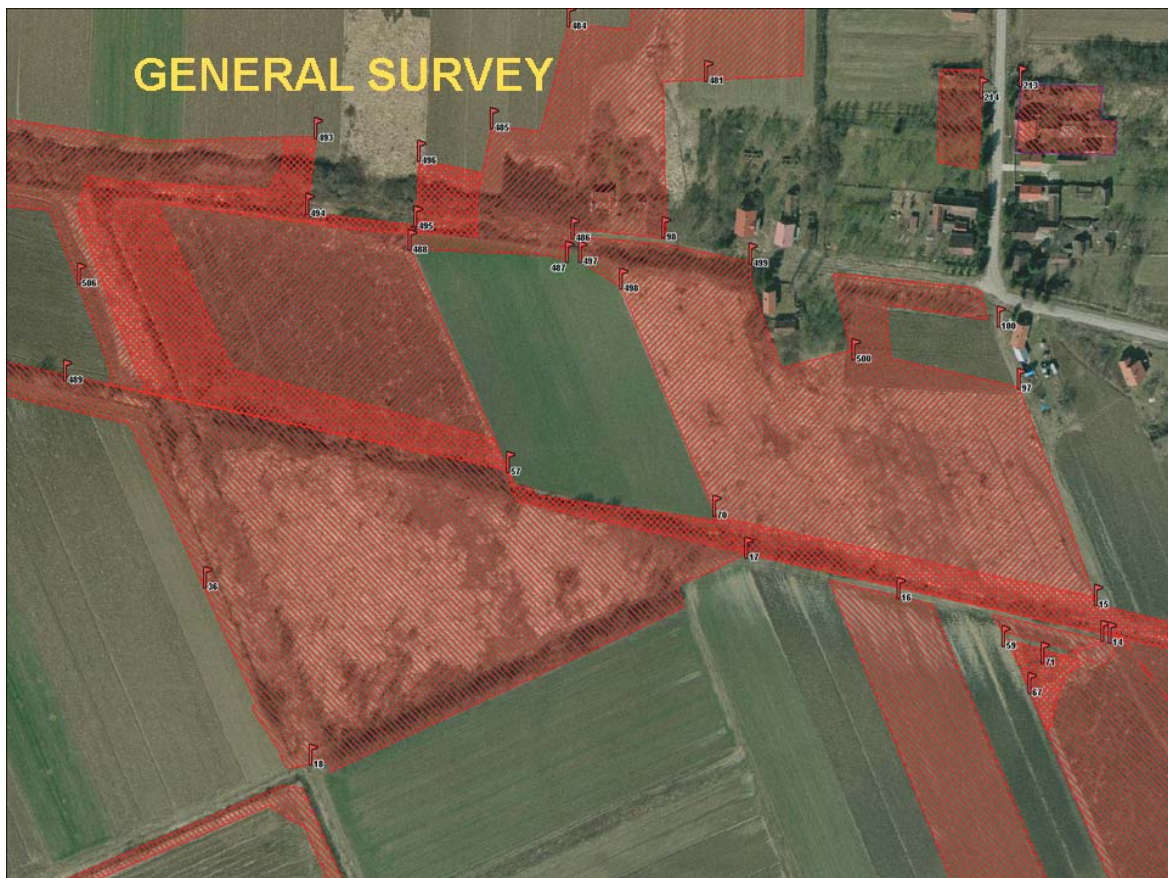


Figure 3 Mine suspected area defined by general survey in DOF-2

procedures. Goals to be reached by general survey are:

- Precise definition of boundaries of mine suspected area
- Categorization of mine suspected area on the area to be searched and area to be demined
- Marking of mine suspected area

Mine suspected area is classified as the one to be searched i.e. demined on the basis of relevant data collected. The area for which there are certain mine contamination data available (minefield record, reliable information on mine contamination etc.) is categorized as the area to be demined. The area for which there are certain indicators of being mine suspected but has no reliable information on mine contamination is categorized as the area to be searched. (Figure 3)

2.2. Mine search

Mine search is a procedure for the establishment of accuracy of data collected by general and technical survey and it establishes the existence of contamination - non-contamination with mines and UXO of the entire MSA and/or building defined by the project.

Authorised legal entities or tradesmen can perform mine search operations at the worksite using the following methods:

- Manual mine detection or,
- Combination of demining machine reaching the depth defined by the project and manual method on the part of the area searched by the machine, or
- Combination of demining machine which does not reach the depth defined by the project and manual mine detection, or
- Combination of demining machine which does not reach the depth defined by the project and mine and UXO detection dogs after the machine, or
- Combination of mine and UXO detection dogs and manual mine detection.

Which of the above-mentioned methods will be applied depends on a number of factors such as soil conditions which define the soil composition, slope, vegetation density and diameter of trees i.e. limitations in the project in relation to the limitations of each of the methods.

Methods applied have to ensure required clearance level i.e. establish the contamination or non-contamination of areas or buildings. The way of applying methods at the worksite is de-

scribed in detail in the execution projects made by authorised legal entity or tradesman and verified by CROMAC prior to the commencement of operations.

The biggest level of economical quality and efficacy in relation to the soil conditions while applying mine search process at the worksite is ensured by the method “Combination of demining machine reaching the specified depth and manual mine detection on the part of the area searched by the machine”. The same method will be elaborated a bit later according to phases of execution at the worksite.

Phase I

In the first phase, the entire area to be searched (Figure 4) is treated with demining machine reaching the depth defined by the project (depths specified in the project are defined by the Enclosure 1 to the Rules and Regulations on the Method of Project Documentation Development in Humanitarian Demining).

Phase II

After the entire area is treated with demining machine reaching the depth defined by the project, CROMAC – Quality Assurance and Quality Control Department, according to SOP 04-02, performs sampling of mechanically treated area abiding by ISO 2859-1. If the medium value of all samples in the lot meets the acceptance conditions, manual mine detection can be applied on the part of mechanically treated area.

Phase III

Deminers of the authorised legal entity or tradesman search mechanically treated area using manual mine detection (metal detectors) every 15 m in a way that they search working lanes 1 m wide horizontally and vertically i.e. following the grid system. They also perform internal control on minimum 5% of searched area. (Figure 5)

At the same time, Quality Assurance and Quality Control Department conducts quality assurance during the execution of operations and establishment of quality of searched area (sampling) according to SOP 04-03 (Sampling for Inspection and Control of the Area Searched by Metal Detector). If the incorrectnesses or non-conformities are established, manually searched area is returned in order to be searched all over again.



Figure 4. Mechanically treated project area – DOF 2



Figure 5 Manual mine detection using the grid system and internal control – DOF 2



Figure 6 Project area treated by the authorised legal entity and QA and QC Department

Phase IV

Mine search by manual detection is conducted using the grid system on the entire mechanically treated area in order to search minimum 15% of mechanically treated area. In addition, authorised legal entity or tradesman is obliged to carry out internal control on minimum 5% of searched area.

Quality Assurance and Quality Control Department continuously conducts quality assurance and samplings during mine search operations in progress covering 2-3% of searched area. At the end, upon completion of mine search operations at the worksite and submission of Statement of the authorised legal entity or tradesman and relevant documentation on executed mine search operations, quality control is conducted over completed mine search operations on minimum 3% of searched area (1% upon entry into force of the Rules and Regulations on Method of Conducting Humanitarian Demining) (Figure 6).

Recapitulation of treated area

a) Authorised legal entity or tradesman:

- 100 % with demining machine reaching the depth specified by the project,

- Minimum 15 % of mechanically treated area with manual mine detection (grid system),
- Minimum 5 % internal control

b) CROMAC, Quality Assurance and Quality Control Department:

- 2 – 3 % quality assurance during the execution of mine search operations
- 3 % (1 %) quality assurance over completed mine search operations

Application of stated method resulted in treating the entire area with demining machine reaching projected depth and ca. 25% of the area by manual mine detection.

If, during the application of stated method, the machine activates mines or UXO, or usage of manual detection in the working lane i.e. visual observation in the field results in detection of mines, UXO or their fragments, it is mandatory to inspect the area in the radius of 20 m from activated mines or UXO and establish systematic contamination based on which demining project is made for the part of systematically contaminated area.

2.3. Demining

Demining operations in the Republic of Croatia are conducted according to regulations that are compliant with the international standards and passed by proper authorities.

3. Reduction of mine suspected area in 2006

During 2006, total mine suspected area of 1.147 km² was reduced for 102.775.024 m² by applying different methods. With general survey method, mine suspected area was reduced for 78.000.000 m², with mine search method for 15.318.174 m² and with method of demining for 9.456.850 m² (Figure 7.)

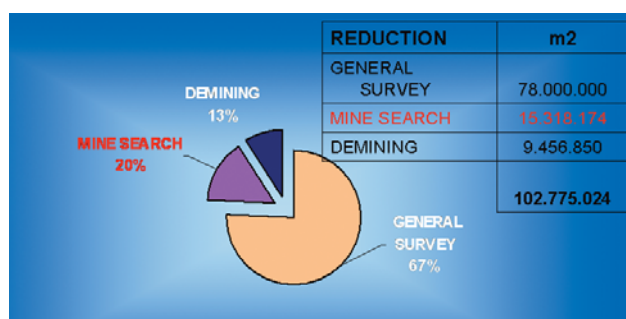


Figure 7 The diagram of reduction of mine suspected area by applying different methods (2006)

During 2006, there were 143 mine search projects realized out of which 97 were smaller than 100.000 m², 36 projects were between 100.000 m² and 500.000 m², and 10 projects were bigger than 500.000 m² out of which 6 were realized using demining machines and the other 4 by manual method due to the configuration and characteristics of soil that made the use of demining machines impossible. (Table 3)

The reason for relatively big number of projects smaller than 100.000 m² is in the fact that certain investors requested demining of the areas necessary for conducting their business.

Table 3 Size and number of mine search projects realized during 2006

MINE SEARCH PROJECTS 2006			
No.	SIZE	TOTAL m ²	%
97	< 100.000	2.551.947	17
36	100.000 - 500.000	4.556.381	30
6	> 500.000	4.904.024	54
4		3.305.822	
143		15.318.174	

Bearing in mind the fact that the advantages of demining machines in relation to other means used become apparent on bigger areas, for the purpose of this paper we will analyze mine search projects bigger than 500 000 m² on which mostly demining machines were used (6 projects). There were 4.904.024 m² searched on the analyzed projects out of which 350.644m² were searched by manual method and the rest was searched mechanically.(Figure 8)

PROJECT AREA m ²	METHODS APPLIED	
	MANUAL MINE DETECTION	MECHANICAL MINE DETECTION
4.904.024	350.644	4.551.854

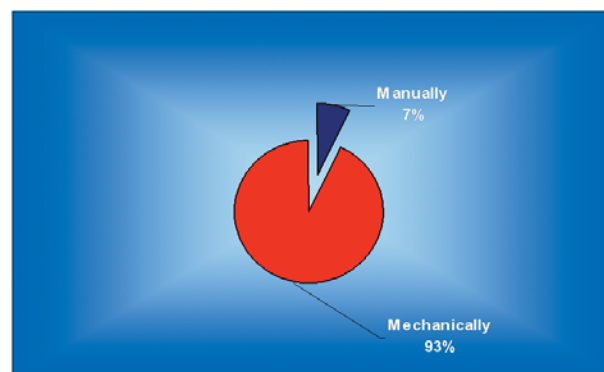


Figure 8 The diagram of the share of demining machines in mine search operations during 2006

From the aspect of the machines used, 47% of the area was searched by heavy machines, 36% by medium machines, 16% by light machines and 1% with excavators.(Figure 9)

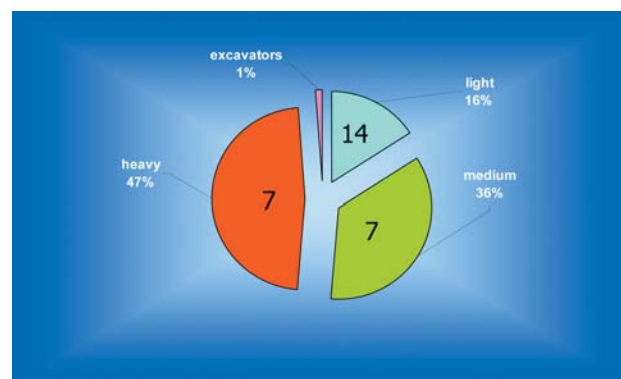


Figure 9 The diagram of the share of each machine type on mine search projects

3.1. Economical quality

Analyzed projects were contracted based on public tenders carried out for the total amount of 4.809.246,77 EUR what gives the average price of 0,97 EUR/m². If the analyzed project were re-

alized using the manual mine detection method as per average price of 1,50 EUR/m², what is the average price for this method in the Republic of Croatia, the amount required for their realization would be 7.356.036 EUR i.e. 2.546.790,03 EUR more than it was contracted. (Figure 10) Stated financial indicators undoubtedly indicate the economical quality demining machines have in relation to other methods.

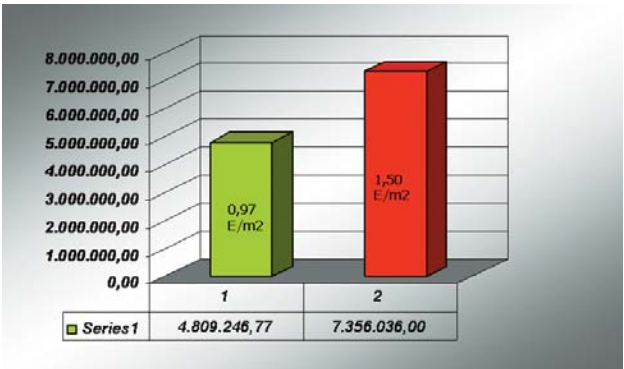


Figure 10 The diagram of financial indicators – economical quality

3.2. Efficacy

Efficacy demining machines reach is more than clearly illustrated by the fact that the average demining machine and three deminers required for internal control reach the performance that would be realized by 62 deminers working without the demining machine. (Figure 11).

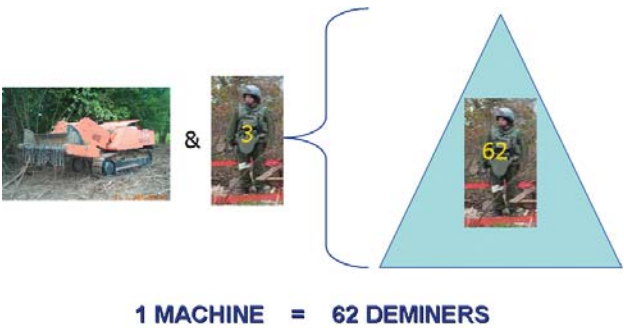


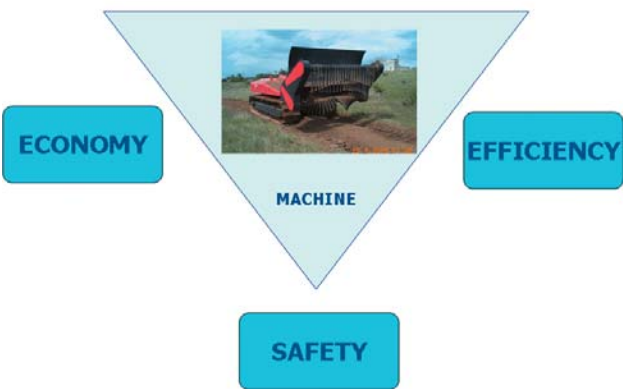
Figure 11 The scheme of efficacy of demining machines in relation to the deminers

Conclusion

1. The advantage of demining machines in relation to other means used in humanitarian demining operations become especially apparent on bigger areas with favourable soil conditions scheduled for mine search.
2. Financial indicators shown undoubtedly indicate the economical quality demining ma-

chines have in relation to other methods.

3. The biggest economical quality and efficacy in relation to soil conditions in applying mine search process at the worksite are ensured by combined method of demining machine and manual detection.
4. Apart from the impact on the increase of efficacy and economical quality that demining machines have in the process of conducting demining operations, they also influence a great deal the considerable increase of safety during the operation what influences, along with prescribed measures of control, the increase of quality of the work done.



5. Bibliography

- (1) CROMAC Standard Operating Procedures
- (2) Dinko Mikulić: Demining Tehnics: modern methods and equipment, demining machines, Zagreb, 1999
- (3) Rules and Regulations on Metods of Humanitarian Demining, Narodne novine (National Gazette), 53/2007, 2007
- (4) Rules and Regulations on Method of Project Documentation Development in Humanitarian Demining, Zagreb, (Narodne novine (National Gazette) 40/2007), 2007

Evaluation of Using Demining Machines in Relation to Soil Trafficability

Dinko Mikulic² Vjekoslav Stojkovic³ Vladimir Koroman⁴ Ivan Steker⁵

Abstract

Digging the soil using flail or tiller in front of the wheels or tracks creates a new loose layer of soil, and a machine has to move over it. Due to the higher level of soil moisture, mobility of the machine is limited, and its work efficiency decreases. Mobility of the machine depends on soil trafficability and working speed of movement of the machine. In the Theory of the machine movement, the soil trafficability has not been researched and explained, yet. Hence, the use of the machine on dry, wet, and extremely wet soil has not been sufficiently defined, so the use of the machine strictly depends on the experience of the evaluating person. It often occurs that the machine, in real mine field situation, does not hold the lane well, that it does not have satisfactory working speed of movement, that it does not have sufficient controllability, so it sways, or skids off the tracks or even rolls over. Occasionally in such conditions, the mine is pressed even deeper into soil. Such sort of machine demining is of poor quality, and thus it is unacceptable. Idea is to evaluate the use of demining machines in relation to actual state of soil, and not according to request, or own will of the demining company. The use of the demining machines in hard conditions should not be unauthorized, since the necessary quality and quality control are not secured, which then decreases efficiency, and increases total cost.

In the paper, the methodology of future research project execution is presented, the project which will offer an analytical model of demining machine usage estimation in relation to state of soil. The model will define acceptable conditions for the use of any demining machines, based on technical characteristics of the machine and soil conditions, be it on dry, wet, or extremely wet soil – the soil trafficability.

1. Introduction

Demining machines treat mine suspected soil mechanically and, in so doing, neutralize buried mines (by crushing them or activating). Demining machine usage depends on condition of soil that needs to be demined. Machine mobility evaluation, from the viewpoint of thier demining usage possibilities, is based on soil trafficability analysis. Soil trafficability is the criterion of possible machine usage in demining. The machine that treats the soil with a flail or tiller digs deep to 20 cm or less, and by that formes a new loose layer of certain thickness in front of the tracks or wheels, through which the machine further drives, Fig. 1 and Fig. 2.

Therefore, it is necessary for the machine to

have the required technical parameters of tracks and wheels for work in such hard conditions, particularly on that new moist layer of soil. The machine needs to keep up its working speed and controllability, without slipping and course violation. The new loose layer of soil („banana layer“) on which the track or wheel proceeds, has very low soil capacity, thereby a problem occurs with trafficability of such a soil layer.

Currently in practice, in accordance with SOP CROMAC, demining machines are not used in the following cases:

- When the soil is frozen and/or covered in snow,
- In case of rain or thick fog,
- When operation of demining machine is limited for the reasons of inadequate soil and climate conditions,
- When it is not possible to ensure machine operating from a supporting vehicle at the safe distance (at least 50 m), or from the machine cockpit

² Polytechnic College Velika Gorica, E-mail: dinko.mikulic@vvg.hr

³ Polytechnic College Velika Gorica E-mail: vjekoslav.stojkovic@vvg.hr

⁴ Brodarski institute d.o.o., E-mail: koroman@hrbi.hr

⁵ HCR-CTRO d.o.o., E-mail: ivan.steker@crto.hr

Problems:

1. Machine usage on moist coherent soil is not sufficiently determined
2. Unsafe hold of machine trace on loose layer of soil (depth, direction, turn)
3. Mines being pressed deeper in the soft soil
4. Machine usage is dependent on implementer's experience (deminer, demining company)

2. New loose soil layer - „banana layer“

In the domain of terramechanics and machine mobility on coherent soil, soil trafficability of very moist loose soil hasn't yet been explored. In this paper, methodology of machine usage research in these conditions is set. Machine usage limitations can come from the side of soil moisture, which utmostly influences the machine usage possibility, and also the impossibility of activating mines on soft soil. This problem exists also for the supporting vehicle, which is usually on wheels. The task is to explore this field of machine use possibility and set out the models of anticipating "banana layer" trafficability under the machine.

Mechanical parameters of soil need to be researched, which include soil cohesion and internal friction as functions of moisture content, compaction and depth of loose soil layer. Soil cohesion and soil shearing stress can be assessed in advance, showing that they are not constant with different soil categories. According to some studies, the soil compaction reduces the cohesion. The soil cohesion and the soil shearing stress decrease as a function of the moisture content. Also, it can be assumed that the traction force which occurs during the tyre/track – soil interface is more precise if the soil cohesion would be a function of the soil moisture content and the soil depth.

Goals of R&D machine usage on soft soil

1. Examine the problem of loose soil layer trafficability at which the machine moves (soil load capacity, machine pressure on soil, sinkage, normal stress, shearing stress, soil cohesion, soil adhesion, ...)
2. Determine the machine usage acceptability model in humanitarian demining
3. Define the machine usage evaluation procedure

Assumption:

Machine usage criterion is its mobility on soft ground. Mobility of the machine, encompasses:

1. Soil trafficability
2. Working machine soil treatment speed (flat ground, climb, inclination)
3. Keeping the trace (line, digging depth, manoeuvre)

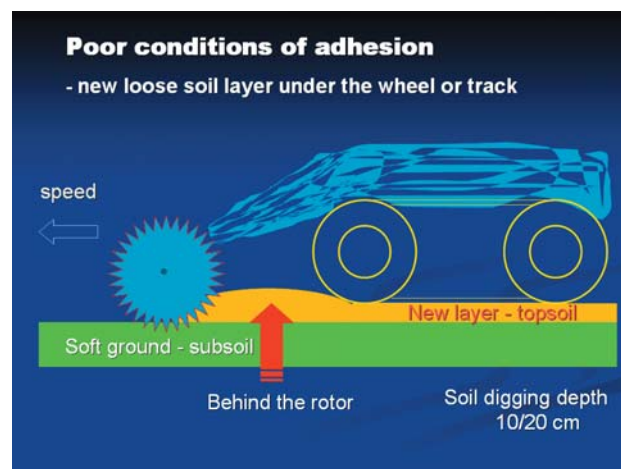


Fig.1. MV-4 Demining machine with flails



Fig.2. Forming of new loose layer of soil under the tracks

3. Soil conditions and categories

Conditions defined by soil type and category, terrain configuration and vegetation are referred to as soil conditions. Soil categorization and vegetation are given in SOP (CROMAC 04.09.). In relation to probing and demining there are:

- a) Favorable soil conditions,
- b) Aggravated soil conditions,
- c) Difficult soil conditions,
- d) Specific conditions.

According to the level of soil moisture there is:

- a) Dry soil,
- b) Soil with increased level of moisture,
- c) Swampy soil.

As reflected in machine category and working conditions, light machines can accomplish the working effect of 500-1000 m²/h, medium machines 1000-2000 m²/h, and heavy machines 1500-2500 m²/h. With regard to difficult treatment of soil with manual tool and demining machines, soil categorization is provided in table 1.

Table 1. Soil categorization

Soil category	Soil features	Method used	Depth
Category I	Medium and hard soil, covered with vegetation, humus, loam, compact sand	Manual tool, probes, shovel, use of machine.	20 cm
Category II	Dirt mixed with rocks, dirt prevails with rare low and medium vegetation. Stone is limestone-schist, soft, easily crushed by machine working tool.	Probe used with difficulties. Use of machine.	10 cm
Category III	Stony soil, stone sheets with dirt between them, low vegetation. Swampy soil.	Probe used on surface. Possible use of machine.	10 cm
Category IV	Specific conditions, very hard soil, other categories not applicable.	Not possible to use probes. Machine is used with difficulties.	-

4. Soil trafficability in the domain of terramechanics

In theory of evaluating machine movement, a couple of approaches are used in researching soil trafficability:

- on the basis of nominal pressure on soil - NGP (*Nominal Ground Pressure*),
- on the basis of calculating the normal stress and soil shearing stress (σ , τ) under track or tyre,
- on the basis of calculating mean maximum pressure on soil - MMP (*Mean Maximum Pressure*),
- on the basis of calculating the cone indeks of soil - CI (*Cone index*) and CI_L (*Limiting Cone indeks*),
- on the basis of cone index of the vehicle - VCI (*Vehicle Cone Index*),
- on the basis of Bekker theory of soil constraint,
- on the basis of wheel and soil slippage analysis,
- on the basis of the equation of the traction force in the tyre – soil interaction.

Nominal pressure on soil - NGP is the marginal tangential pressure of wheel on soil, which doesn't provide us with relevant comparison between two different wheels because of neglecting the tyre deformation influence of the laden wheel whilst in movement. Similarly, it can be applied to tracks (different shapes and parameters of tracks). Relevant indicators of terrain vehicle mobility assessment, both on tracks and wheels, are based on the british model of MMP pressure and the american model of VCI pressure which was adopted as the referent NATO model of evaluating military machine mobility, on wheels and tracks - NRMM - *NATO Reference Mobility*. However, practically there still doesn't exist an explained and defined machine movement on loose soil of high moisture.

4.1. Demining machine's mass complying to trafficability requirements

Machine categorization is known: light machines, weighing up to 5 tons, medium machines, 5-20 tons, and heavy machines, with a mass of over 20 tons. Machine mass influence is very significant in trafficability indicators of MMP and VCI. Machine mass needs to be adjusted to soil capacity. Cone index for very soft soil is $CI < 300$ kPa. The capacity of such soil depends on soil moisture (w %). For soft soils, the capacity ranges from 50 (100) kPa to 300 kPa. That means all machines (light, medium or heavy) can have mean maximum pressure on soil to, at most, 300 kPa.

According to above mentioned, the greatest allowable demining machine mass, on soft terrain, can be determined. Depending on the cone index, machines can be fastly evaluated. However, there always exists the problem of measuring low soil capacity in high moisture conditions.

4.2. Soil Trafficability

Soil trafficability analysis, because of machine usage evaluation, is conducted on the basis of comparison between soil load capacity and mean maximum machine pressure on soil. Interaction between soil and wheels and tracks, includes:

- 1. Soil consistency
- 2. Wheels and tracks
- 3. Machine pressure on soil
- 4. Deformation of soil under the wheel
- 5. Soil trafficability simulation (as function of the moisture content, compaction and depth of the loose soil layer)
- 6. Model of machine usage acceptability

Soil consistency according to moisture, 4 state types:

- Firm state
- Half-firm state
- Plastic state
- Liquid state

Note

Simulation and testing of soil trafficability re-search of loose soil layer under wheels and tracks, can be seen on Fig.3.

Simulation model:

- 1. Normal stress, σ
- 2. Tangential – shearing stress, τ
- 3. The equation of the traction force
- 4. Machine testing in real conditions

All three indicators of soil trafficability (MMP, VCI i Z) can be calculated for each machine. This provides machine usage evaluation on soft soil (CI_L) and machine comparison, Fig. 4, Fig. 5 and Fig. 6.

5. Conclusion

Soil trafficability needs to be estimated on demining projects, on demining machine usage guidelines in various conditions and seasons.

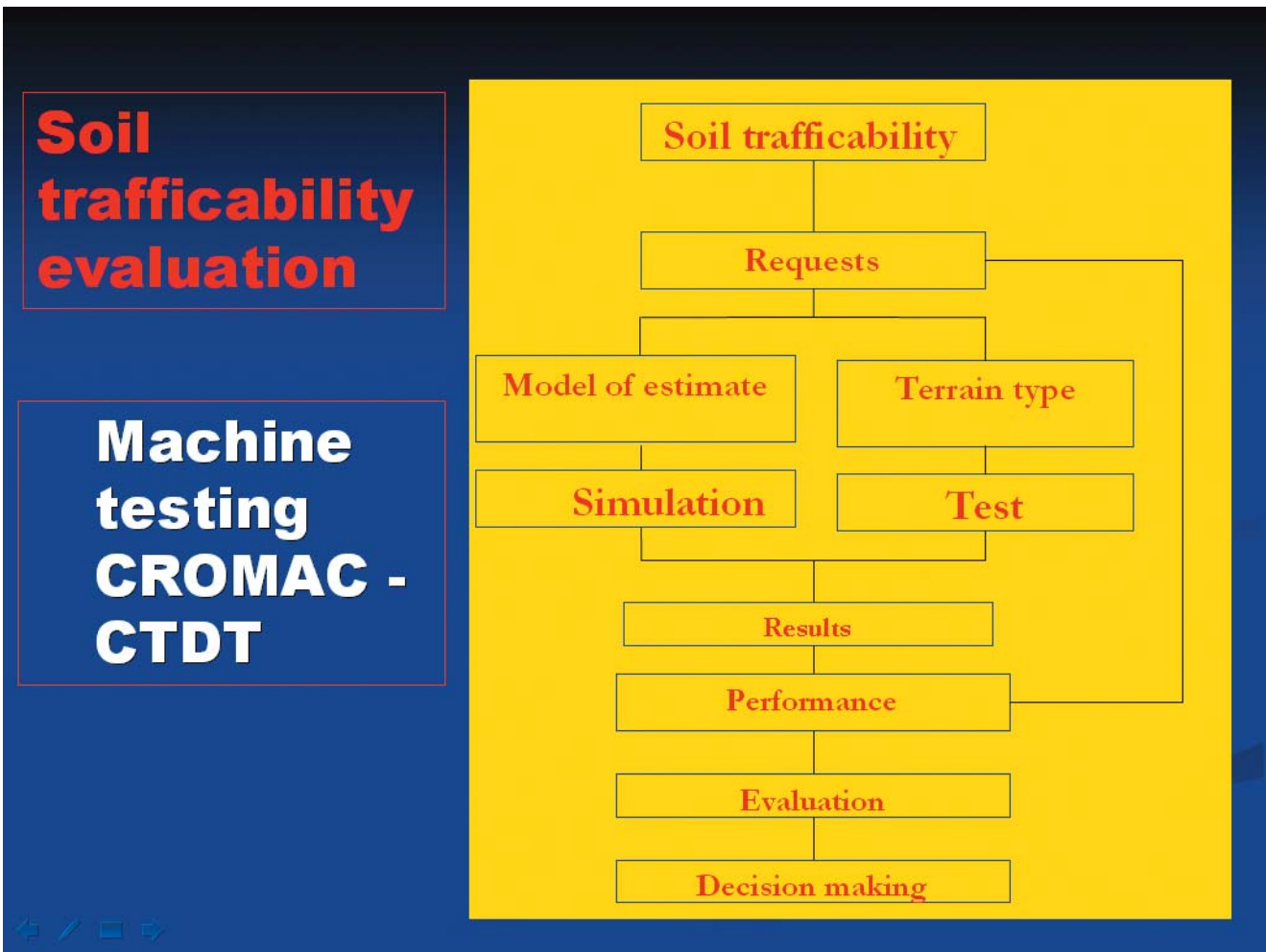


Fig. 3. Progress of soil trafficability research, CROMAC-CTDT



Fig. 4. Soil trafficability testing on moist soil



Fig. 5. Soil trafficability testing on very moist soil



Fig. 6. RM-KA-01 Demining machine on extremely moist soil

Therefore, soil trafficability has to be distinguished and evaluated in all categories of machines and supporting vehicles. Models for calculating machine mobility need to be compiled. Maps of machine movability on certain terrain have to be created, in accordance with their usage assessment in mine-suspected area.

Guidelines

1. Soil load capacity and soil moisture measurement
2. Determining machine features in the tyre/track – soil interaction
3. Determining machine usage acceptability

Bibliography

1. J. Y. Wong: Theory of Ground Vehicles, drugo izdanje, Department of Mechanical and Aerospace Engineering, Carleton University, Ottawa, Canada, Wiley-Interscience Publication, John Wiley & Sons, Inc, New York, 1993.
2. M. Sarrilahti: Soil Interaction Model, Appendix No. 2., Development of a Protocol for Eco-Wood, Part I, WES Mobility Models, University of Helsinki, Department of Forest Resource Management, 2002.
3. J. D. Priddy, W.E. Willoughby: Clarification of vehicle cone index with reference to mean maximum pressure, Journal of Terramechanics, Volume 43, Issue 2, Pages 85-96, 2006.
4. A Study of Mechanical Application in demining, GICHD, Geneva 2004.
5. D. Mikulic: Demining Techniques, Modern methods and equipment, demining Machines, Book/Knjiga, Sisak-Zagreb, 1999.
6. Mikulic D., Koroman, V., Majetic, V.: Machine Demining Features, Proceedings of the 7th International symposium on technology and mine problem, NAVAL POSTGRADUATE SCHOOL MONTEREY, CALIFORNIA, CD, 2006.
7. SOP CROMAC 04.09, Sisak, 2005

Advantages of Use of the Hand-Held Magnets and Rakes in Combined Demining Method

Ivica Raguz⁶

1. INTRODUCTION

During demining by manual detection (as the first method, or as the second method upon mechanical area treatment) except for standard equipment, metal detectors and prodders, various auxiliary tools are also used. These are usually excavation tools, rakes and hand-held magnets. Different types of rakes are used from the very beginning of mine clearance in Croatia while hand-held magnets are being used more recently and their usage is insufficient i.e. very limited. Magnets placed on demining machines are still not used in the Republic of Croatia.

Usage of magnets is very simple and does not require any additional training of deminers but the method of work with magnets should nevertheless be described in the SOP's. For now, not one company has a described method of working with auxiliary tools and hand-held magnets in their SOP.

Advantages of the application of magnets are obvious such as acceleration of work and in reliability. The advantage is especially observable in metal-free projects and projects characterised by high metal contamination. In our country, the best example is Town of Vukovar where we have ca. 50 detections per square meter. An additional problem in Dalmatia is that clutters under the impact of corrosion take the colour of the ground. Smaller clutters become almost impossible to be visually observed upon detection.

In mid-2006, I was occupied with various methods of increasing the confidence on the demining projects in Vukovar. Then I started with testing i.e. proving the advantages of hand-held magnets usage at the worksites in Slavonia.

At the same time, I have realized that ITEP and TNO (The Netherlands Organization of Applied Scientific Research) are conducting research «Magnetic clutter reduction efficiency» in Cambodia in cooperation with CMAC. I have

not knowledge of whether or not the research was carried out in the first place. The aim was to prove that usage of hand-held magnets can increase productivity for 50%. Testing should have been carried out in a real minefield. I have collected all these information from the Questionnaire I received from TNO. The Questionnaire was relating to the type and frequency of hand-held magnets applications in Croatia. I sent them information on magnets of the company Dok-Ing with which I carried out my testing.

Rakes:

Different types of rakes are used from the very beginning of mine clearance in Croatia. From 1995 they have been used very frequently, then accident happened and usage of the rakes rapidly decreased. Mine was activated pulling the tripwire by rakes. With increasing mechanically treated areas (from year 2000) rakes were back on worksites again. The reason is very simple, machines eliminate tripwires. Productivity with usage of the rakes is higher.

Hand-held magnets:

Hand-held magnets usage in demining is insufficient in the Republic of Croatia. Magnets placed on demining machines are still not used. It is few reasons because of that. Main reason is reliance on mechanical preparation of the ground, which is really good in Croatia. Second reason is that nobody took serious consideration about advantages of usage of the hand-held magnets. Most far went company Dok-Ing but even they did not capitalized investment in very quality magnets what they own.

With observation on the field and comparison of the work in first and combined method, with and without hand-held magnets, productivity increase is so obvious in magnets favour. Productivity difference is higher with high metal contamination. With minimal contamination productivity is the same but in areas with very high metal contamination (especially with small clutters) difference is over 50%.

⁶ CROMAC, QUALITY CONTROL OFFICER, ivica.ragus@hcr.hr

Description of the Dok-Ing hand-held magnets:

- working width, diameter - 25 mm, wider diameters of the magnet increase his weight and handling is more difficult

- weight - 250 g
- nonmagnetic casing assure easy of the removal of clutters from the magnet
- strength – on 50 mm distance attract 1 g, 10 g and 100 g, hold 4 kg metal piece
- different lengths of the handles assure standing and kneeling working position

2. TEST

Testing is done on working sites in Slavonia. One part of the test should be done in Dalmatia but it was not possible because of organization problem. Anyway, this does not have some influence for test results.

All test samples were in real minefields and actual working sites. We did not targeting recorded minefields but also we did not choose areas without mines. Samples were chosen randomly, depending of work progress on the worksite.

Testing was carried out from October 2006 till March 2007. Whole testing procedures could be done faster but it was performed during normal working time, on actual working sites and was depended of the many others circumstances. According to this, we did not require any extra spends.

At first, we started with work in lanes. Very soon I realized that deminers equipped with magnets advance much faster. I could not supervise all of them in same time. After that I organized work in boxes. With few test probes we find out optimal box size. Most ideal size was 25 m², 5 x 5 m. On this way we could cleared few boxes in one day, advance together and work in same site conditions.

My idea was that we clear 4 to 5 samples on medium size working site (200.000 m²). One sample is three boxes, which mean five samples are fifteen boxes.

One sample consist three boxes in dimensions 5 x 5 m, just few boxes were in dimensions 1 x 25 m. Different kind of working tools were used on different boxes.

On each box all of the deminers use same kind of the metal detector adjusted on same sensitivity. With metal detector additional tools were:

- Box No 1 – prodder
- Box No 2 – prodder and rakes
- Box No 3 – prodder, rakes and magnet

Each signal was checked with prodder, at first. If mine identification is negative, it is allowed to use rakes and magnet.

After each sample deminers change their positions and working tools. On this way we try to avoid subjective influence on test results.

Recorded parameters are time (minutes) and confidence (percentage). During the work I supervised deminers working procedure (prodder at first) and recorded clearance time for every box. Confidence had to be as at metal-free projects.

Each box was checked twice (clearance and quality assurance).

All results are recorded in written form and in photographs, for each box and sample. On the end we have some average values for comparison. In total it was done 18 samples on 4 work-sites, what are 54 boxes.

3. RESULTS

Total values, Σ 18 samples

Box No.	t - minutes	Metal pieces, clearance	Metal pieces, QA
1	808	253	8
2	669	250	3
3	453	257	0

Average values, Σ 18 samples

Box No.	t - minutes	Metal pieces, clearance	Metal pieces, QA
1	45	14	0,5
2	37	14	0,2
3	25	14	0

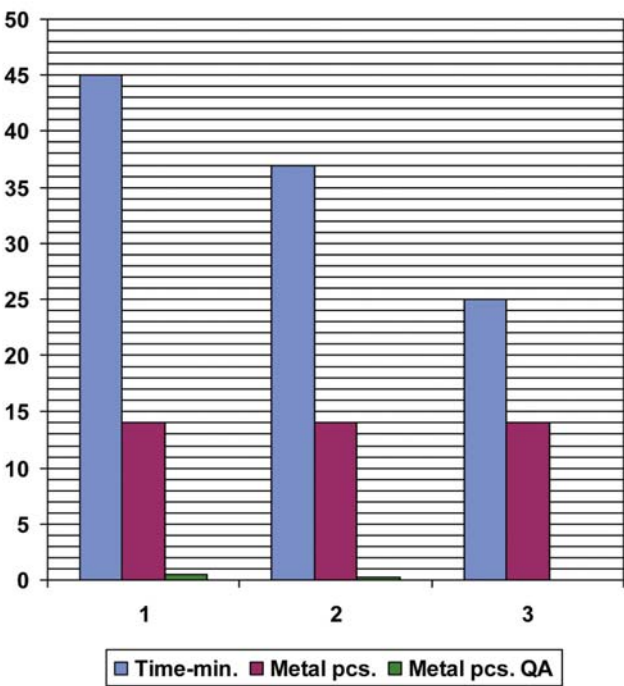
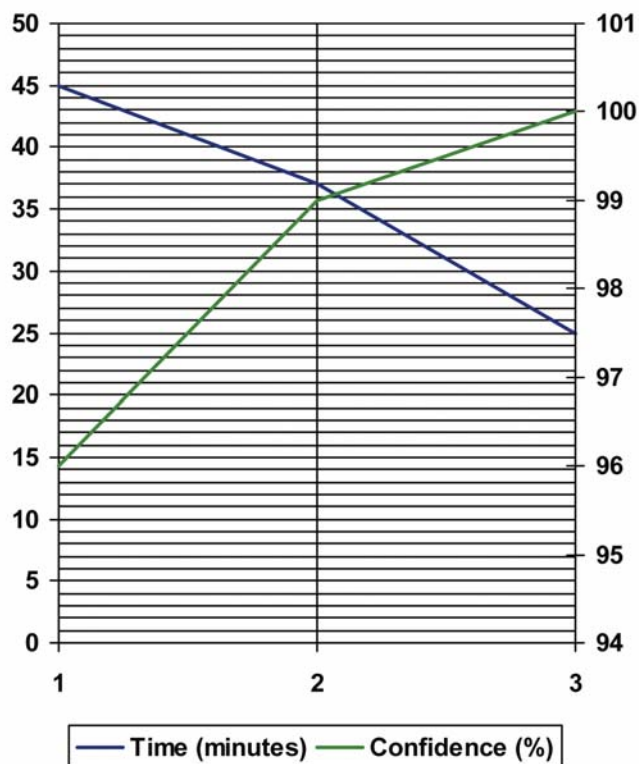


Diagram of the average values



Relation between time and confidence

$$\text{Confidence} = 100 - (qa / mp) \times 100$$

qa – metal pieces found in quality assurance

mp – metal pieces found in clearance

4. CONCLUSIONS

Advantages of use of the hand-held magnets are increased productivity and confidence. Different test results will be for different kind and strength of the magnets. Most advantage affront of standard tools is in high metal contaminated areas. Demining companies in The Republic of Croatia should include working procedure with magnets and other auxiliary tools in their SOPs and Execution projects

Personal Protective Equipment for use in Humanitarian Mine Action Standardised Test and Evaluation Methodologies (CEN Workshop Agreement)

Kaj Hörberg⁷, Tim Lardner⁸

Abstract

The risks a deminer is exposed to are different to those that military personnel encounter. The working situations are significantly different and this leads to different requirements for protective equipment. Many manufacturers of Personal Protective Equipment (PPE) have developed PPE focussing on the needs of the Humanitarian Mine Action Sector.

The test methodologies so far used to test these equipments has been NATO STANAG 2920. The STANAG is a well accepted methodology but designed to test the level of protection against fragments. This does not give all the information that is needed for PPE for HMA.

The CEN Workshop 26 proposes a three step test methodology for PPE for HMA. The first step will cover protection against secondary fragments (i.e. soil debris) by using NATO STANAG 2920 but with steel projectiles replaced by a material with a density and brittleness similar to stone. The second step is a blast test where the integrity of the whole system is tested when exposed to blast and blast ejecta. These two first tests are laboratory test. The last and third step is an ergonomic suitability test to be carried out in the field by any demining organisation.

Background

The European Commission has granted a mandate to the European Standardization Bodies to proceed with standardization for humanitarian demining. Such standardization includes the test and evaluation of any tool in support to humanitarian demining.

The Committee for European Standards (CEN) has, through their Working Group 126 (CEN BT/WG 126) “Humanitarian Mine Action”, delivered in March 2002 as an action plan, the CEN response to the EC “Mandate to the European Standardization Bodies on Technologies for Humanitarian Demining” (M/306)⁹, interpreted to cover humanitarian mine action. In this response, a particular action was identified on “PPE for HMA”.

Methodology and timeframes

The work has followed the standard procedure for the CEN Workshop Agreement (CWA) which is open for all and is a way to formalise “best prac-

tice” and where the participants, based on the knowledge available, agree on a test procedure for PPE. The decisions are taken in consensus. To develop a full CEN standard is time consuming and expensive and could only be done among CEN members which does not fit well to global HMA. The CEN workshop agreement procedure has been proven to be an effective and cost-effective way to formalise available knowledge into well accepted “standards”.

The Kick-off meeting was held in June 2006. The first technical meeting was held in September 2006, the second in December 2006. The third and final meeting was held in March 2007. The participants agreed on a methodology for PPE test procedures for use in HMA. There still remain some final data to be verified but it is planned to submit the results to the CEN authorities for final formalities - including a 60 days public consultation period. In early autumn this year we believe we will have a CEN Workshop Agreement that is formally approved by CEN. It is ultimately expected to have the CWA integrated into the International Mine Action Standards (IMAS) but decision will be taken by the IMAS review board.

Scope

The scope for the workshop was to specify methods for testing, evaluation, and acceptance

⁷ Swedish Standard Institute, SE-118 80 Stockholm, Sweden

⁸ GICHD, PO Box 1300, CH-1211 Geneva, Switzerland

⁹ Mandate to the European Standardization Bodies on Technologies for Humanitarian Demining, EC Joint Research Centre and Research Directorate-General, M306 EN, Brussels, 25 August 2000.

of PPE for mine action against anti-personnel blast mines.

Only critical, life threatening and vision affecting injuries are addressed.

Anti-personnel fragmentation mines are excluded from the process.¹⁰

Risks, protection and test scenarios

The PPE provided for the deminer shall minimise the risk of fatal and critical injuries, as well as those affecting the vision.

All PPE will cause the deminer some degradation in performance due to increased weight, reduced opportunity for body cooling, reduced mobility/flexibility and so on. It is important that the level of protection is balanced against the need for protection and the operating environment. If this balance is not achieved, the degradation in performance can be counter-productive and may be a contributory factor in an accident.

With that in mind we agreed that the torso (excluding the back) shall be protected in addition to the shoulders/armpits, neck, and groin. Full face protection shall extend to the full height of the head. The face is defined as the frontal part of the head extending to just in front of the ears, just below the chin and extending to the top of the head.

An exploding anti-personnel blast mine will normally form a blast cone. If the operator is too close to a exploding mine (depending on a number of factors including size of charge, distance and burial depth), the blast impact will be so significant that no viable PPE will protect the deminer.

The deminer's working position, as well as distance¹¹, are essential to ensure effective PPE functioning. The impact from blast and the blast ejecta decrease quickly with distance. The further away from the centre of the blast cone, the safer the deminer will be. It is likely, for example, to be safer for the deminer to be close to the seat of the explosion at ground level as opposed to the same distance in the centre of the blast cone over the mine.

Based on empirical data, it appears that the kneeling and squatting positions present the highest threat to the deminer in the event of an explosion and these positions are therefore assumed to be the most dangerous.

¹⁰ It is recognised that hazards from AP fragmentation mines do occur and that it may be desirable to assess this specific requirement as part of a separate process.

¹¹ Nerenberg J et al, Enhancing deminer Safety Through Consideration of Position, joint paper with Med-Eng Systems Inc, US Army CECOM and Defence R&D Canada

To set the level of hazard, the PMN anti-personnel blast mine was chosen. It is one of the most widespread anti-personnel blast mines and has an explosive content of 240 grams of cast TNT. While there are anti-personnel blast mines with higher explosive content, the PMN has been chosen as most representative for this category of mines. Most other anti-personnel blast mines have a lower content of explosive.

Ballistic test

We focus on the anti-personnel blast mine as the threat and therefore the ballistic test will measure the level of protection a certain material used in PPE has against secondary fragments, which mostly contains soil debris. NATO STANAG 2920 is a widely used standard for testing the protection level against primary fragments. The Canadian Centre for Mine Action Technology Found the behaviour of secondary fragments to be significantly different to that of primary fragmentation¹². The test methodology in NATO STANAG 2920 has been adapted to account for these differences. The Simulant Formed Projectile (SFP) formed of steel has properties that are far from the properties of an average stone. The average density in a stone is about 2700kg/m³ compared with the density of steel that is about 7800kg/m³. Aluminium has a density comparable to stone. Stones are usually brittle and that is, to some extent, copied by choosing an aluminium alloy that is hard and brittle. In the event of an accident the deminer will be close to the exploding mine and the secondary fragment will have a very high velocity. We propose that the same test shall be applied to eye, face and body protection.

Test parameters

- The projectile shall be a right circular cylinder (RCC) 4 mm long and 4 mm (+/- 0.05 mm) diameter.
- The projectile shall be made of an aluminium alloy with a yield strength of xxx MPa (+/- 5 MPa) and a mass of 0.14g (+/- 0.003g).
- The V_{50} of the PPE shall be 1000 m/s.

The exact aluminium alloy and its strength is still under investigation and the result will come soon but is currently not available to be included in this paper.

The V_{50} value mentioned above is valid for woven type materials such as Aramid. Other armour components involving different materials may result in a different V_{50} value for the same level of protection.

¹² Damage caused by soil debris ejected from buried Anti Personnel Mines, Jennifer Mah, Benoit Antcil, Matthew Keown for Canadian Centre for Mine Action Technologies, 2006

Blast test

The purpose of the blast test is to demonstrate that different parts of PPE work together as a system for the protection of the deminer and show the integrity of PPE when exposed to the forces from a blast.

Blunt trauma from a blast has not been demonstrated to be a significant contributing factor to deminers injuries¹³. A number of simplifications have, therefore, been made to ensure more effective application for the mine action environment. The threat increases with proximity to the charge and the assumption is made that a reasonable distance is maintained between the deminer and the hazard.

For the test, a simulated mine will be used. It is made of a plastic container with an explosive content that is equivalent to 240 grams of cast TNT. The simulant mine is put in the centre of a box filled with dry medium grain sand. The simulant mine has an overburden of 20 mm of sand

The PPE to be tested is put on a pedestrian version 50th percentile male Hybrid III anthropomorphic dummy (more commonly known as a crash test dummy). The PPE shall fit the dummy correctly. Kneeling and squatting positions have been identified as being the most hazardous and as such, the workshop agreed that a kneeling position, with the tip of the dummy's nose 550 mm and at 70° from horizontal to top centre, of the simulated mine.

Underneath the PPE, the dummy is wrapped in a witness sheet of woven cotton cloth. The outer edges of the PPE are marked on the witness sheet. After the blast the witness sheet is visually inspected and there should be no penetration within the protected zone.

The test shall be carried out twice with a new set of PPE. If either test is a failure, the test shall be undertaken once more. If this additional test is a failure, the PPE has *failed* the test. Sand that is affected by the blast shall be replaced after each test. Quality control of each blast will be made by measurement of the pressure in free air close to the head of the dummy.

¹³ Effectiveness of Personal Protective Equipment (PPE) for Use in Demining AP Landmines (:c Chichester – U.S. Army CECOM, C.R. Bogess, M. Davis – University of Virginia, D.M. Bergeron – Defence R&D Canada – CCMAI, E Sanderson, G. Di Marco – U.S. Army Aberdeen Test Center). Proceedings of the 2001 UXO Conference, New Orleans, USA, April 2001

Ergonomic suitability test

The ergonomic suitability test is a field test that is designed to be made by any demining organisation without the need of expensive equipment. The aim of the test is to ensure that the end users of the PPE shall be comfortable with the protective capacity of the PPE. It may also be used as a part of a procurement process.

The PPE shall be supplied by the manufacturer complete with labels, or copies of the proposed labels, and the information Supplied by the Manufacturer that will be supplied with the products. The sizes should be suitable for the body size of the deminer in the environment to be operated in.

The testing organisation selects a test panel that are habitual wearers of PPE (deminers). They shall be selected to represent the typical user of the PPE. They shall be medically fit. At least three deminers shall be available as test panel members for the practical ergonomic tests.

Before PPE is put on by test panel members it shall be inspected for sharp edges, rough surfaces, protruding wire ends or any other feature that might cause harm to a deminer. If serious faults are found no user trials shall be carried out. The results of the examination shall be recorded in the test report.

Before the wearer trial, the PPE shall be fitted and adjusted according to the instructions supplied by the manufacturer. The deminers shall wear clothing with the working clothes that are normally worn in field operations.

The assessor and deminer shall agree whether the fit is adequate or not.

Ergonomic assessment by wearer trial

The deminers in the test panel shall complete seven different types of movements and exercises such as standing up and laying down, walking 500 metres etc. After each activity they shall complete the questionnaire. The movements shall be carried out both while wearing the PPE and without it. Around half the movements are to be carried out without the PPE first. The deminers shall answer the questions by comparing their comfort, their sense of impediment, their sense of effort, the accuracy of their accomplishment of the movement, and their fatigue, when

wearing the PPE and when not wearing it. The scores given shall be based on the summary below taking into account the differences between carrying out the movements with and without PPE.

The questionnaire gives the test panel the possibility to select among five levels

Score 0 - No problems;

Score 1 - A slight problem of comfort or impediment;

Score 2 - Problems of comfort or impediment and of fatigue or accuracy of movement;

Score 3 - More severe problems of comfort and fatigue that would limit the duration of tolerable use of the PPE;

Score 4 - A severe problem that makes the PPE unsafe, or hazardous to wear because of severe impediment to movements, or gross shifts of the armour on the body that interfere with the wearer's ability to complete further movements, or because it obstructs vision.

No armour would normally be acceptable that scores 4 except in movements that would not be undertaken wearing such armour.

The question scores of all panel members are added together and calculated to give an average score of the three test panel members. The PPE shall be considered satisfactory ergonomically if the score is below a certain level. The result from the ergonomic suitability test shall be evaluated by assessor taking the local condition into consideration.

Findings for the future

The current IMAS requires the level of protection such that the PPE shall protect against blast from a PMN AP-mine at a distance of 60 cm. Investigations made as part of the workshop show that a realistic average working distance is closer to 45 cm than to 60 cm. We propose a reduction in the test distance to 55 cm. It is recommended that further research is made to improve test methodologies to meet a more realistic deminer operating distance. Such a methodology will increase the possibility to develop more effective PPE in the future.

The IMAS do not give any requirement on the optical quality of the eye protection. The outcome of some accidents has been worse because the eye/face protection has not been worn correctly and it is often suggested that one of the contributory factors may be poor visual properties. There is an EN standard that specifies three optical classes where class 1 is the best and class 3 the worst. It is recommended that class 2 or better shall be used. There may be some technical problems caused by thickness and curves of the protective material but we still believe that a deminer needs as minimum the same optical class of his eye protection as a fire fighter.

The current V50 value is linked to the extant qualities of Aramid. In the future, as materials develop, this V50 figure may require to be adapted.

Portable Mechatronic System for Demining Applications: Control Unit Design and Development

Szymon Kostrzewski¹⁴, Rusiru Dasantha Apputhanthri¹⁴, Jawad Masood¹⁴, Emanuela Elisa Cepolina¹⁴

Abstract:

A new participatory approach that makes use of and improves local end-users knowledge has been used to design a new portable mechatronic system for humanitarian demining applications in Sri Lanka, using power tillers as core module. They are very simple and versatile machines with large scale diffusion in developing countries, where they are commonly used for agriculture and transportation purposes.

The system, composed by a tractor unit, a ground processing tool and a vegetation cutting tool is firstly introduced. The paper then focuses on the portable control unit allowing to control the machine from remote distance, in case unexploded ordnance or other fragmentation weapons are known to be present. The module allows forward motion by acting on the clutch, differential and acceleration of the power tiller; steering is controlled by additional brakes, mounted on the driving axle. Two wheels supporting the ground processing tool on the front of the machine are connected to the rear driving ones through tracks. The module can be fit to every kind of power tiller actuated by levers, using differential gear, after only little adjustments. The control is pneumatic and it is powered by the engine of the power tiller itself. The unit, like the others modules, responds to the requirements of safety, low-cost and simple effectiveness.

Keywords: mechatronic demining system, modularity, remote control, pneumatic actuation, low-cost design.

1. Introduction

There is increasing consensus on the fact that landmines heavily affect the development of contaminated countries and that mine action activities need to be integrated into general development initiatives.

There is also general acknowledgment that machines have fallen short of expectations: only few are actually employed in the field and are often down for maintenance waiting for spare parts or experienced technicians able to fix them coming from abroad [1].

These reasons are at the base of the idea of adapting commercially available power tillers to demining applications by designing different modules attachable to the main tractor unit in a participatory way together with deminers. In fact we believe that involving deminers into the whole design process would allow them to get familiar with the innovation process, which is a key component of the development process, and would help realizing a machine nearer to real needs, sustainable because made of materials available locally and therefore more efficient.

The project presented here therefore regards the participatory design and development of a new small machine for helping removing landmines in the Vanni region in Sri Lanka.

This paper focuses on the control unit, which allows forward motion and steering, leaving gear change to be done manually, at the beginning of the working lane.

2. Requirements and system design

A one-month trip to northeast Sri Lanka was organized, at the beginning of the project. Deminers asked for their preferences during group interviews, expressed a strong desire for new small, light and cheap machines. They want machines to help in the most boring/difficult parts of their job, particularly cutting vegetation and processing the ground, specially the hardest one, currently scarified using a simple rake called heavy rake, to remove the soil hiding mines [2].

Therefore, the target of the project is to develop a modular system using as core module a power tiller and equipping it with modules specialised for ground processing and vegetation cutting. A special end-effector to process the soil and bring mines up to the soil surface is being designed. Each machine can be considered a semi-autonomous

¹⁴ PMARlab, Department of Mechanics and Machine Design (DIMEC), University of Genova, Italy
Contact E-mail: emacepo@dimec.unige.it

system, helping a single deminer in his work, and a certain number of machines can be controlled automatically to perform area-reduction operations, working as a multi-agent system.

Deminers will always assist machines: once a mine is found and lifted up on the soil surface by the special end-effector, a deminer can remove the mine manually. Manual mine removal has been introduced in order to lower the complexity and cost of the machines, as well as to allow a quicker integration of machines in operational procedures.

A modular top-down design approach was chosen. Starting from the task, defined by deminers, the mechanical modules able to accomplish the work were conceived. The machine exhibits modular structure, as two end-effectors compatible one to each other can be attached to the tractor unit: one is dedicated to ground processing and the other to vegetation cutting.

Therefore, the project involves the mechanical design of three modules: tractor unit, ground processing tool and vegetation cutting tool. The project includes also the implementation of the remote control that needs to be used when Unexploded Ordnance (UXO) and fragmentation Anti Personnel (AP) mines are known to be present.

The tractor unit is the power tiller, opportunely modified to be adapted to remote control and equipped with tracks to provide sufficient traction [3], while the ground processing tool is the means by which landmines are lift up on soil surface to facilitate later hand removal by deminers. The ground processing tool is placed on the front of the machine, to allow landmines to be removed before the tractor unit passes over them. The vegetation cutting module can be attached on the front of the machine when vegetation is too thick for the machine to pass through; it is powered by the power tiller engine and is supported by the same supporting frame of the ground processing tool.

The overall essential requirements the machine has to satisfy are:

- reliability: 100% clearance
- safety of operator: 100%
- depth of demining: 100 mm
- width of clearance: 1200 mm
- speed of clearance: higher than manual
- types of mines: small plastic blast-type AP mines
- cost: 20.000 €
- remote control distance: 20 m

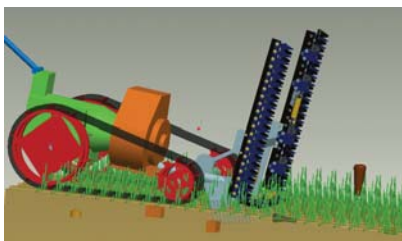
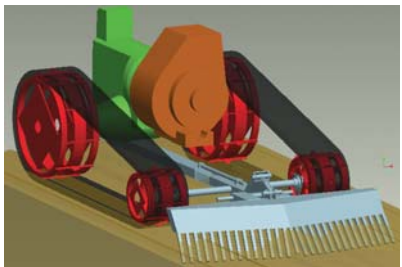


Fig 1. Power tiller and digital mock ups of the system designed, composed by three modules: tractor unit, ground processing tool and vegetation cutting tool.

Considered mines are small because they are between the less harmful existing ones, containing up to 50g of explosive only. UXO and fragmentation mines are also present, especially Claymore types, but only in certain known minefields. The machine is specifically designed to be proof against AP blast mines and to resist damages caused by fragmentation devices.

Cost is one of the main points of the project. The cheapest machine for humanitarian demining applications available on the international market, the Tempest which is classified as minifail, is used for cutting vegetation and costs US\$120,000 [4]. Although entirely produced in Cambodia, it is entirely specifically designed for demining purposes and therefore is inherently expensive.

Cost has to be contained as much as possible being one of the major causes of poor adoption of machines into demining programmes. The price of €20.000 does not include the research and developing cost and is equally divided between the modules and the control.

Attention is being paid to keep the machine extremely simple, avoiding adding complex modifications or tools to a very simple basic unit such

as the power tiller. Therefore, parameters have been identified that contribute to achieve extreme simplicity and effectiveness, referred to as *Simpleffectiveness*.

The features the machine has to present in order to be *Simpleffective* are shown in the box beside.

SIMPLEFFECTIVENESS	
forward/backward motion (traction)	
steering: 1m curve radius	
energy supply to end-effectors	
stability	
assessment of ground processing depth	
mine disposal	
safety of operator	
shock wave protection for machine	
(and operator, in manual use)	

3. Control unit

The control system has to allow to operate the tractor unit remotely in forward motion with steering acting on the semi-axes. In fact, even most basic power tillers, with no differential gear, present two semi axles and turning can be achieved by acting on them separately.

Generally power tillers are controlled manually by an operator walking behind them. Speed and direction of movement are influenced by using:

- gearbox – to choose one of the gears defining speed and reduction (torque on wheels),
- forward/backward lever – to choose between forward and backward movement; neutral position is also allowed,

Feature	Motion type	Actuator type
Differential	Angular and linear; linear easier to apply; deadlocks during switching the differential on	Single-acting cylinder, return stroke by spring
Clutch	Linear motion, big force, no deadlocks, one-side force needed	Single-acting cylinder, return stroke by spring
Acceleration	Linear motion, low force, position holding	Double-acting cylinder
L / R brake	Linear motion, one-side force, no deadlocks	Single-acting cylinder, return stroke by spring

Tab. 1. Power tiller actuated features

- differential – mechanism allowing for coupling and decoupling synchronous movement of wheels,

- clutch – coupling/decoupling actuation on wheels,
- acceleration – angular speed of engine.

After having started the machine manually, while keeping clutch pressed, the gear is shifted and forward/backward motion selected. After this, the clutch can be released causing wheel to decouple and motion starts. The operator follows the machine adjusting the acceleration according to working needs. When direction needs to be changed, firstly the differential is actuated to allow non-synchronized movement of the wheels. Direction is manually changed acting on handles. When the power tiller is moving in proper direction the differential can be switched off to preserve the direction.

After having analysed manual operations, the features to be actuated by the control system need to be selected. All existing levers can be automated but changing direction, which is usually performed by the operator, rises up a problem. As a solution, external braking system was considered. The system consists of two disk brakes attached to each wheels and works in the following way. When direction is not relevant the differential firstly is actuated. Then, when wheels can be moved in not coordinated way, one of the brakes can be applied decreasing the speed of the wheel. This causes the direction to change proportionally to the difference in wheels speed. After reaching the proper direction, the brake should be released and differential switched off forcing synchronous motion.

According to previous considerations, the features selected for actuation are shown in table 1. Motion type analysis indicates that linear motion is needed mainly. In some cases actuation is needed in both movement directions in others one direction is passive. Deadlocks possibility should be regarded as source of further possible actuation problems.

Control system actuation can be realized in three ways: electrically, hydraulically and pneumatically. Advantages of the electric control system are:

- all parts of electric system i.e. DC motors, relays, sensors etc. are easy available,
- accurate position control (with usage of external sensors),
- easy to assembly, small and shock resistant wiring system,
- low cost of most commonly used parts.

Electric system drawbacks are mainly:

- difficult (in case of this project timing) remote control — microchip circuit board is needed,
- difficult and not resistant to deadlocks realisation of linear motion,
- actuators are not resistant to vibrations and contamination.
- Instead, advantages of hydraulic system are:
- slow motions and big forces,
- angular and linear motion,
- is resistant for vibrations and contamination,
- has biggest available power/mass ratio.

And drawbacks are:

- pumps, valves and actuators are expensive,
- additional equipment i.e. oil sump and oil accumulator is needed,
- wiring system is very extended and can be easily damaged.

Pneumatic system was chosen having the following significant advantages in this application:

- natural linear motion,
- resistance to deadlocks,
- resistance to vibrations and contamination,
- very big variety of actuators available,
- can be integrated with hydraulic system
- (brakes) with usage of pneumo-hydraulic amplifiers.

While electric system needs power generator and hydraulic one needs a pump the pneumatic system needs an air-compressor.

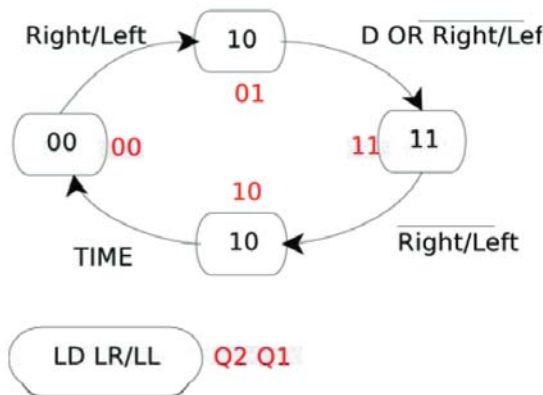


Fig. 1. State flow diagram for logics design

Control system was designed accordingly to digital control system design Moore approach. The state flow diagram is shown on figure 1. Corresponding to this and concerning Karnough tables as a result the following control laws can be obtained:

- | | |
|---|--------------------------------------|
| • State equations: | Output equations: |
| $S_1 = Q_2 \cap \text{Right/Left}$ | $LD = Q_1 \cup Q_2$ |
| $R_1 = Q_2 \cap \text{Right/Left}$ | $LR/LL = Q_1 \cap Q_2$ |
| $S_2 = Q_1 \cap \text{Right/Left} \cup D$ | $LL = \text{Left} \cap \text{Right}$ |
| $R_2 = Q_1 \cap \text{TIME}$ | $LR = \text{Right} \cap \text{Left}$ |

The logic equations presented before can be implemented in different ways: as relay circuit (ladder diagram), digital logic circuit (using available electronic stuff), microchip program and predefined controller available in stock. For this application we have chosen Siemens Logo controller which is cheap and robust, allows for software based programming, conventional switches are not needed and extended communication features can be used. This selection fulfils requirements as well as provides some additional advantages which can be useful in the future.

4. Conclusions and further work

The control unit of a small cheap machine to help demining operations in the Vanni region of Sri Lanka has been presented. The overall work to finish the project encompasses the finalization of ground processing and vegetation cutting modules design, the manufacturing of parts and the general assembly. The control unit design is complete, only fixtures need to be finalised and sent to the workshop for manufacturing.

References:

[1] Cepolina, E.E.; Bruschini, C. & DeBruyn, K., (2005). Field Survey Results, EUEM2 publications, Available from: http://www.eudem.vub.ac.be/files/FieldSurvey_Results_V1.0.0.pdf Accessed: 2007-04-17.

[2] Cepolina, E.E., (2006). Power tiller and Snails for demining in Sri Lanka. Journal of Mine Action, Issue 10.1, August 2006, pp. 76-79, ISSN: 1533-9440.

[3] Cepolina, E.E. & Hemapala, M.U., (2007). Power tillers for demining: blast test, International Journal of Advanced Robotic Systems, Vol.4 N2, June 2007, ISSN 1729-8806.

[3] Koppetch, K., (2006). Mechanical Demining Equipment Catalogue 2006, GICHD, ISBN: 2-88487-026-1, Geneva.

Project website: <http://www.dimec.unige.it/PMAR/demining>

INTERNATIONAL SYMPOSIUM “HUMANITARIAN DEMINING 2007”

24 - 27 April 2007, ŠIBENIK, CROATIA

MAIC Survivor Assistance Projects

Lois Carter Fay¹⁵

Three survivor-assistance projects of the JMU Mine Action Information Center were highlighted during a presentation at the demining symposium. They are:

1. Casualty-data best-practices guidebook
2. Survivor-assistance training
3. Adaptive Technology Catalog

All three projects being conducted at the request of the U.S. Department of State Office of Weapons Removal and Abatement Bureau of Political-Military Affairs. The survivor-assistance training is being conducted under the leadership of The Polus Center for Social and Economic Development.

Casualty-data “Guidebook” Project

Many in the mine-action/unexploded-ordnance community have trouble effectively gathering, managing and interpreting casualty data, although some mine-affected countries have created good casualty-data systems and planning procedures. In our research at MAIC, we have found that while there is a significant amount of casualty data collected by various entities around the world, it is often not effectively used to inform the decision-making and planning processes in mine action. It is the use of the data that is really driving this guidebook, which will be published in September 2007. Some countries and programs are challenged to effectively collect needed landmine/UXO casualty data; others collect the data and then seem to do little with it. Many programs collect and use landmine/UXO “accident” data to inform their mine-risk education and clearance projects. For instance, if the data shows that there has been one or more casualties in a particular location, the country’s mine-action authority will assume there is a pocket of landmines or unexploded ordnance located there and consequently choose to mark and clear the area. More recently, with the increased focus on developing mine-victim assistance plans, national authorities are more interested in obtaining additional information about accident survivors in or-

der to plan and deliver rehabilitative services. The guidebook will research what is actually being done in selected mine-affected countries and assess their effectiveness, drawing conclusions regarding which approaches should be considered “best” practices.

The guidebook will be comprised of lessons learned and identified “best practices,” instructive, detailed case studies, and a set of recommendations to guide planners, which will be short and broadly applicable to most situations.

Survivor-assistance Training

In a recent survey conducted by the MAIC (as a follow-up to the Senior Managers Courses MAIC has presented for the United Nations Development Programme), more than half of the mine-action centers responded that landmine survivor assistance was a “top” or “high” priority, yet an even greater number

reported that “no one [in their mine-action center/agency] had received any training” in survivor assistance. Consequently, the MAIC and The Polus Center for Social and Economic Development are working together to create a series of training workshops for national mine-action and survivor-assistance staff to aid them in developing and implementing programs that effectively meet the needs of landmine survivors and other people with disabilities in their countries.

The Polus Center assists people with disabilities in developing countries to become valued members within their communities. Its programs emphasize community-based rehabilitation, self-advocacy and community inclusion. It has extensive experience in working with local partners to create and implement projects to assist people with disabilities, particularly landmine survivors, in several countries. The Polus Center takes a social approach to landmine survivor assistance. It is focused on developing sustainable, person-centered projects for full social integration of landmine survivors.

Polus began working internationally in 1997 in Nicaragua and later expanded to Ethiopia, Honduras, Guatemala, El Salvador and Mexico. These collaborative efforts have resulted in two community-based prosthetic outreach projects, an accessibility project,

¹⁵ Mine Action Information Center James Madison University MSC 4018 Harrisonburg, VA USA 22807, Email: editormaic@gmail.com, Web: <http://maic.jmu.edu>

a disabilities leadership center, a regional wheelchair-manufacturing project, and a series of capacity-building mini-grants to local organizations and individuals. The Polus Center uses a locally based, holistic approach to ensure that project beneficiaries are the ones driving services forward, and broad support is created in the community where they live. The MAIC staff and JMU’s faculty consist of subject-matter experts in survivor assistance, mine action and management; we are also experienced in developing and delivering curricula for a variety of constituencies, including program planners and project implementers, such as those for whom this survivor-assistance training program is designed. These workshops will provide tools to understand and apply current best practices and integrate a social approach into planning and programs. Workshops can be delivered individually (one day each) or as a series spread over five days.

Adaptive Technology Catalog


The project goals for the Adaptive Technology Catalog are to assist communities and nations recovering from conflicts in providing economic security for individuals who have become disabled by landmines and other explosive remnants of war. We will do this by finding and compiling into a catalog a variety of tools to help survivors get back to work and gain independence.



The Adaptive Technology Catalog will be available as a DVD/CD or PDF in September 2007. [IMAGE COURTESY OF MAIC]

The Catalog was researched with the help of the Canadian firm, Project Assistance, and will be published in September 2007. It will incorporate low-cost, low-technology products that can either be used directly off-the-shelf or can be easily modified by local vendors. It focuses primarily on the agricultural and mechanical sectors, and is designed to help landmine/ERW survivors become gainfully employed using simple, inexpensive technology. There are also several products related to kitchen work, computers, personal hygiene or grooming and transportation. Many items are under &S\$10. Most of the tools are under US\$500; a few are about \$1,500. With over 600 tools listed, organized by tool function—auto, agricul-

ture, construction, kitchen, mobility, recreation, etc.—there are ideas for overcoming many disabilities.



Steerable Rolling Seat with Tool Tray

If you've had to crouch for long periods of time to change a tire, paint a fence or work in the garden, you will appreciate the value of a rolling seat. This one has the added convenience of steering to maneuver as needed, even around the garden. This rolling seat is also useful for low-to-the-ground chores such as washing cars, fixing machines or chopping vegetables.

The comfortable metal tractor-style seat is adjustable from 17" to 20" high and swivels 360° so you can position your body comfortably while working. The rolling base, constructed of 1" diameter powder-coated steel tubing, has four wide pneumatic tires that move easily through soil without sinking. Includes an under-seat poly tool tray and a rear storage basket to keep supplies and tools handy. Measures 31" long by 18" wide and weighs 35 lbs. Some assembly required.



To Order:

Lee Valley Tools Limited
P5210 US\$67.50
Online: www.leevalley.com
Phone: 1-800-871-8158
Fax: 1-800-513-7885
Mail: P.O. Box 17850
Ogdensburg, NY 13669-8780 USA
Quantity Discounts Available for Orders of 10 or More.

Tools not included.

This is a preliminary sample page for the Adaptive Technology Catalog. It shows a simple rolling seat, originally designed for gardening use, that can be adapted to many different jobs. [IMAGE COURTESY OF MAIC]

It is expected that the Adaptive Technology Catalog will be an excellent resource for survivor-assistance personnel, governments and organizations planning rehabilitation projects, donors and physical trauma survivors.

There are many benefits to a catalog of this type, including that it:

- Allows people to get back to work
- Gives donors something specific to fund
- Creates survivor independence

The Mine Action Information Center staff enjoys providing useful, needed products to the mine-action community as well as partnering with like-minded organizations to develop and deliver the projects. For more information about any of these projects, please Lois Carter Fay at editormaic@gmail.com.

Biography



Ms. Lois Carter Fay joined the Journal of Mine Action as Editor-in-Chief in 2005 and more recently has also served as Project Manager of the Adaptive Technology Catalog project. Her project management, writing, publishing and editing skills have been a solid addition to the MAIC’s staff. Lois is an accredited public relations professional (APR) and holds a B.A. in psychology from the University of Wisconsin-Milwaukee.

INTERNATIONAL SYMPOSIUM “HUMANITARIAN DEMINING 2007”

24 - 27 April 2007, ŠIBENIK, CROATIA

HCR-CTRO Evaluates Mini MineWolf for Humanitarian Demining Operations in Croatia

Operational capabilities, endurance and quality of results tested and verified

Christoph Frehsee¹⁶

During October 2006, the remote-controlled medium size demining machine “Mini MineWolf” underwent mandatory testing and accreditation by the Croatian Mine Action Centre for Testing (HCR-CTRO) for operation in Croatia against anti-personnel (AP) mines. Testing was carried out during 16-18 Oct. 2006 at the Cerovac test site for demining machines near Karlovac. The goal of the test, which was successfully achieved, was to determine:



Mini MineWolf in 20 Foot Container



Mini MineWolf in Operation

- **Clearance Quality:**
 - Effectiveness, endurance and survivability against multiple live AP mines (PMA-1(A), PMA-2(A), PMA-3, PMR-2A, PROM-1)
 - Soil processing depth over different types of soil
- **Clearance Capacity:**
 - Output in terms of square meters per hour
 - Possibilities of clearance in different types of soil, terrain gradients (horizontal and vertical slope), as well as for vegetation clearing

• Running Costs:

- Necessary machine logistics, servicing and maintenance requirements
- Tool running costs

AP Mine activation and survivability results

On 26 October 2006 testing was conducted with a variety of antipersonnel mines at the test site for demining machines. The following results were achieved:

- 1) **PMA-1A:** 5 mines were placed at the planned depth (5, 10, 10, 15 and 20 cm) at 4 m distance and armed with appropriate fuses. **Result: The machine activated all mines. Neither the working tool nor the machine was damaged**
- 2) **PMA-2:** 5 mines were placed at the planned depth (5, 10, 10, 15 and 20 cm) at 4 m distance and armed with appropriate fuses. **Result: The machine activated all mines. Neither the working tool nor the machine was damaged**



AP mines PMA-1A and PMA-2 prepared for testing of the “Mini MineWolf”

¹⁶ MineWolf Systems AG, Senior Technical Advisor, c.frehsee@minewolf.com

- 3) **PMA-3:** 5 mines were placed at the planned depth (5, 10, 10, 15 and 20 cm) at 4 m distance and armed with appropriate fuses. **Result:** The machine activated all mines. Neither the working tool nor the machine was damaged



AP mines PMA-3 and PMR-2A prepared for testing of the "Mini MineWolf"

4) **PMR-2A:**

- **First mine** – was placed in front of the machine at around 8 m distance and armed with appropriate fuse. **Result:** the tiller activated the mine leaving shrapnel marks on the machine and work tool, but not affecting operation of the machine.
- **Second mine** – was placed in the same manner. **Result:** The tiller activated the mine. Neither the working tool nor the machine was damaged.



Shrapnel marks of PMR-2A on the "Mini MineWolf"

5) **PROM-1:**

- The PROM-1 bounding fragmentation mine has killed or injured more clearance personnel in the Balkans than all other mines combined. Effectiveness against PROM-1 is therefore a high priority. The first PROM-1 was placed and prepared for tripwire activation. **Result:** the tiller activated the mine leaving shrapnel marks on the machine and work tool, but not affecting operation of the machine.
- Second PROM-1 was placed and prepared for pressure activation. **Result:** The mine was activated by the machine. Neither the working tool nor the machine was damaged.



PROM-1 prepared for testing of "Mini MineWolf"

Summary of performance against AP mines: the machine activated or destroyed all 19 mines in the test with only superficial damage. Minimum 20cm clearance depth achieved, and effective remote controlled operation over a variety of terrain, vegetation and gradients was demonstrated.

Other performance aspects

The value of a small remote controlled machine for a demining program has to be measured in various dimensions in addition to mine-activation and blast survivability. Clearing results must also be evaluated in terms of quality, quantity and costs:

- **Clearance Quality:**
 - minimum 20 cm constant ground penetration (achieved)
 - effective clearing of dense vegetation (achieved)
 - easy manoeuvring around buildings, trenches and trees (achieved)
 - ability to climb steep gradients (proven)
 - low ground pressure in muddy terrain to avoid getting stuck (proven)
- **Clearance capacity:**

- Based on the Mini MineWolf's track record in Bosnia-Herzegovina in 2006, more than 500,000 m² on various terrains was achieved within 91 days of operations (average performance between 600 – 1500 m²/h)
- **Low Running Costs:** Although costs for oil, filters and service of the Mini MineWolf are comparable with other comparable machines, 90% of the running costs are determined by the running costs of the working unit: flail or tiller! After clearing the first 500,000 m² (operated by Norwegian People's Aid, NPA) it became clear that the tiller of the Mini-MineWolf can be operated at less than 20% of the running costs of a flail system in comparable size and output.
- Minimum downtime: the Mini MineWolf is based on a stable, mature technology resulting in minimum downtime due to design flaws or technical problem (the machine design is based on a stable, proven larger version).



HCR-CTRO recommendation: Based on the testing results as well as on the criteria of the "Programme of Testing and Usability Evaluation of Machines used in Humanitarian Demining Operations",

the machine may be used, with its tiller, for performing humanitarian demining tasks in the Republic of Croatia.

To date MineWolf Systems has its demining machines operating in the Balkans, Jordan and Sudan, with multiple Mini MineWolfs operating in Croatia and Bosnia-Herzegovina. Each Mini MineWolf has exceeded expectations regarding performance and no faults have been identified in the design. The depth control has been tested on both dry and wet terrain and is functioning perfectly to ensure a continuous ground penetration of more than 20 cm.

Annual Verification of Demining Machine Characteristics Used in Humanitarian Demining Operations

Nikola Gambiroža¹⁷, Ivan Šteker¹⁸

Abstract:

Humanitarian demining operations are often conducted in extremely aggravated and specific conditions and are accompanied by lots of risk and threat to people's lives and health. These specifics in particular direct the constructors and machine manufacturers towards identification of optimum solutions for technical requirements demining machines should fulfil. Based on these technical requirements and compatibility assessment one can establish whether the machines are capable of performing the task they are designed for, determine their efficiency, endurance in terms of impact of antipersonnel and antitank mines, whether they are safe for the machine operator and acceptable for specific conditions and environment.

As per Rules and Regulations on Technical Requirements and Compatibility Assessment of the Machines Used in Humanitarian Demining Operations, verification of machine characteristics is performed once a year in order to establish the status of the machine in relation to the status established by compatibility assessment procedure.

Annual verification of characteristics is carried out in order to verify the machine acceptability, soil treatment depth, soil treatment density and machine efficiency on a prepared lane with compacted soil of local composition.

The paper presents and analyzes annual verifications of characteristics of the machines and excavators carried out during 2006 that established functional dependences of machine performance, soil treatment density and depth on maintenance and renewal of vital parts for the operation of working tool and the tool itself as well as trainability, experience and preparedness of the machine operator.

Key words: *technical characteristics and compatibility assessment, demining machines, annual verification, efficiency, soil treatment depth, characteristic of soil treatment density*

Introduction

Demining machines are required to search and demine the biggest areas possible in the shortest period possible i.e. to reach required performance. While doing so, the machines need to meet the requirements set, primarily the safety of machine operator, quality of soil treatment as well as meet the requirements for protection of people's health and environment.

Machine testing serves for checking up prescribed performances that will guarantee that the demining machine is capable of performing the tasks it is designed for with adequate acceptability.

All machines used in humanitarian demining operations are subject to compatibility assessment and verification of machine characteristics. Compatibility assessment is based on exact test-

ings and verifications on polygons or worksites prepared for that purpose.

Verification of machine characteristics (regular-annual and/or additional) identifies the status of the machine in relation to the status established by compatibility assessment procedure.

Annual verification of characteristics runs a check on soil treatment depth, machine movement speed, soil treatment depth and machine performance on a prepared lane with compressed soil of local composition (according to CWA 15044).

The penetration profile of working tool printed on the fiber boards placed in the lane (Point 2.6 – Working tool penetration profile, CWA 150449) is assessed and measured.

Depth of a strike (print) of a flail digger or a mill tooth on fiber board barriers along the entire length of working tool is measured. Medium value of 20 separate measurements is calculated (measurements are patterned along the entire length of a print and start with the first damage

¹⁷ Croatian Mine Action Centre, Assistant Director, A. Kovačića 10, 44000 Sisak, Croatia, nikola.gambiroza@hcr.hr

¹⁸ HCR-CTRO d.o.o., ivan.steker@crto.hr

on any side of the fiber board) for each test barrier.

Medium value for all three test barriers in the test lane is taken into account while making the final assessment of soil treatment depth for one test lane.

Soil treatment density is not satisfactory if there are one or more «blank spaces» on the test board (blank space - place with no print-undamaged barrier) in the length bigger than the diameter of the smallest antipersonnel mine.

If medium value of soil digging depth measured on the polygon test lanes in the first soil category is bigger than 17 cm and smaller than 19,5 cm, demining machine can be assessed as successful in treating the first category soil to the depth of 20 cm

under the condition that neither one separate measurement on the test lane is smaller than 12 cm.

2. Compatibility Assessment Procedure and Annual Verification of Demining Machine Characteristics

Book of Rules and Regulations on Technical Requirements and Establishment of Compatibility Assessment of Demining Machines Used in Humanitarian Demining Operations (Narodne novine (National Gazette), 153/05) prescribes the requirements demining machine system should meet. Basic procedure of testing and annual verification of characteristics is presented schematically - see Figure 1.

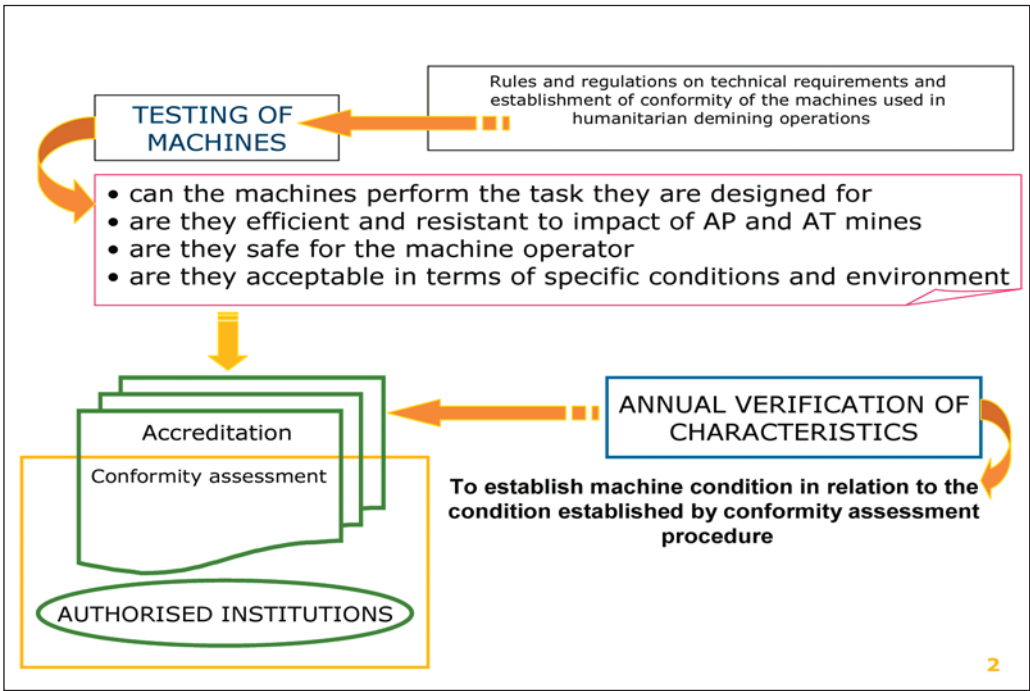


Figure 1 The scheme of procedure of compatibility assessment and annual verification of demining machine characteristics

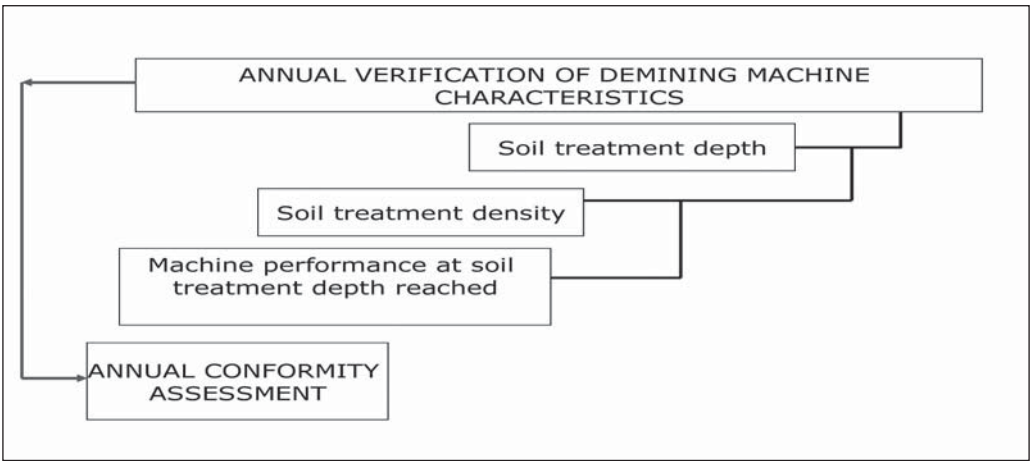


Figure 2 The diagram of technical requirements for annual verification of machines and compatibility assessment procedure

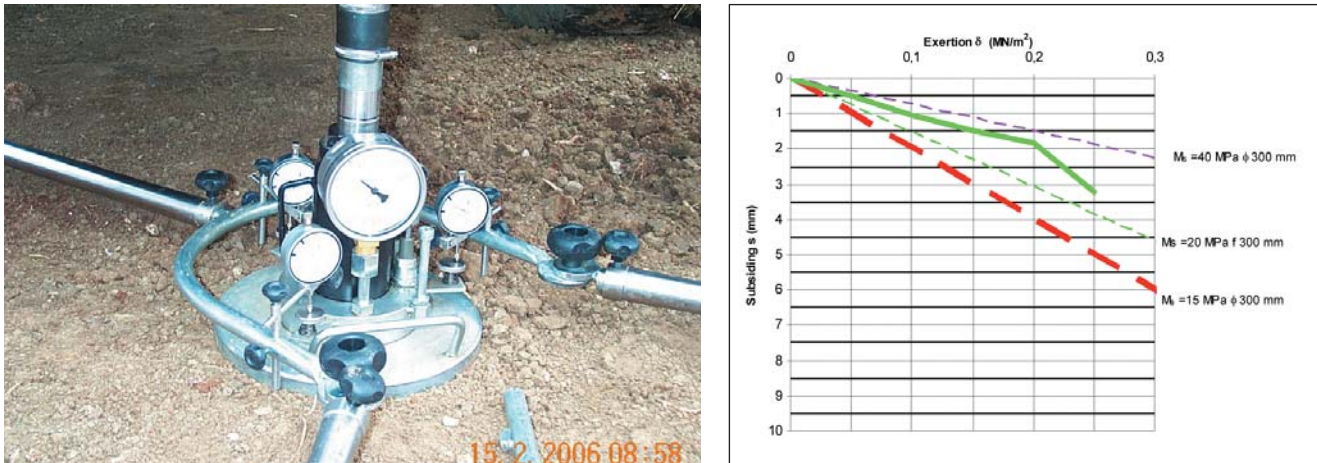


Figure 3 The apparatus for measurement of compressibility and the diagram showing subsiding of the soil in the period passed at certain exertion

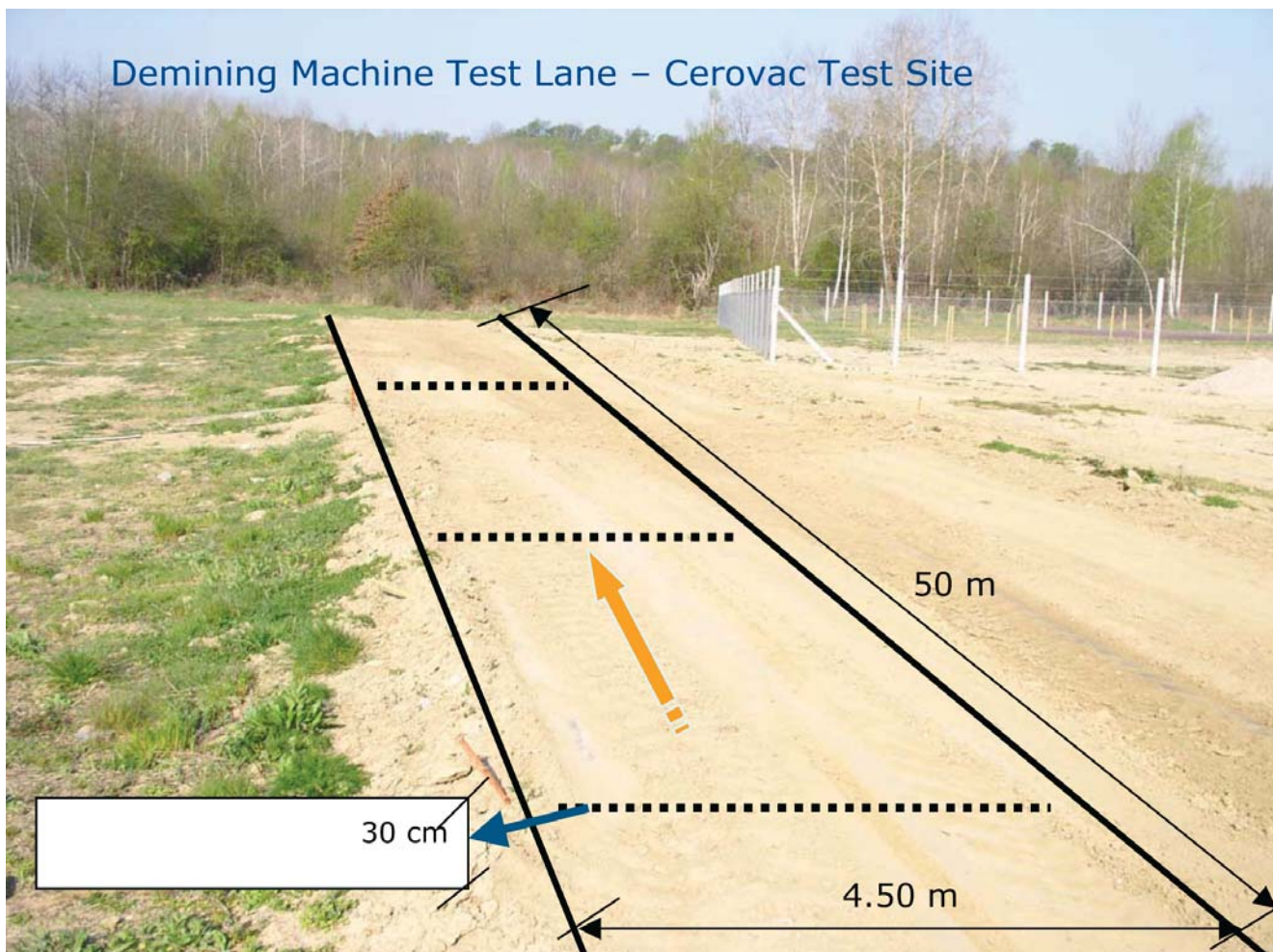


Figure 4 Test lane scheme

Based on annual verification of demining machine characteristics, accredited institution issues a certificate of compatibility. For the diagram of verified characteristics see Figure 2.

Verification is performed in one lane under the controlled conditions with homogenous soil of local composition as prescribed by CWA 15044. The penetration profile of working tool printed

on fiber boards buried into the lane are assessed and measured.

Lane preparation – compactness controlled by instrument for measurement of compressibility: type "STO"-M (HRN U.B1.046), Figure 3. For the scheme of the test lane in Cerovac test site (Croatia) see Figure 4.

Annual verification and establishment of opti-

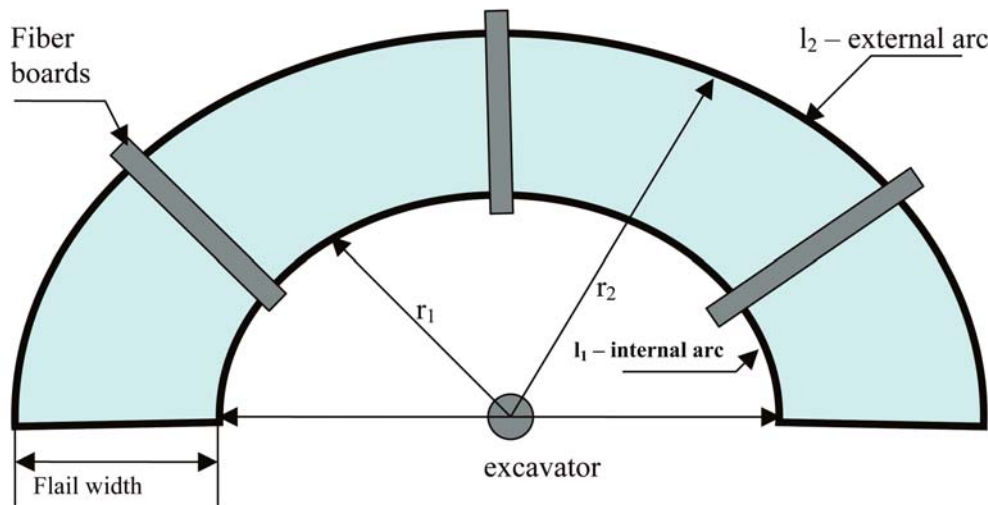


Figure 5: Test lane scheme for excavator with test stripes and fixed position of the excavator with extended crane in working position

imum performance of the excavator with flail as working tool, soil treatment density and depth are measured in specially prepared test lanes with local soil. Lanes are in form of an arc defined by the size of an excavator crane and working tool width. For the sketch of a test lane with fiber boards see Figure 5.

Excavator performance calculation procedure:

Treated area, m²: $P = ((r_2^2 - r_1^2) \times 3.14) / 180$
Excavator performance, m² / h : $U = (P / t) \times k$

where:

P – area treated in a particular time interval at constant speed of working tool (flail or mill) arc moves,

t – time during which the area A has been treated
k – coefficient of excavator move (for excavator movement in a straight line k is 0.35)

By determining the compressibility module Cm, there was the estimate of compactness of soil in the test lane performed and assessed the appropriateness of lane preparedness for annual verification of each machine type as per diagrams presented in Figure 6.

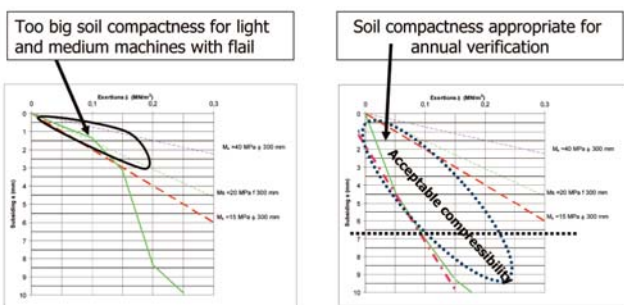


Figure 6: Diagram of appropriateness of soil compactness for annual verification of characteristics

3. Analysis of Annual Verification of Demining Machine Characteristics

3.1. The change of performance in relation to soil treatment depth

Analysis of testing results for the first usability assessment of the new light machine no. 4 established functional dependence between machine performance and soil treatment depth. Soil and weather conditions were pretty much the same and machine operator was experienced and skilful in machine operating. Results given are presented in the Figure 7.

It can be seen from the diagram that the performance of stated light machine in the 1st category of soil while reaching acceptable soil treatment depth between 19 and 20 cm was ca. 1100 m² /h. On the demining project with low and medium vegetation present and acceptable compactness of the 1st category soil, performance in real conditions is 20 to 35% lower.

3.2. The Impact of Trainability, Experience and Skilfulness of the Machine Operator on Soil Treatment Depth

In order to achieve good quality mechanical demining, technological machine movement speed and working tool speed must be coordinated and that results in soil treatment density controlled by annual verification of characteristics on the annual basis.

On the basis of regular performing of annual verifications for light machine with flail of the code 4/04-01 operated by machine operators with dif-

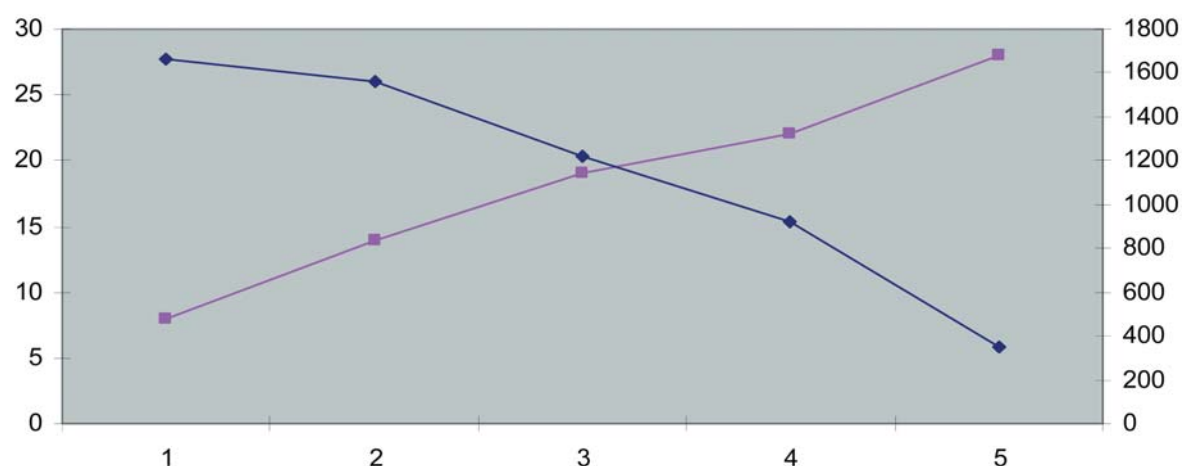


Figure 7 The diagram showing the change of performance in relation to soil treatment depth

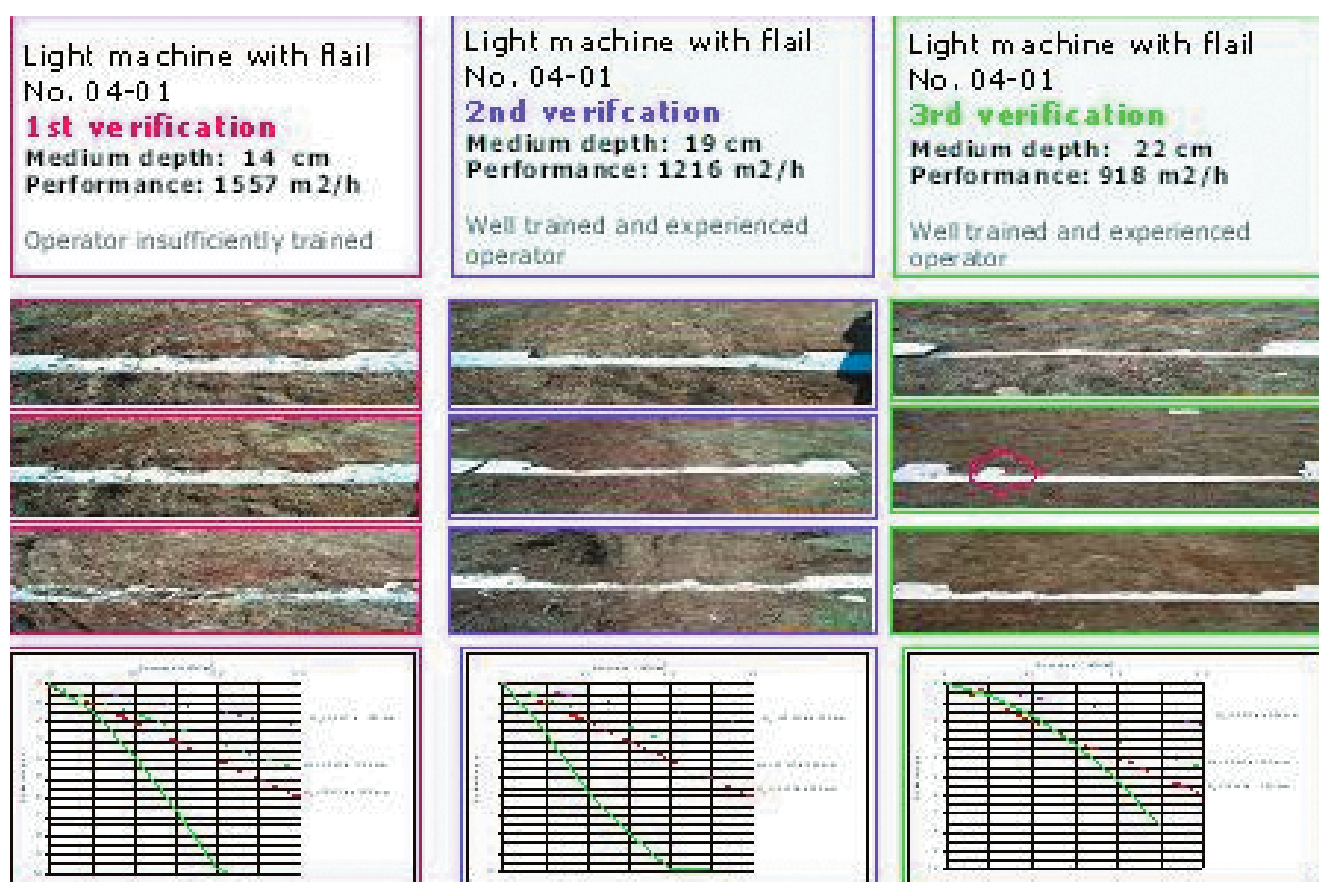


Figure 8 Soil treatment depth and density for the same machine with different machine operators

ferent level of trainability and experience, it was established that the trainability, experience and skilfulness of the machine operator influence the soil treatment depth result up to 40%. The results obtained are presented in the Figure 8. Table 1 represents the impact of machine operator on the results achieved. In the column "Remarks" there are the situations for each case described. Table 2 represents the results of annual verification for the same type of light machine with flail (No. 4). All the machines were well-maintained and well-prepared. Soil conditions were

pretty much the same with the appropriate soil compactness, as per diagram given in the Figure 6. The results are related to the experience of machine operator (number of working hours worked off on a particular machine: over 100 hrs, over 50 hrs, up to 50 hrs and less than 10 hrs) and machine operator's skilfulness (machine operating skills were evaluated from 1 to 5). Table 3 represents the results of annual verification of the same contents as the Table 2 with one difference – table 3 is relating to the light machine with flail (No. 89).

Table 1: Impact of machine operator on the results achieved (treatment depth and machine capacity) – light machine with flail no. 04/04-07

Testing/ Annual verification	Medium soil treatment depth-soil (cm)	Machine performance m2/h	Remark
First testing –new machine	24	944	Excellent machine operating. Machine operator – manufacturer's test operator
First verification	14	1302	Unstandardized machine operating. Operator insufficiently trained.
Second verification	13	827	Bad machine operating. Frequent corrections during the drive.
Repeated second verification	24	1098	Excellent machine operating. Machine operator – manufacturer's test operator

Table 2: Impact of experience and operator's skills – the same machine type (No. 04), machine well-prepared and technically correct

No./Machine code	Medium soil treatment depth-soil (cm)	Machine performance m2/h	Experience (hours)/ operator skills (grades: 1-5)
1. /04-12	26	885	Over 100 hours/4
2. /04-08	25	947	Over 100 hours/4
3. /04-13	24	1203	Over 100 hours/5
4. /04-07	24	1098	Over 100 hours/5
5. /04-04	23	734	Over 100 hours/4
6. /04-10	23	612	Over 50 hours/3
7. /04-02	22	918	Over 50 hours/4
8. /04-06	21	885	Over 50 hour/4
9. /04-15	21	529	Over 50 hours/3
10. /04-05	20	653	Up to 50 hours/3
11. /04-08	16	1019	Up to 50 hours/3
12. /04-02	14	1557	Up to 50 hours/4
13. /04-07	13	827	Less than 10 hours/3
14. /04-05	14	941	Less than 10 hours/3
15. /04-12	14	742	Less than 10 hours/2

Table 3: Impact of experience and operator's skills – the same machine type (No. 08), machine well-prepared and technically correct

No./Machine code	Medium soil treatment depth (cm)	Machine performance m2/h	Experience (hours)/ operator skills (grades:1-5)
1. /08-04	23	1000	Over 100 hours / 5
2. /08-04	20	1159	Over 100 hours / 5
3. / 08-02	21	847	Over 100 hours / 4
4. /08-03	18	416	Over 50 hours / 3
5. /08-03	16	1263	Over 50 hours / 4
6. /08-01	16	698	Up to 50 hours/ 3
7. /08-04	15	960	Up to 50 hours / 3
8. /08-02	15	758	Less than 10 hours / 3
9. /08-02	13	1006	Less than 10 hours / 2

3.2. The Impact of Technical Correctness, Maintenance and Working Tool Modifications on Machine Performance and Soil Treatment Depth

Regular maintenance of demining machine, replacement of motor, hydraulics and working tool worn out i.e. prompt replacement of damaged working tool parts are the second most important factor for good quality soil treatment: treatment density, treatment depth reached and machine performance.

Table 4 represents the results of annual verification of light machines with flail no. 04 and 08 with some technical imperfections (replacement of chain length, no. of chains and diggers on the

working tool, motor and pumps worn out, inadequate maintenance etc. Machine operating is often aggravated as well as placing the rollers behind the tool, loosing the power on the tool, halt on the test lane, unstandardized operation etc.

Figure 9 represents the results of annual verification for the machine with flail (no. 13/04-01). The operator was the same during all verifications with the experience over 100 hours on the stated machine. Apart from results achieved (treatment depth and performance) Figure 9 also presents the appearance of fiber strip upon verification. Figures 10 and 11 represent the results of verification for the medium machine no. 14-01 and machine no. 29-01 with comments.

Table 4: Impact of technical correctness, maintenance and modifications on the flail – light machines with flail (No. 04 and 08)

Machine code	Working tool	Medium soil treatment depth (cm)	Machine performance m ² /h	Remark
04-18	flail	9	521	Aggravated machine operating
04-18	flail	17	440	2 wheels behind working tool
08-02	flail	13	1006	Aggravated machine operating, machine acceleration
04-19	flail	7	1610	Smaller no. of chains and hammers, bigger hammer area
04-07	flail	13	827	Roller placed behind the working tool
04-01	flail	23	740	Stopping on the lane-aggravated operating
04-13	flail	16	1019	Roller placed behind the working tool
08-04	flail	15	960	Loosing power on the tool, unstandardized operation

Medium machine with flail: No. 14-01

(the same machine operator- with experience over 100 working hours/4)

No.	Testings/ Annual verification	Medium soil treatment depth (cm)	Machine performance m ² /h	Remark The same operator during all verifications
1	First testing – new machine	26	2118	Extremely well prepared machine
2	First verification	17	2647	A wish of an operator to reach big capacity
3	Repeated first verification	23	1659	Drive on the depth over 20 cm
4	Repeated second verification	20	2000	Reaching maximum capacity

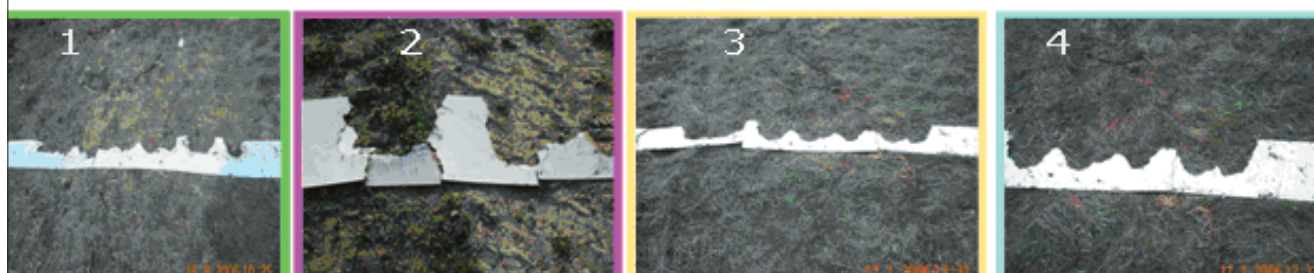


Figure 10 Medium machine with flail no. 14/04-01

Medium machine with flail: No. 29-01			
Testings/ Annual verification	Medium soil treatment depth- soil (cm)	Machine performance m ² /h	Remark Change of operators
First testing – new machine	23	1323	Machine operator- manufacturer's test operator
First verification	17	818	Insufficiently trained operator and badly prepared machine
Second verification	24	898	Machine operator- manufacturer's test operator

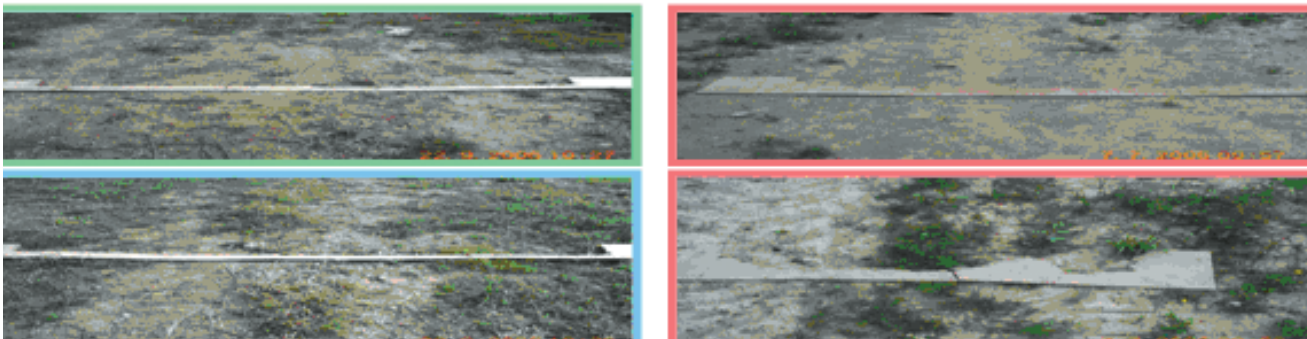


Figure 11 Medium machine with flail no. 29-01

Heavy machines with mill	
<ul style="list-style-type: none"> • Average depths reached – over 24 cm • Average performance achieved - from 2 000 to 4 900 m²/h 	
No. 27-02	No. 27-02
No. 31-01	No. 27-03
No. 09-01	No. 11-01
No. 10-01	No. 27-03

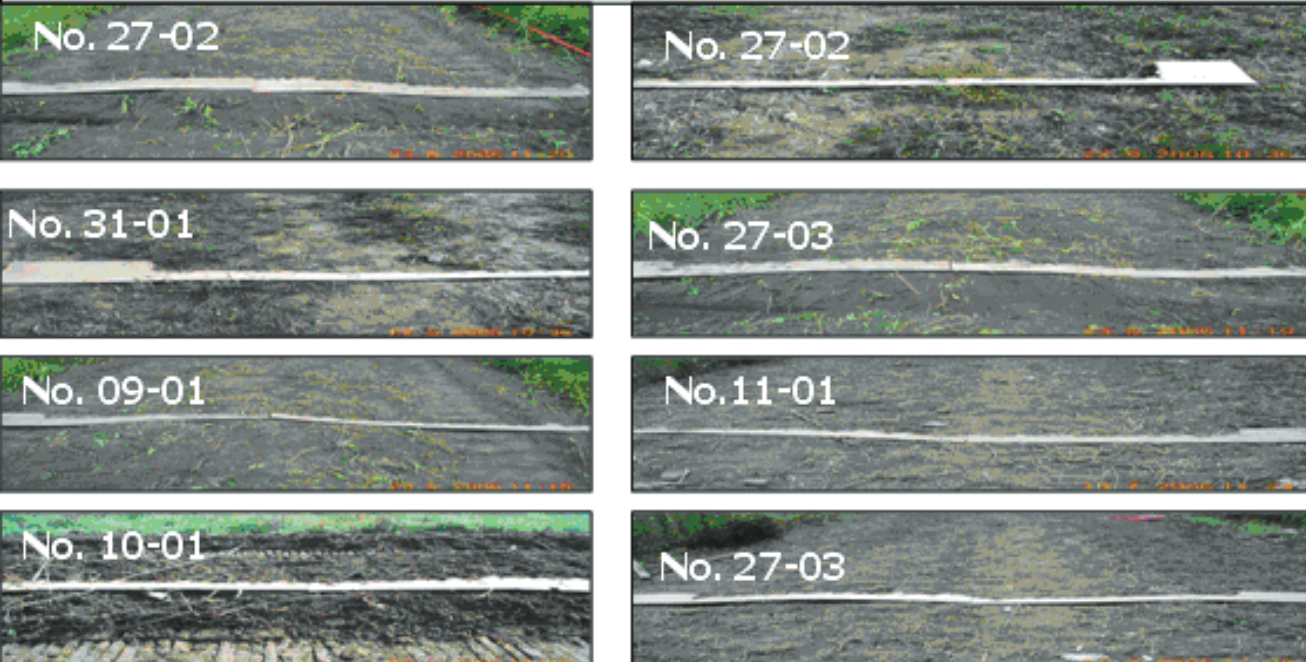


Figure 12. Heavy machines with mill

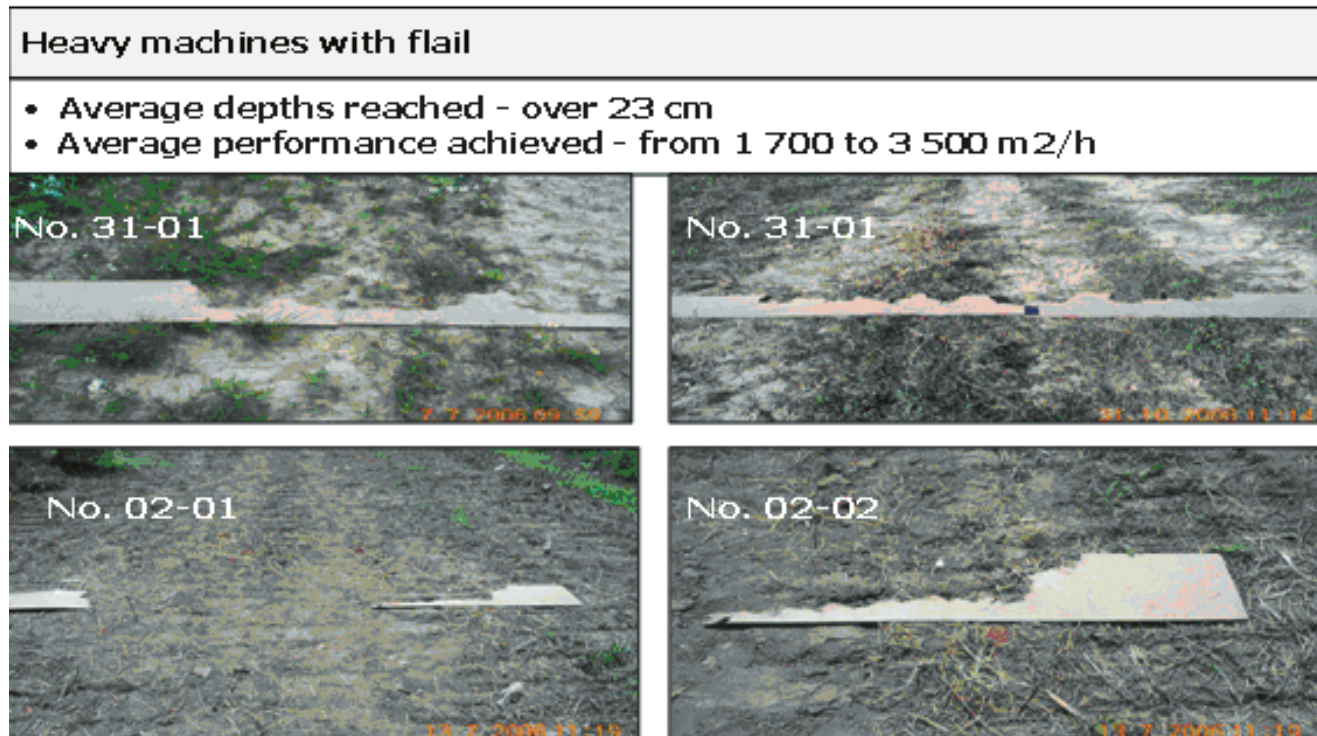


Figure 13 Heavy machines with flail

Figures 12 and 13 show the verification results of heavy machines with flail and mill. Due to their size, weight and transport costs, annual verification is performed on demining worksites themselves. Considering the fact that heavy machines easily reach the depth required and good soil treatment density, figures only show their average results and working tool print appearance on fiber boards.

CONCLUSIONS

1. Analysis of annual verification results achieved by demining machines, especially of light machines with flail, established direct dependence between performance, soil treatment density, level of trainability and experience of machine operator.
2. Level of trainability, experience and skilfulness of machine operator influence the result of soil treatment depth up to 40%.
3. Regular maintenance of demining machine, replacement of motor, hydraulics and working tool worn out i.e. prompt replacement of damaged working tool parts are the second most important factor for good quality soil treatment: treatment density, treatment depth reached and machine performance.
4. Apart from high quality construction solutions, training of machine operator will result in

complete coordination of technological speed of machine movement and working tool spinning speed. This will, on the other hand, result in good quality of soil treatment i.e. complete clearance of mine suspected area.

LITERATURE

- (1) Rules and Regulations on Technical Requirements and Establishment of Compatibility of Machines Used in Humanitarian Demining Operations, Narodne novine (National Gazette) no. 53/2007, Zagreb, 2007.
- (2) ITEP, CEN, Workshop Agreements / CWA 15044:2004
- (3) Dinko Mikulić: Demining Technics: modern methods and equipment, demining machines, Zagreb, 1999

Measuring Productivity and Cost Effectiveness of Machines for Humanitarian Demining

Dr Robert Keeley¹⁹

Abstract

Machines have been used in humanitarian mine action since the earliest days, but their use, and in particular their benefit, has remained contentious. Machines are expensive and managers operating on restricted budgets might face the difficult question of laying off manual deminers in order to have the necessary funds to purchase the machines. Demining managers also face the difficult question of choosing between machine types. Whilst the demining community has developed objective regimes to test the technical effectiveness of machines, there is no comparable method in general use to determine the productivity of machines in terms of square metres per hour. Furthermore, even once the productivity of machines is established, it is necessary to take several other factors into consideration before a true estimate of their cost-effectiveness can be determined. This paper sets out the steps necessary for demining managers to determine the potential improvement to the cost-effectiveness of their programs offered by a new machine.

Introduction

History of machines in mine action

The history of machines in mine action parallels the development of the mine (and indeed the tank). The first demining machines were introduced in the Second World War, and their history is laid out in a number of commendable publications, including those by Croll²⁰ and De la Force²¹. No more need be said about their history except to note that these machines were introduced to improve the *speed* of demining rather than their effectiveness, and the balance between “faster, cheaper or safer” has been an issue that demining managers have faced for a decade or more²². This paper makes the assumption that all machines under consideration are technically fit for purpose. The question remains: even if it is faster, will it actually turn out to be cost effective?

Machine purchases as an irreversible decision

Machines are expensive to purchase. Even the cheapest machine has a purchase price of around

\$100,000, and this does not include the cost of spares packs, training or running costs. Furthermore, due to the small market for such machines, their purchase must be considered an ‘irreversible decision’ for mine action program managers. In effect, once a machine has been purchased it remains the property of the purchaser and cannot be sold on. In other words, a poor procurement decision cannot be easily reversed. Hence the need to ensure that the purchase of a machine takes its cost-effectiveness into account

Relevant Definitions

At this point it may be helpful to confirm a few definitions of what is being discussed in this paper. These definitions are all easily obtained on the internet, and their source is included in the footnotes for ease of reference:

- **Cost effective(ness):** economically worthwhile in terms of what is achieved for the amount of money spent²³
- **Cost effectiveness analysis (CEA)** A systematic quantitative method for comparing the costs of alternative means of achieving the same stream of benefits or a given objective²⁴
- **cost allocation** is the use of program budgeting and accounting practices to allow managers to determine the true cost of providing a

¹⁹ RK Consulting Ltd, www.rk-consulting.net

²⁰ “The History of Landmines” by Mike Croll, published by Leo Cooper, 1998

²¹ Churchill’s Secret Weapons” by Patrick Delaforce published by Hale, 1998

²² Robert Keeley: “Added value: the requirements of mine clearers and donors from new mine detection technologies” (1996); Proceedings of EUREL International Conference on the Detection of Abandoned Landmines, IEE Conference Publication 431, London, pp. 21-5

²³ Microsoft Encarta online encyclopedia, accessed 3 March 2007

²⁴ www.nps.navy.mil/drmi/definition.htm

given unit of service²⁵. Sometimes called ‘cost capture’.

- **Productivity** Also known as “labor productivity” or “worker productivity”; value of goods and services produced in a period of time, divided by the hours of labor used to produce them²⁶.
- **Opportunity Cost** The cost of passing up the next best choice when making a decision²⁷.

Two Problems: the productivity problem and the cost-effectiveness problem

Given the definitions set out above, demining managers face two questions.

- How do I determine the productivity of the machine?
- How can I use information about a machine’s productivity to determine whether it is cost effective?

These questions are addressed below.

CEN and the Productivity Problem

Current Status

The CEN workshop agreement (CWA) on the testing of demining machines²⁸ set out an objective means by which the technical effectiveness of a demining machine could be determined. However, as was determined during its development, the CWA did not address questions of productivity, nor did it address how to test machines used in vegetation clearance and ground preparation. Thus, the existing CWA does not – in itself – provide the answers to the two problems faced by the demining manager, though one would of course want to know that the machine could do the job in question, and the CWA does provide a basis for determining this.

Measuring Productivity in Test Environments

Any test of productivity must, in accordance with the above definitions, consider the time taken to process a measurable piece of ground. This may be based on either (a) the time taken to process a fixed area, or (b) by measuring

the area cleared in a set period of time. Either method provides a calculation in terms of m²/hr. Testing authorities may also want to control for effectiveness by including a number of mine targets in the test area, and control for varying ground conditions by repeating tests in different conditions of hardness, undulation or slope. Ground targets should also be of the same size and shape in order to control for issues of access and manoeuvrability. A hectare is certainly large enough for each test plot, and it may be possible to justify smaller plots providing – especially in comparative tests – equal conditions are given to all machines. It is therefore comparatively simple to formulate an objective test for productivity.

Intrinsic Capability and Actual Productivity

A manufacturer states that their machine can process “nearly 1,000m² of land in one hour”. Is this statistic sufficient? The principles of non-destructive testing set out by Dr Christine Mueller during the development of the CWA provide an insight into this question. As Dr Mueller explained, a machine’s intrinsic capability is the maximum one can expect. So therefore if a machine has a forward speed (whilst working) of 5 linear metre per minute and is 3 metres wide, its *intrinsic* capability over one hour is 3x5x60 = 900 minutes, so the manufacturers claims would be broadly accurate in terms of intrinsic capability. However, as Dr Mueller continues, environmental factors and human factors detract from this capability to produce the *actual* productivity.

Hence: AP = Ic – Ef- Hf (where AP = actual productivity, Ef = environmental factors and Hf = human factors)

Setting aside human factors such as working hours, environmental factors – such as the distance to be tracked between working areas, and even the amount of time taken to reverse out of working lanes and line up to the next – must be taken into account when measuring actual productivity. This will, almost certainly, be far less than the intrinsic capability. Eventually, a machine working in the field will produce the best data, as it will be possible to determine average performance over longer work periods, but by then it will be too late, as the purchase of the machine is an irreversible decision. Hence there is a need for a more informative test than the current CWA process. Once an accurate esti-

²⁵ <http://ag.arizona.edu/fcs/cyfernet/cyfar/Costben2.htm>

²⁶ <http://www.moneychimp.com/glossary/productivity.htm>

²⁷ http://www.investorwords.com/3470/opportunity_cost.html

²⁸ CEN Workshop Agreement CWA 15044:2004

mate of actual productivity, in terms of square metres per hour of operation, is determined, it is then possible to use this data to estimate the cost effectiveness of the machine. However, this can only be done once another series of calculations is carried out. This is the 'cost effectiveness' problem and it is addressed in the following section.

The Cost Effectiveness Problem

Determining cost-effectiveness in terms of opportunity cost

Cost-effectiveness is a term that is used in a non-specific manner in everyday language, but as defined above it has a specific meaning, which is particularly relevant in the context of demining machines. It is useful to interpret cost-effectiveness in terms of opportunity cost because, given that it is a large piece of any demining organisations budget, the purchase of a machine represents two choices.

- Do I spend this amount of money on this machine or another machine, given that once I spend it I will not be able to get it back?
- Do I spend this amount of money on this machine or on more manual deminers?

Cost-effectiveness is a relative issue

Cost-effectiveness analysis assumes that a certain benefit or outcome is desired, and that there are several alternative ways to achieve it. The basic question asked is, "Which of these alternatives is the cheapest or most efficient way to get this benefit?" By definition, cost-effectiveness analysis is comparative²⁹. In the context of a demining machine, we hope to be able to say that "Machine X is more cost effective than Machine Y" or "manual deminers are less cost-effective than Machine X". In order to do this, it is best to establish a baseline, and it is recommended that manual demining processes, which are comparatively standard and well understood³⁰ are used as the benchmark. However, as the GICHD study showed, there are significant variations, certainly between different countries, and one should therefore bear this in mind when making broad comparisons. For example, a machine that is cost effective in a program where labour

costs are high may not perform so well in a country where manual demining is comparatively cheap.

Comparing machines with manual

Comparing a machine with manual demining can be considered in two ways, though, as will be explained, in practice the calculations are the same. Firstly, one might consider whether the machine is used to augment the productivity of manual deminers. In this case, one would take the cost of the program, identify the cost of the manual demining component, and add the cost of the machines. One would then identify the additional productivity produced by the machines and calculate the resulting cost per square metre. It is a comparatively simple exercise to use the same calculations to determine what would have happened if the alternative (in this case, more manual demining teams) had been funded. Where machines might be used to replace deminers, the calculation process would be the same, however the cost of the deminers being removed from the program would be subtracted³¹. This process is a practical type of cost effectiveness analysis (CEA). The MMAC budgetary analysis model, developed by the author and referred to in the GICHD study, provides a quantitative structure for making these calculations.

Comparing machine types

Once the above calculations are completed, one need only repeat the process to compare another machine with the benchmark of manual demining. One will then be able to make a statement like the following:

- Cost/m² of manual process at existing budget: \$2.00/m²
- Cost/m² using Machine X to augment the manual process \$1.82/m²
- Cost/m² using Machine Y to augment the manual process" \$1.87/m²
- Therefore, in this program, Machine X is more cost-effective than Machine Y

³¹ Whilst this process will identify the financial benefit (or otherwise) of a particular machine, it does not take the full economic costs into account, in terms of the numbers of deminers being employed. This is significant because in most mine action programs the machines are imported whilst the manual deminers are recruited locally, and thus re-invest their salaries into the local economy. It is therefore suggested that a machine must show significant rather than incremental benefits if it is to be regarded as worthwhile.

²⁹ University of Arizona, Ibid

³⁰ "A Study of Manual Mine Clearance" GICHD, August 2005

One would then repeat the CEA calculations to determine the impact of the equivalent amount of funds on increasing the number of manual deminers.

Cost Allocation and the Attribution of overheads

"Cost allocation is a simpler concept than cost-effectiveness analysis. At the program or agency level, it basically means setting up budgeting and accounting systems in a way that allows program managers to determine a unit cost or cost per unit of service. This information is primarily a management tool. However, cost allocation provides some of the basic information needed to conduct more ambitious cost analyses such as cost-benefit analysis or cost-effectiveness analysis³²". In the demining context, this primarily involves the attribution of overheads (i.e. costs not directly attributable to a unit of output). This has been covered in a previous paper by the author³³ and so is not repeated here.

Through life costs

The second level of complication, particularly in the case of machines, is the need to take account of through life costs. This will involve the costs of fuel, replacement parts and maintenance, plus the time lost to production through downtime for planned maintenance or repair. The through life costs should be factored into the calculations, whilst the downtime counts as an environmental factor in assessing the actual productivity of the machine. The MMAC model provides a means to incorporate these costs into the calculations.

The fungibility issue of donations

There is one final factor that must be considered in this process, which is the fungibility of donations. Some donors are happy to make cash donations to programs, either bilaterally or through some multilateral structure such as a UN-managed trust fund. Some donors may wish to earmark these funds for particular machines (usually made in their own country) or even provide the machines as in-kind contributions. These three vectors for funding a machine are clearly very different in terms of their fungibility (i.e.

the ability of the manager to use the funds for other purposes). However, it is still equally valid for a demining manager faced with a 'take it or leave it' donation of a machine to carry out the above calculations. It may be that the machine is actually a net drain on program resources, and these calculations will help determine this before the machine is brought into the country. It might be better to politely decline the offer!

Conclusions

In conclusion, there is no doubt that there is a role for machines in humanitarian mine action, and that the CWA has helped demining managers establish their technical effectiveness. However, the purchase of a machine is an expensive, up-front decision, and is irreversible. Given that some machines are not cost-effective, program managers need more information about machines to assist in purchase decisions, a development of the CWA to measure actual productivity would help in this regard to help establish the actual productivity of machines.

Program managers should consider how they set out their own accounts, and use CEA as a tool to determine whether any particular machine is a potential benefit, taking all costs and overheads into account.

³² University of Arizona, Ibid

³³ The Cost Capture Issue in Humanitarian Mine Action by Robert Keeley. maic.jmu.edu/journal/7.3/index.htm

Effectiveness of the DEMICHAIN Concept

René JOECKLE³⁴ and Bernard GAUTIER³⁴

Abstract

DEMICHAIN is a new concept of mechanical demining, in which an horizontal web of heavy chains is hanged several meters above a surface to be cleared. The release of the heavy chains web in a free fall delivers a mechanical impulse over the whole surface hit by the chains and a pressure wave is generated, which triggers the active landmines. As compared to flails and rollers, this concept affords several advantages, as for instance efficiency on uneven grounds, capability of triggering deep buried landmines, low cost and homely construction of the tool, which can be adapted to machines already in use on demining sites. The Association of Research of Innovative Techniques in humanitarian Demining studies this technique by measuring the pressure delivered in the ground with buried pressure detectors which react when the pressure is high enough to trigger landmines. The results obtained until yet show that this tool is able to clear many types of grounds. It could be efficient for area reduction, as a complementary tool of other techniques like the flails for clearing the uneven grounds, as well as a cheap tool for small organizations or for small surfaces to be cleared.

Introduction

Two types of action can be exerted by demining machines:

- The rollers and the flails exert forces at the surface of the ground and generate stresses in-depth. These stresses trigger active landmines, which explode and are destroyed.
- The tools of many other devices penetrate in-depth, trigger, crunch or extract the landmines, as well as other exploding devices, in the ground. Flails can also work in a similar way.

The first type of action offers many advantages: it is generally more economical in terms of energy; it respects the structure of the upper ground and can be used for area reduction. However, these techniques are ineffective on explosive items that are insensitive to pressure. Another drawback results from the fast decrease with depth of the generated stress¹. A landmine with a small pressure plate can therefore remain dangerous if deeply buried. We propose another concept, named DEMICHAIN².

This concept is not yet in use in minefields, and careful tests are needed before using such tools on live ground. However, its many advantages motivate a study of its expected effectiveness.

After a description of the concept and of its theoretical effectiveness, the investigations carried out by our association will be described. Tests on

real landmines are now required before using the DEMICHAIN tool for demining.

Description of DEMICHAIN

DEMICHAIN means “DEMIning with CHAINS”. This idea has been discovered by Jacques DEMICHELIS and developed in the framework of the ARTID³.

The DEMICHAIN concept consists in a free fall of an horizontal chains web with an area of several square meters. A large area is simultaneously under stress and the resulting forces decrease slowly with depth.

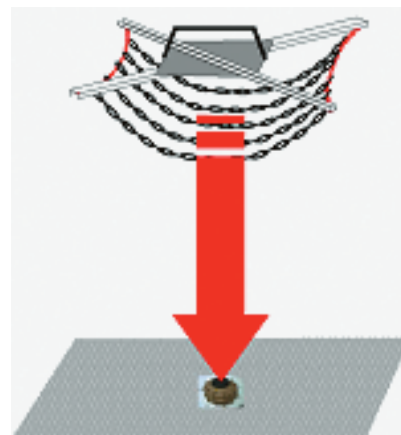


Fig.1: principle of DEMICHAIN

The main characteristic of this concept, as compared to rollers and flails, is that the forces are vertical and evenly (uniformly) distributed over

³⁴ ARTID, 8 rue des Roses, 68300 SAINT-LOUIS (France),
e-mail: association@artid.org

a large surface. The dimensions of this area are more than ten times larger than the depth to be considered (20 cm). Therefore it is assumed that the phenomenon is one-dimensional.

A theoretical description can be made⁴, assuming that the soil is elastic and is hit by a uniformly distributed mass, with a velocity V_0 of about 8 m/s. After a few microseconds, it can be assumed that the surface of the soil moves with a velocity of V_0 and is compressed. This elastic strain generates a vertical stress and results in a pressure wave which propagates in depth at the velocity of sound. The theoretical value of this stress on the surface (at the very beginning of the impact) is given by the Timoshenko expression:

$$\sigma_0 = \rho \cdot c \cdot V_0$$

where ρ the mass density and c is the velocity of sound in the soil.

This varies strongly with the water content of the soil, between 160 m/s and 1000 m/s. Even with the lowest value, the stress for an initial velocity of about 8 m/s generates a vertical pressure ($4 \cdot 10^6$ Pa) which is much higher than the pressure which triggers a landmine. Other theoretical considerations yield the following conclusions:

- The initial stress depends only on the velocity of the chains when they hit the ground
- The duration of the pressure pulse is proportional to the weight per unit area (in the ms range).

APL	Area of the pressure plate	Triggering force	Triggering pressure
Type 72	44 cm ²	5-10 kg	$2,3 \cdot 10^4$ Pa
MI AP DV 59	3 cm ²	5 kg	$17 \cdot 10^4$ Pa
VS-50	19 cm ²	10 kg	$5 \cdot 10^4$ Pa
PMN	80 cm ²	8 – 25 kg	$3 \cdot 10^4$ Pa
M14	18 cm ²	9 – 16 kg	$9 \cdot 10^4$ Pa
PMA-1	42 cm ²	> 3 kg	$3 \cdot 10^4$ Pa

Table 1: set-off pressure of several APL

How will it work?

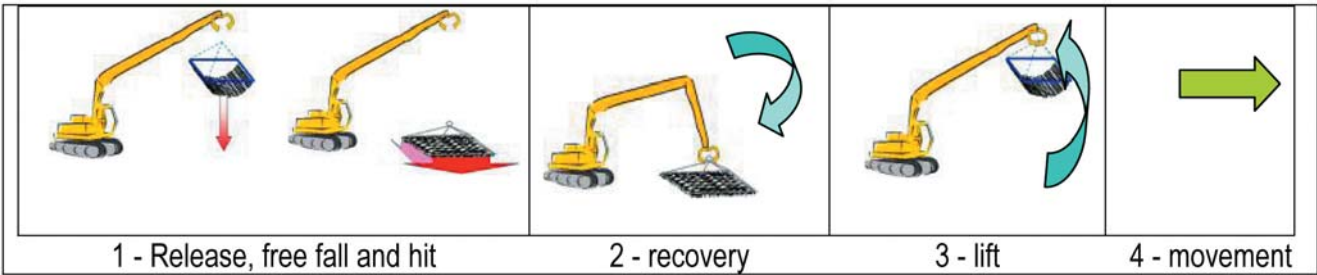


Fig. 2:the four phases of a cycle

The demining process occurs during a fraction of second over an area of several square meters. However, it must be followed by a change of the positioning of the chain web. This occurs in a cycle of 3 to 4 phases:

1. The chain web is released to fall freely, impact the ground, and detonate any mines present
2. (Optional) The crane recovers the chain web
3. The chain web is lifted to the required height
4. Movement to the next place to be demined

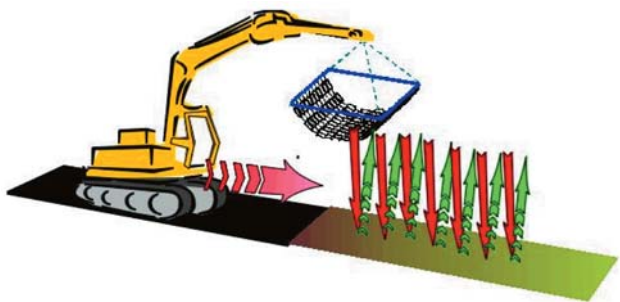


Fig. 3 : a succession of cycles

The demining operation consists in a succession of cycles, either just in front of the machine (as for flails and rollers) or by covering a broader zone by combination of linear movement and the rotation of the crane.

For security the surface must be impacted several times. Movement must therefore be adjusted as a function of this requirement and the dimensions of the chain web.

Two types of lifting devices can be used:

- A conventional hydraulic arm, with which the second phase requires a skilled operator and a certain amount of time. This type of machine is widely used in mine-affected countries and on many demining sites. The DEMICHAIN device then consists simply of the chain web.
- A crane equipped with a free fall winch (as for instance a dragline); in this case the second phase disappears and the device can therefore easily be controlled remotely.

If this latter accessory is not available, the DEMI-CHAIN device has to be made up of the chain web and free fall winch, to be adapted either to a conventional hydraulic arm or to remote-controlled machines.

Comparison with other mechanical demining concepts

In comparison with the flails and the rollers, DEMICHAIN affords several advantages:

The developed forces are vertical and can work on uneven ground. Ground which is obstructed, for instance by stones, small rocks, banks, ditches, small fences or barbed wire, cannot be cleared by flails or rollers but could be demined with DEMICHAIN.

The chain web is cheap and rugged; it could be built locally. Its geometry could be adapted to the place to be demined (for instance a road or a trail, with ditches and banks). It is a tool which could be adapted to many lifting machines. This concept is within the reach of small or poor demining organizations, which cannot afford specialized machines. On another side, it is also well-adapted to dealing with problems such as small areas or uneven parts of large areas.

Our study

Methodology

DEMICHAIN being a new concept, it must be well understood before being used on live areas. Taking advantage of the characteristics of DEMICHAIN (one-dimensional effect), ARTID is performing a study of the forces developed by the free fall of a web of chains on buried force detectors.

If the results of this study show that these forces will trigger any buried landmines, and if the required parameters for obtaining these forces can be specified for the landmines likely to be found and the ground to be demined, then a second phase can be undertaken: tests on real landmines.



Fig. 4: the "light" prototype



Fig. 5: the "heavy" device

Prototypes

So far, we have built two prototypes:

- The "light" or "agricultural" device, with 400 kg of chains on a web of $2 \times 1.75 \text{ m}^2$. It is handled by the hydraulic arm of a conventional tractor and adapted to performing measurements (fig. 3).
- The "heavy" device, with 1300 kg of chains and a surface of $2.5 \times 2.8 \text{ m}^2$, handled by a wheeled industrial excavator equipped with a multi-tine grapple, may be used on live areas provided the excavator has to be armoured (fig. 4).

Force measurement

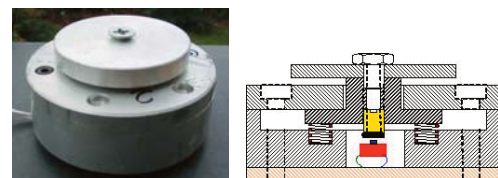


Fig. 6: the pressure detector

We have built rugged detectors in which springs are compressed as a piston moves and closes a micro switch as soon as the force exerted on the pressure plate exceeds 15 kgf (150 N). The diameter of the pressure plate ranges from 4 to 9 cm. An electronic unit collects data from up to 10 detectors and records the transient signals from the micro-switches. These detectors are generally buried at depths of about 20 cm.

Results

Very positive results have been obtained, showing that the detectors buried 20 cm deep react

positively to both prototypes, with a height of free fall of more than 2.5 m. Different soils have been tested: agricultural soil (meadow), gravel, sand and sandy soil (rubble); this last was very dry and firm whereas the others were water-logged. No differences of behaviour have been observed. One test, with detectors buried 45 cm deep in sandy soil, was also positive with a height of free fall of 3 m.

A further test was made by putting stones (more than 10 cm in diameter) among the buried detectors. Most of the detectors react positively; those that did not were located at the edge of the impacted zone. A careful investigation of the useful area will be made, because the propagation of the pressure wave at the edge is no longer one dimensional.

Where could this tool be useful?

The toolbox of the deminer can be completed by a DEMICHAIN tool for dealing with following problems:

- Area reduction (the DEMICHAIN tool is very versatile and does not destroy the surface of the ground).
- Demining of road sides and of difficult ground (maquis for instance)
- As an accessory of other mechanical demining techniques, for operating at the sides of the main surface
- As a ground preparation tool for small tasks or for small organizations

Another potentially interesting application (not yet investigated) consists in the ability to generate the required forces at great depths. This is an interesting feature for sandy areas like deserts, where the burial depth can vary due to the movement of the sand.

Conclusions - tests with real landmines

As soon as the current study can be positively completed, tests on real landmines will be required before the device can be used on live ground. The CTRO is specially adapted for such tests. The problem today is to obtain the necessary funding.

In fact, the purpose of our Association ARTID is to perform research into new ways to help eradicate AP mines. Other organizations can take our results and develop, test and use the DEMICHAIN tool in order to eradicate AP mines faster. The DEMICHAIN idea, the results of the study are published and not patented.

Acknowledgements

The authors would like to thank all the members of the ARTID who helped in the tests and in the fruitful discussions, namely Christian BARAS for the electronics, John CRAWFORD for a good translation in English and many discussions, Robert GOEPFERT for all the work done with the "light" prototype in RANSPACH-le-BAS, Claude HARTMANN for the building of the prototypes, Jean-Pierre HANCY as well as Danielle and Michel SAMIRANT for their participation to the tests. They are especially thankful to Jacques DEMICHELIS for his nice idea and also his interesting suggestions.

References

- ¹ V.S. Shankhla "Unravelling flail-buried mine interaction in mine neutralization" Technical Memorandum DRES TM 2000-054 (December 2000)
- ² René Joecklé "Research of new tools for demining by ARTID" p. 680, EUDEM2 – SCOTT Conference, Brussels, September 2003
- ³ ARTID: Association for Research of Innovative Techniques for *humanitarian* Demining (in French: "Association de Recherche de Techniques Innovantes en Déminage *humanitaire*") is a French association, set up in 2000 to find and develop new techniques for humanitarian demining. Most of its members are retired scientists or engineers. It is located in SAINT-LOUIS, a small French city at the junction of the borders between France, Germany and Switzerland. One of its tasks is gathering and diffusing information about demining techniques (website www.artid.org).
- ⁴ Scott, R.A., Pearce, R.W., "Soil compaction by impact", 1976, Institution of Civil Engineers: Symposium Report.

International Trust Fund For Demining and Mine Victims Assistance

Roman Turšič³⁵

ITEMS:

1. Short overview of achievements of International Trust Fund for Demining and Mine Victims Assistance (ITF)

International Trust Fund For Demining and Mine Victims Assistance is a humanitarian, non-profit organization devoted to eradication of the landmines from the ground in the region of South East Europe and the world.

When first established by the Slovenian government in March 1998, ITF was to assist Bosnia and Herzegovina in solving its landmine problem, and help surviving landmine victims with physical and social rehabilitation/reintegration. However, as BiH was not the only country in the region affected by landmines it was only fair to spread its operations to all other mine-affected countries in SE Europe as well. Presently, ITF is working in Albania, Bosnia and Herzegovina, Croatia, Macedonia, Montenegro and Serbia.

The ITF headquarters is located in Ig, Slovenia where twelve people are employed. In addition to its main office, the ITF also opened an implementation office in Sarajevo for activities conducted in Bosnia–Herzegovina that employs a further five people. ITF also opened an office in Croatia where 1 person is currently employed. The ITF finances demining and mine victims' assistance activities in the region of South-East Europe from donations raised for this purpose. One of the reasons for the ITF's success and very positive results in the field of mine clearance in the SEE region is the “matching fund” mechanism provided by the United States government. The “matching fund” mechanism means that every dollar contributed to the ITF triggers an additional dollar from the United States. This means that the effect of the original donation is

in fact doubled as the matching funds are also used for mine action activities in the SEE region. By April 2007, the ITF has managed to raise more than 225.43 million USD from the 28 donor countries, EU and UNDP and over 100 donor organizations, companies and individuals.

The matching fund is not the only reason behind the ITF's success. The main advantages contributing to the ITF's evolution into one of the most important players in mine action in South-East Europe are: the ITF's close cooperation with the responsible authorities in the countries where it conducts its operations, cost-effectiveness, transparency and low cost of its operations. The ITF retains only three (3) percent of contributions to support its administrative and project costs.

By June 2007, more than 76,44 million square meters of mine and UXO contaminated land in South-East Europe was cleaned through programs managed by ITF. In the field of mine victims assistance, 928 mine victims were rehabilitated at the Slovenian Institute for Rehabilitation and in rehabilitation centers in Bosnia and Herzegovina.

2. Experience in the field of mechanical ground preparation

Mechanical ground preparation is a part of ITF activities in the field of humanitarian demining and is significant especially for Bosnia nad Herzegovina. Mechanical ground preparation was carried out within the demining and technical survey activities of Norwegian Peoples Aid and Army of Bosnia and Herzegovina.

There were two Community based integrated mine action plans (CIMAP) financed by Germany and implemented by Norwegian Peoples Aid in Year 2006. CIMAP was carried out in community Grebnice Ogradice in Posavska County, where 959.463 square meters were cleared with 125 mines and 108 UXO mostly through operations of technical survey. Another CIMAP was

³⁵ ITF, Head of ITF Implementation Office in Sarajevo, tursic@itf-fund.si

implemented in community Omerbegovača in Brčko District where 481.789 square meters were cleared with 239 mines and 25 UXO mostly through operations of technical survey. MGP was done by demining machine Mine wolf and followed up by NPA deminers and NPA Mine Detection Dog Teams (MDD).

Army of Bosnia and Herzegovina played significant role in the field of demining in BiH in 2006. Out of 10,2 mio square meters cleared in Bosnia and Herzegovina in 2005, Army of Bosnia and Herzegovina managed to clear 2,02 mio square meters of land (20 % of all cleared land in 2006). In demining activities were engaged 300 Army deminers organized in 32 demining teams. Additional 3 tenders in total surface of 270.000

square meters were issued in 2006 for MGP and were performed by Commercial companies/NGOs and then followed up by Army deminers. The most important and significant result of MGP was the cleared land turned over to local population for their use. Due to the fact that Army of Bosnia and Herzegovina does not have enough capacities on the field, MGP is very important phase for them, since the demining and TS activities are much easier and safer for Army deminers.

ITF will continue with the support of MGP for the NPA projects and projects, where Army deminers are involved due to its significance for humanitarian demining results in Bosnia and Herzegovina.

Machine Demonstration Analysis and Preliminary Results

Geoff Coley³⁶

In support of the HCR-CTRO symposium in April 2007, a machine demonstration was conducted. In this event 10 parallel test/demonstration lanes were prepared in the Skradin-area demonstration field. In each lane three fibreboards were placed in the manner described by CWA15044. Three additional decoy areas, or strips, were prepared so that the machine operators could not tell where the three boards were located. The manufacturers/operators were given an instruction about how to use their machines (see attachment below). The machines were timed on the outbound 50m lane, and they were timed on their turnaround. The fibreboards were set to be able to capture the outbound lane plus the intended 30cm overlap. In the end only nine machines were present to run the course.

Using this information plus the manufacturers' published working width, it was possible to present a snapshot of the digging capability of each machine and to extrapolate the time required to process a 100m x 100m area including working time and turnaround time. Of course it is possible that each of the machines could have been operated faster in order to improve the 1 ha processing time. It is also possible that slower operation might have resulted in better depth results. The MV-4 suffered some kind of breakdown part way through the run. The Hydrema MFV2500 working head was driven hard enough to bog down a couple times. The Samson 300 created such a cloud of dust that the operator could not see and had to stop briefly, and the machine had apparently been mistakenly set for a depth of 15cm instead of 20cm. The Minewolf was operated at a very high speed but the working head porpoised up and down throughout the run. Clearly each of the machines might have been able to achieve different or possibly better re-

sults had they been operated in a different manner. The limitation of this demonstration is that it provides just a single snapshot into the performance of each machine. There are many other important factors in the evaluation of a machine, including fuel consumption, spares needed, training, transportability, and maintenance.

Although most of the machines looked impressive from the viewing area, inspection of the lanes showed that some of them did not dig as deeply as they were capable. None of the depths achieved was very deep. This was not a function of the soil conditions as test team members have seen some of these machines dig deeper in harder soils. It appeared that some of the machine owners or the operators might not have taken the soil working portion of the day very seriously, with some of the test team wondering if some of them would have done a better job if they had been working a real minefield.

For the purposes of this discussion, the following definitions and conditions apply:

- **Target Overlap:** Machines were to create an outbound lane, turn around and then create a return lane having a 0.3m overlap with the outbound lane.
- **1 ha Processing Time:** Using the time to process the 50m outbound lane, the time to turn around, the published working width of the machine and the 0.3m overlap, a time was calculated for the machine to complete a hypothetical 100m x 100m area.
- **Centre Band:** Assuming that lanes were to have a 0.3m overlap, the centre portion of the working width was calculated for each machine. For example, the Bozena-4 has a published width of 2.22m. With a 0.3m overlap shoulder on each side, this amounts to a centre band of 1.62m (2.22-0.3-0.3), or 73% over

³⁶ Defence R&D Canada –Suffield Ralston, AB, T0J 2N0 Canada,
e: geoff.coley@drdc-rddc.gc.ca

- the published working width. ROI, or Region of Interest is the same as Centre Band.
- Target mine: While no mines were used in the demonstration, a hypothetical round mine of diameter 5cm (similar to a PMA-2) was used for the purposes of calculations.
 - Maximum Effective Depth: Based on the three fibreboards, this is the minimum depth at which a target mine might have been able to hide without being contacted by the machine. In this calculation the two 0.3m wide shoulder areas are disregarded and only the remaining centre band is considered since it is assumed that poor performance in the shoulders would be erased when the next lane is overlapped. MED for the full width is also

available.

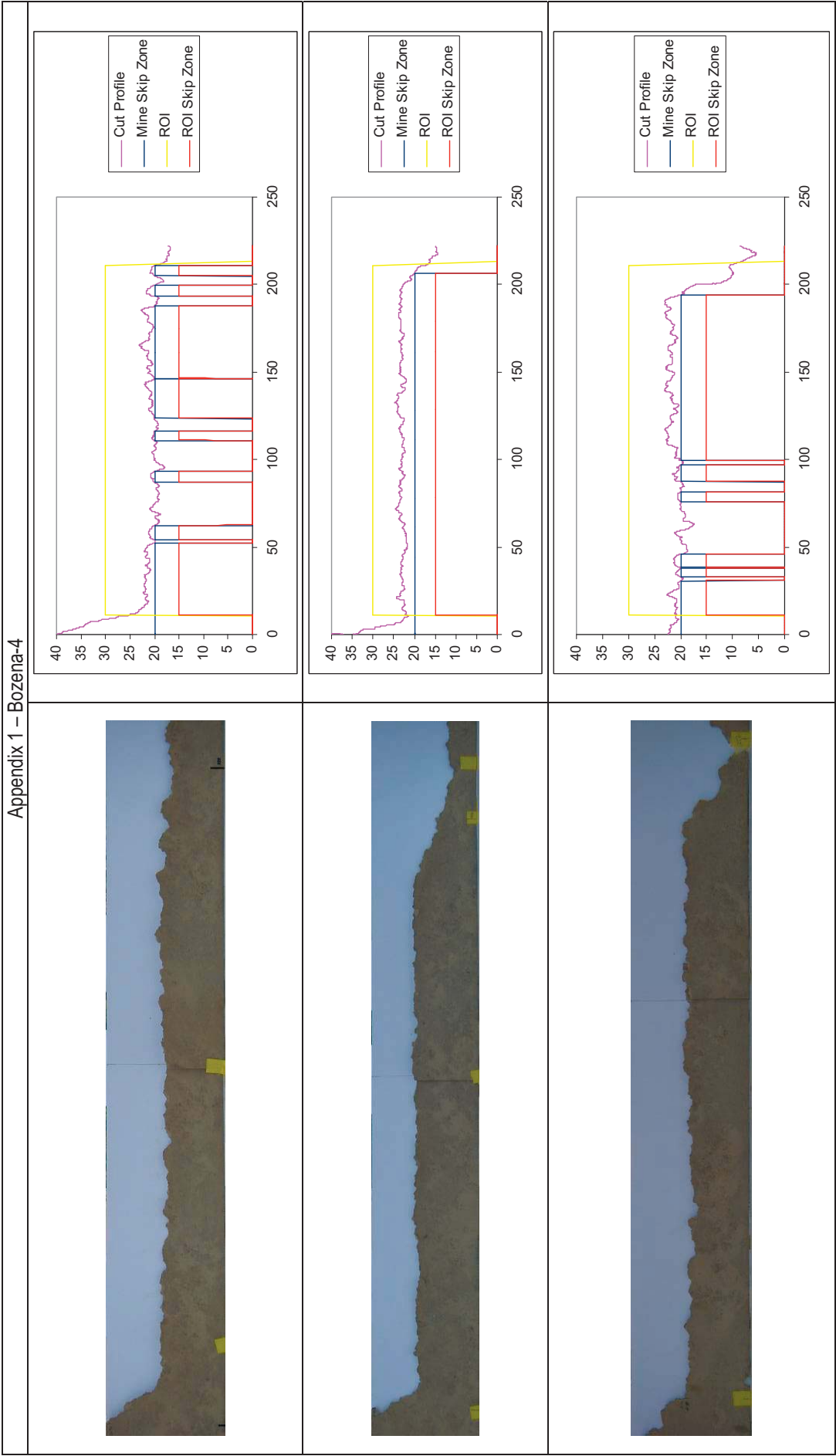
- Penetration Efficiency (PE(20)): Based on the three fibreboards, this is the percentage of the lane that was successfully processed to the indicated depth (in this case, 20cm). For example, if PE(20)=92%, it suggests that the machine was able to process 92% of the lane to a depth of 20cm. Similar values are given for depths other than 20cm. Like MED, this considers only the centre band, although the full width data is available.


The summary of performance assuming a goal of 20cm depth is shown in Tables A1,A2 and A3. The results are presented in more detail in the appendices that follow.

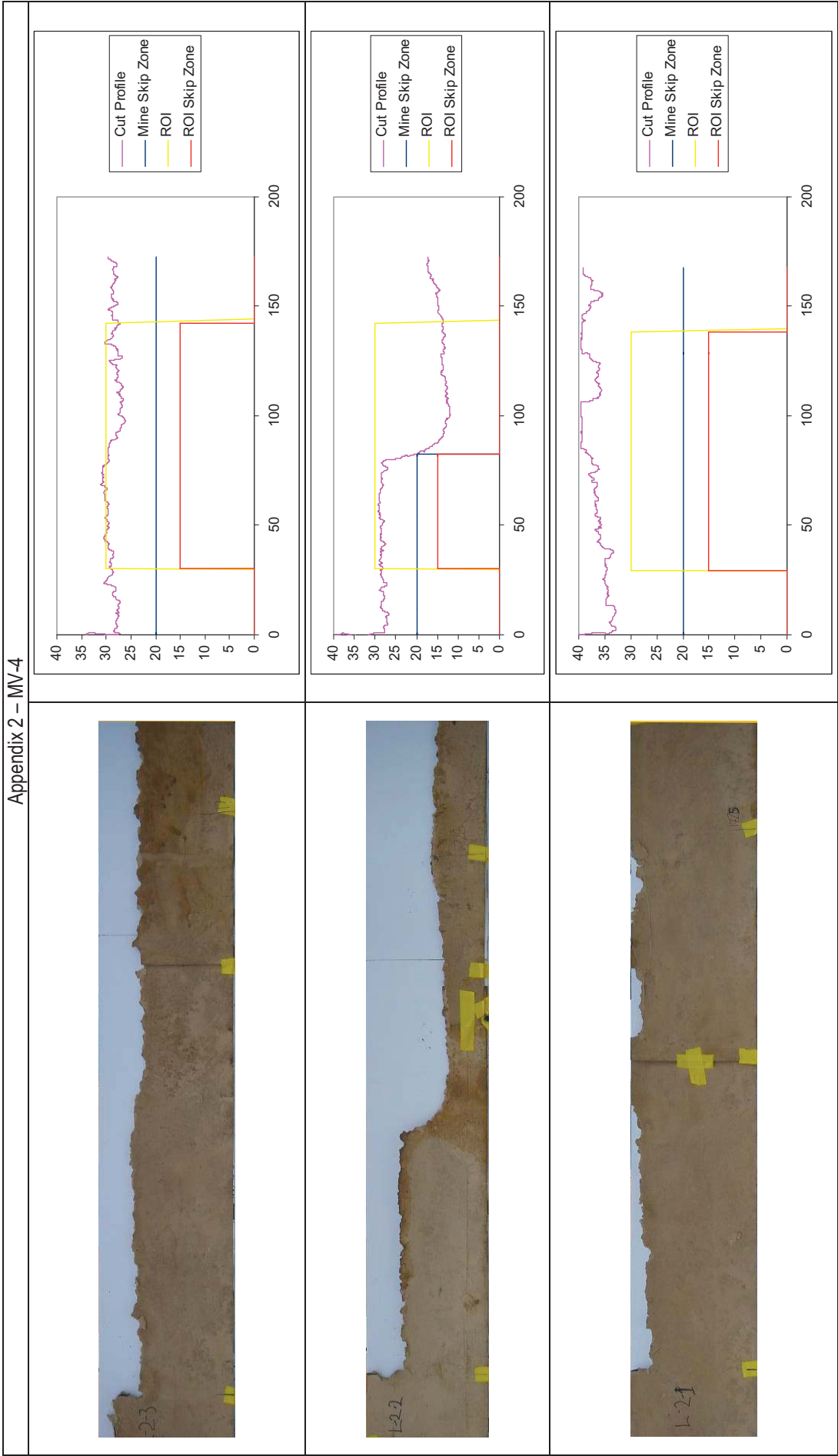
Table A1 – Performance Summary – Light Machines				
Machine	Lane	1ha Processing Time (hours)	MED (centre band) (cm)	PE(20cm) (centre band) (%)
Bozena-4	L1	23.14	16	20%
MV-4	L2	13.82	0	18%

Table A2 – Performance Summary – Heavy Machine				
Machine	Lane	1ha Processing Time (hours)	MED (centre band) (cm)	PE(20cm) (centre band) (%)
Minewolf	T2	3.60	10	18%

Table A3 – Performance Summary – Medium Machines				
Machine	Lane	1ha Processing Time (hours)	MED (centre band) (cm)	PE(20cm) (centre band) (%)
RM-KA-02	S1	7.28	1	17%
Samson-300	S2	9.07	8	0%
Mini-Minewolf	S3	10.77	19	90%
Bozena-5	S4	11.31	11	85%
HydremaMFV2500	S5	12.27	7	0%
MV-10	S6	8.28	9	25%



Appendix 1 – Bozena-4	
<div><div><div>Cut Width Published = 2.22m Overlap target = 0.3m</div><div>1 ha processing time = 23.14 hr</div></div><div><div>Penetration Efficiency</div><div><div>■ Bozena-4-Full Width</div><div>■ Bozena-4-Centre 73%</div></div></div><div><div>Maximum Effective Depth Centre Band = 16cm</div><div><div>PE(%)</div><div>100 90 80 70 60 50 40 30 20 10 0</div><div><div>510152025</div><div>Depth</div></div></div></div></div>	<div><div></div><div>Photo not taken at symposium demonstration</div></div> <div><ul style="list-style-type: none">Dead crawl all the way through – appeared to have consistent speed control. Some evidence of soil wave suggesting that machine may have been under manual depth control.</div>



Appendix 2 – MV-4

Cut Width
Published = 1.725 m
Overlap target = 0.3m

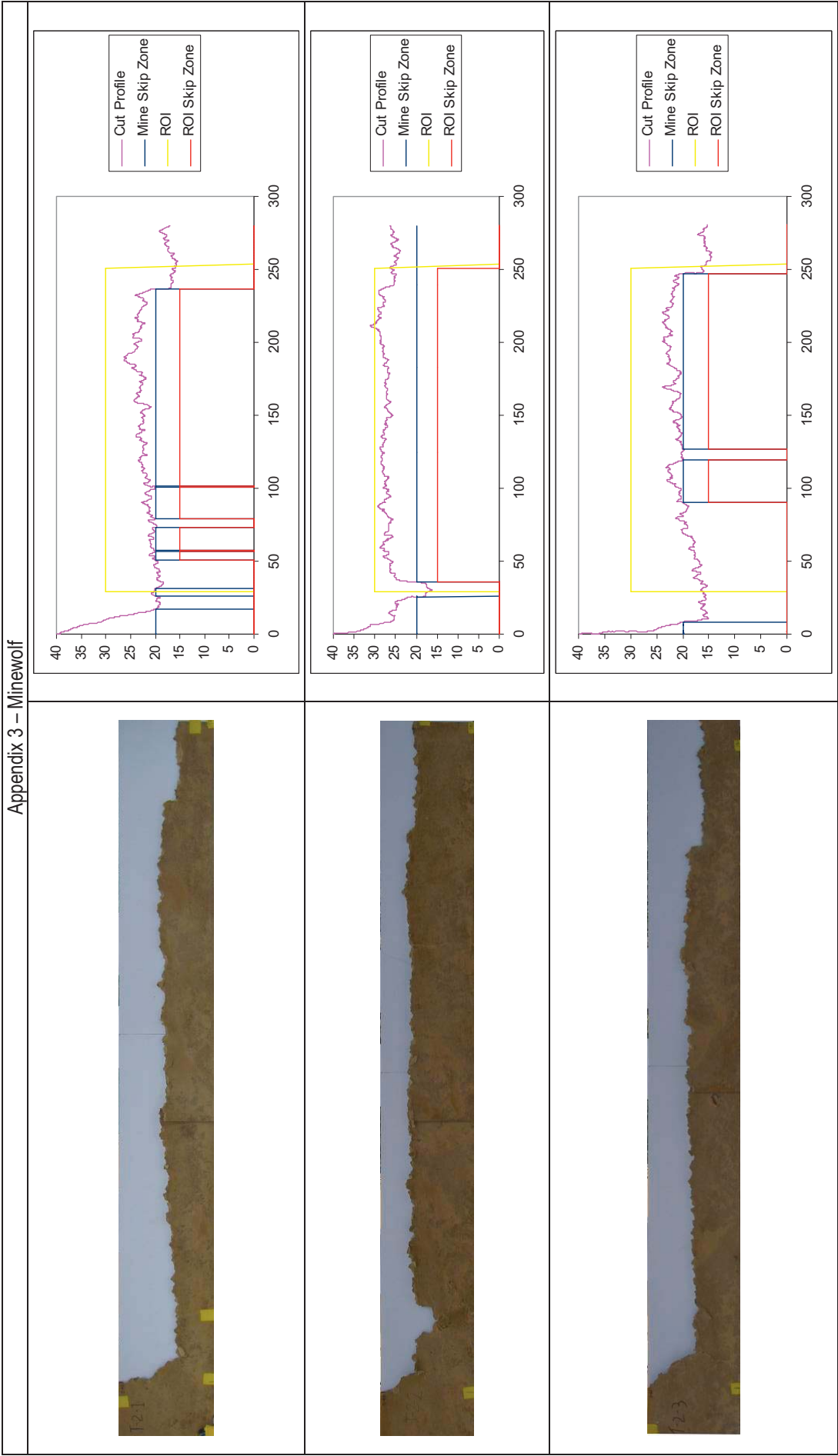
Penetration Efficiency

■ MV-4-Full Width ■ MV-4-Centre 65%

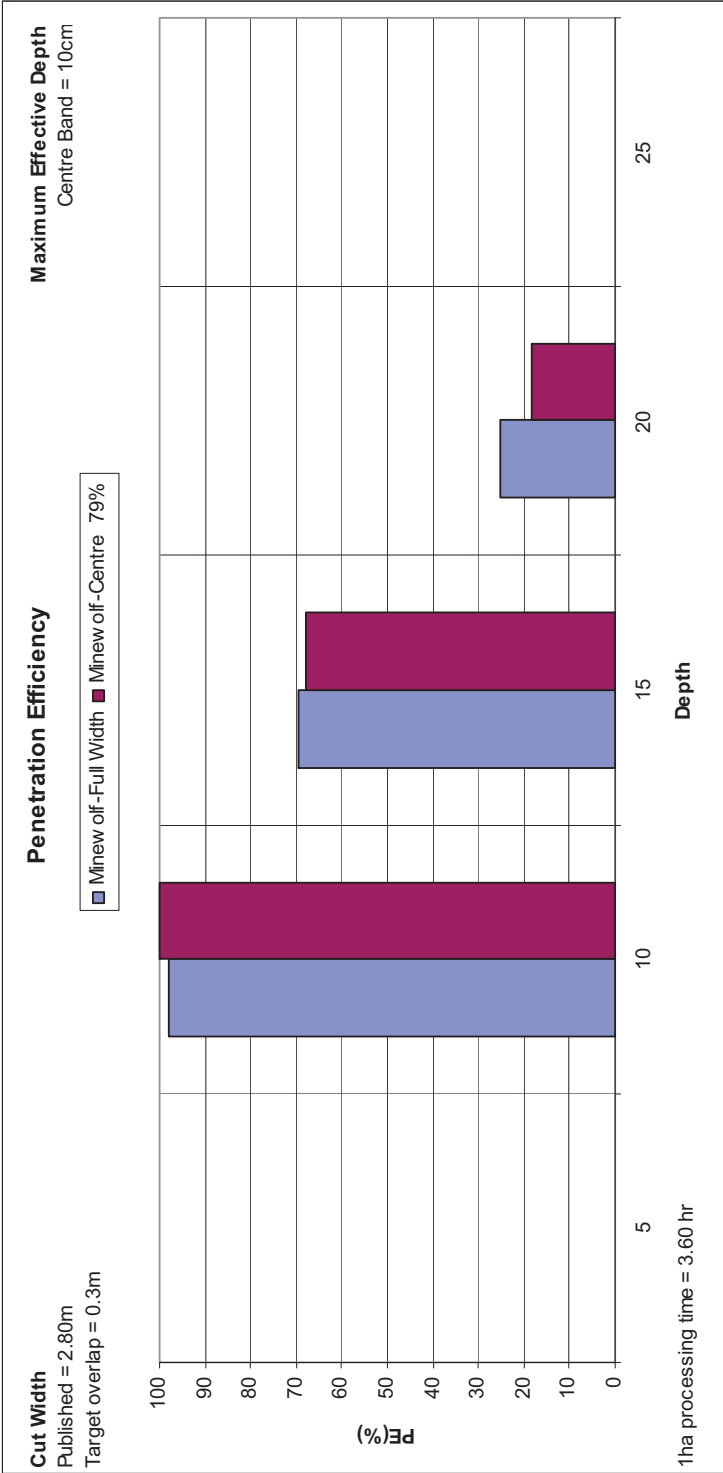
Maximum Effective Depth
Centre Band = 0 cm

1ha processing time = 13.82 hr

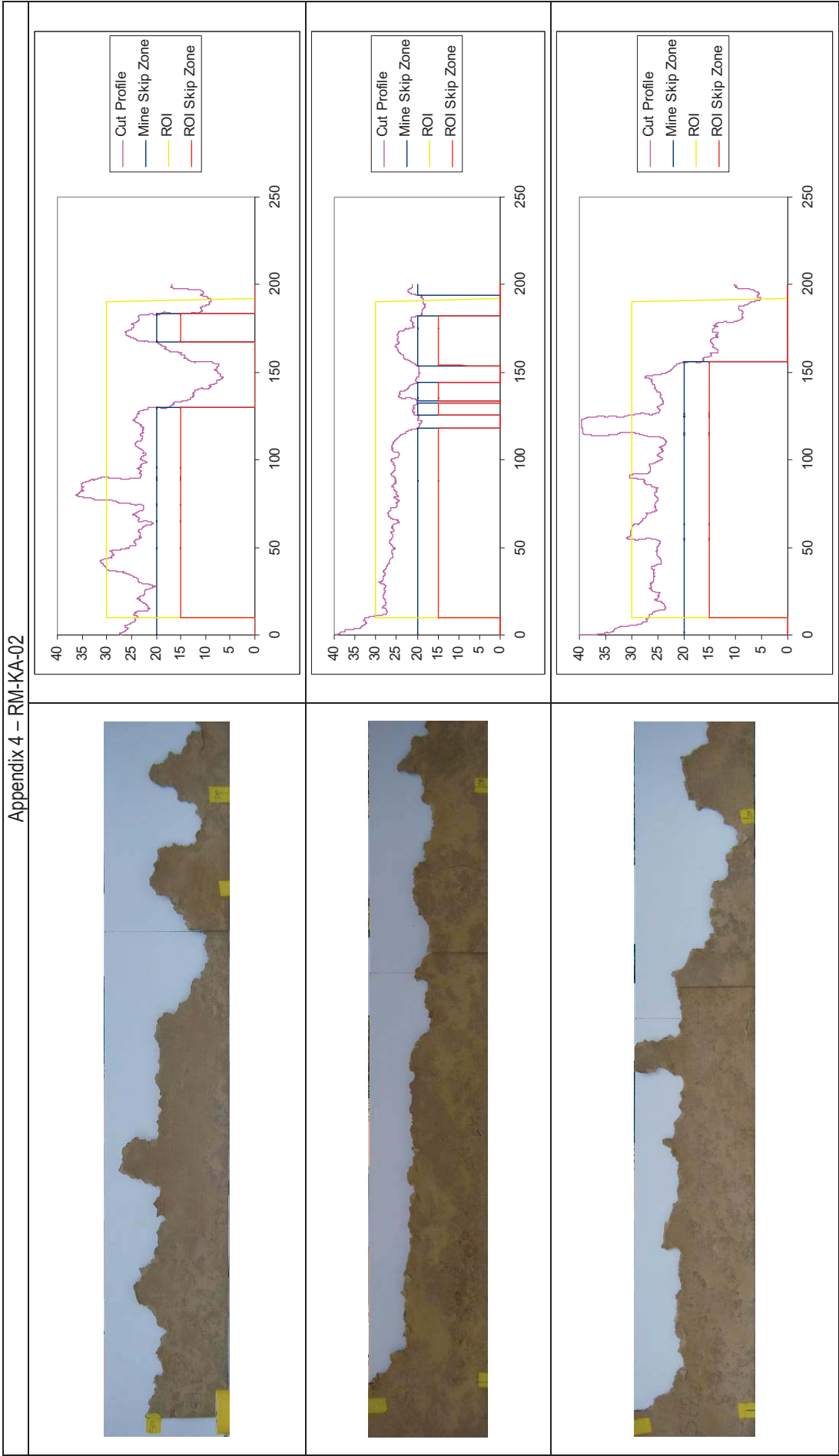
Depth (m)	MV-4-Full Width (PE%)	MV-4-Centre 65% (PE%)
10	58	60
15	18	18
20	15	15



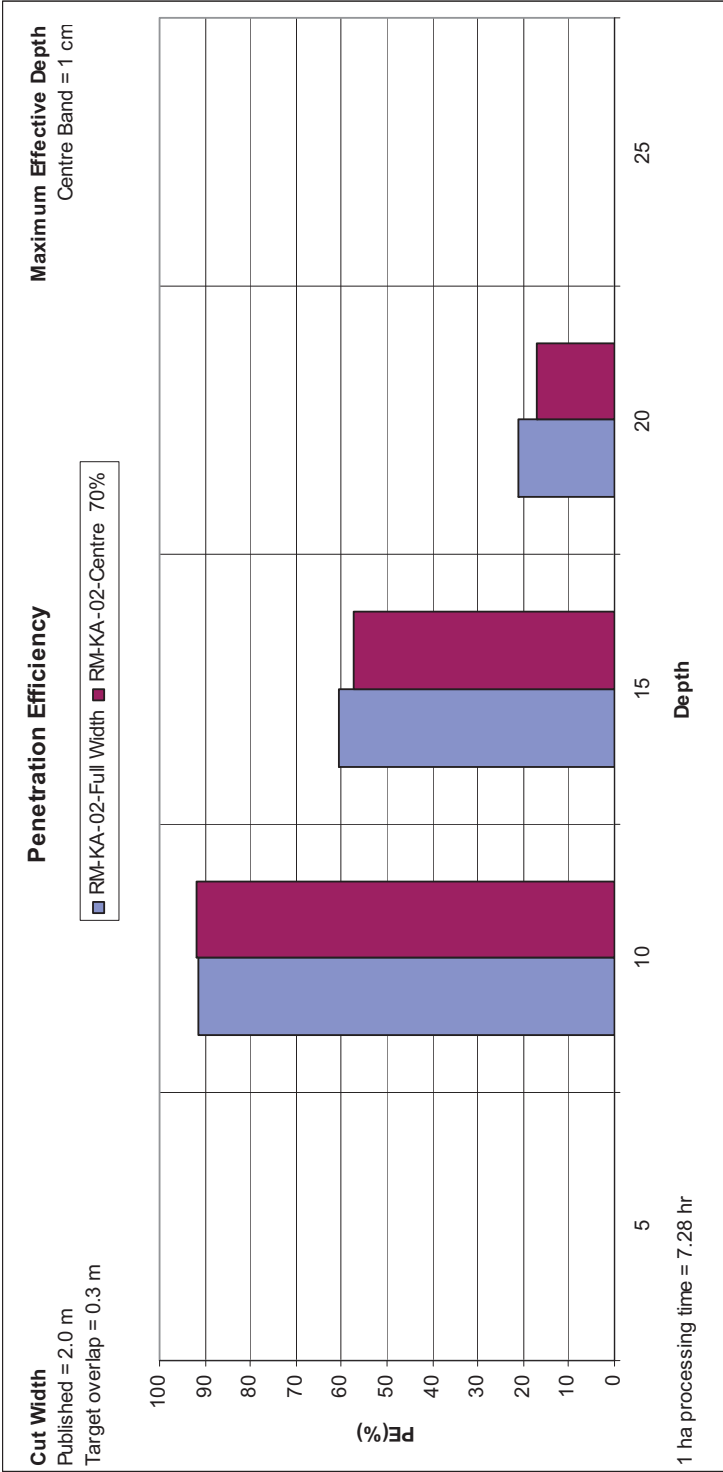
Appendix 3 – Minewolf



- Operated very fast and with erratic depth control. Very little dust cloud as soil is sliced, not pulverized. Throws a lot of debris under/behind machine. Speed consistent throughout. Tiller head porpoised its way through the test – operator control or a lag in the feedback?

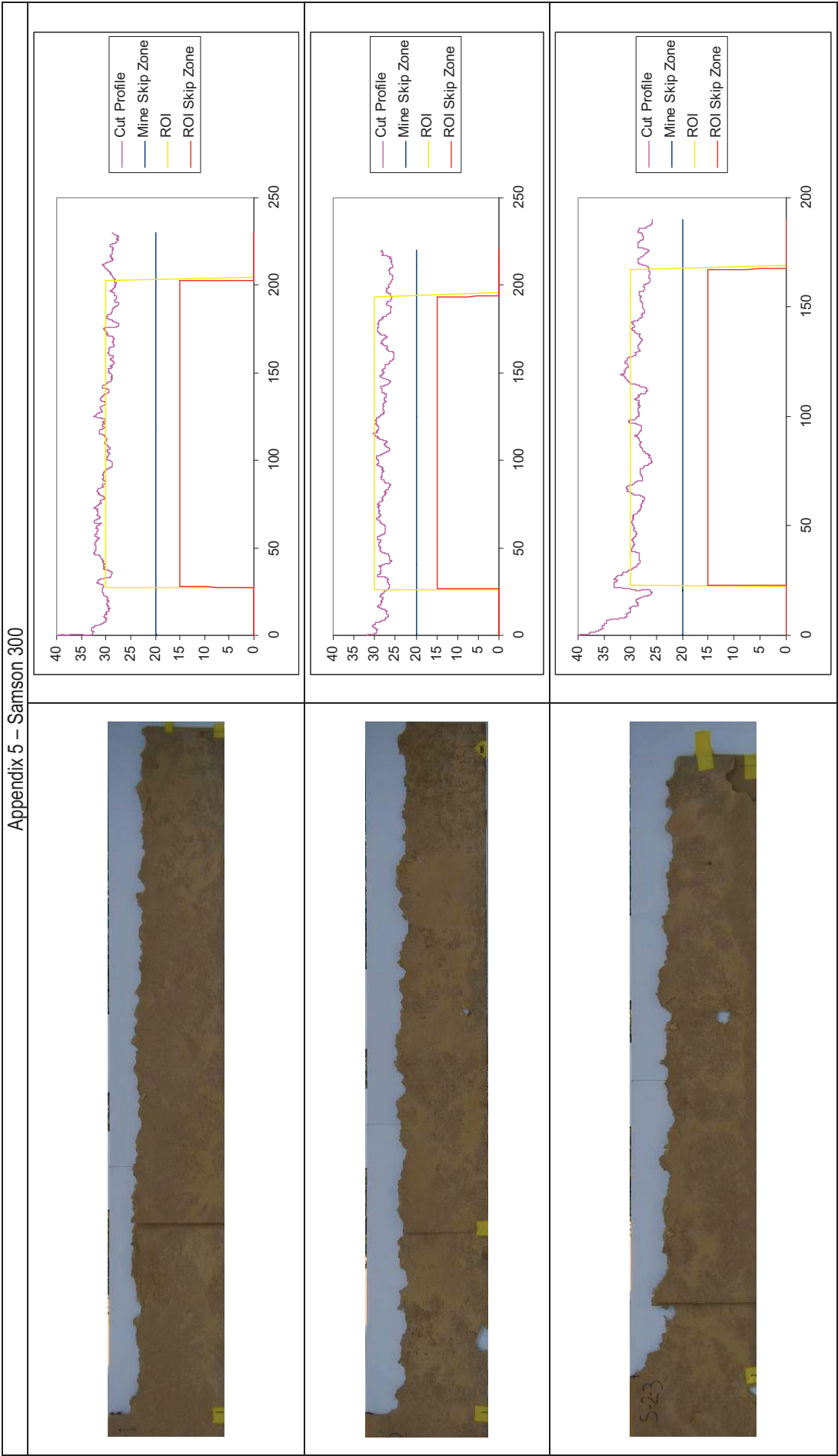


Appendix 4 – RM-KA-02

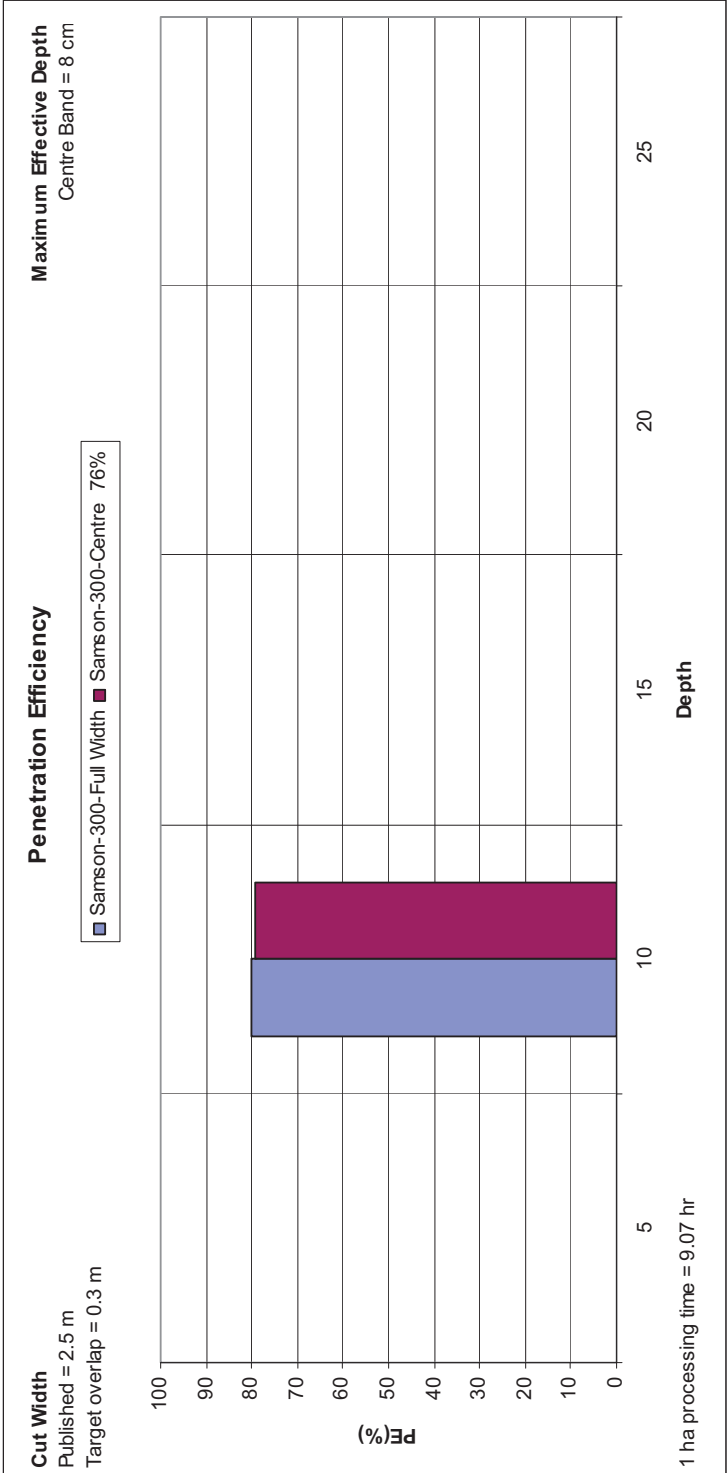


- RC operator wandered well into the test lane following the machine (far closer than the 50m requirement) until called back by official. (Was first machine to run so requirement may not have been clear to the operator.) Was forced to stop once on the return run because the visibility of the operator was obscured by a cloud of dust created by the operation of the Samson machine.


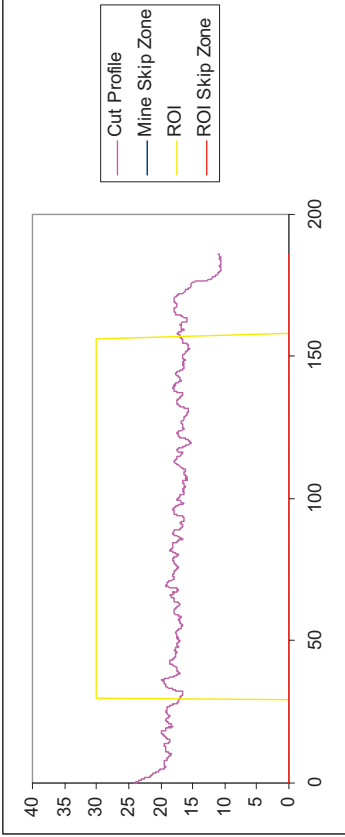

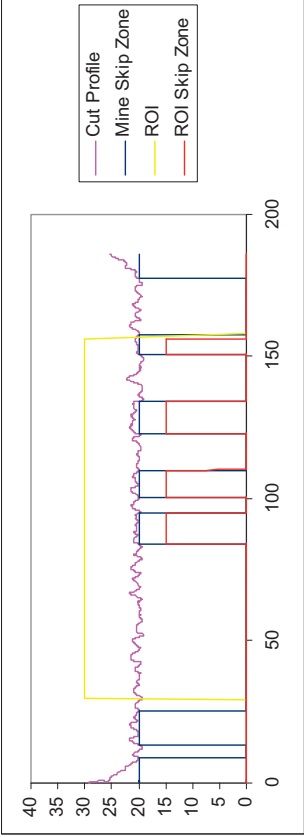

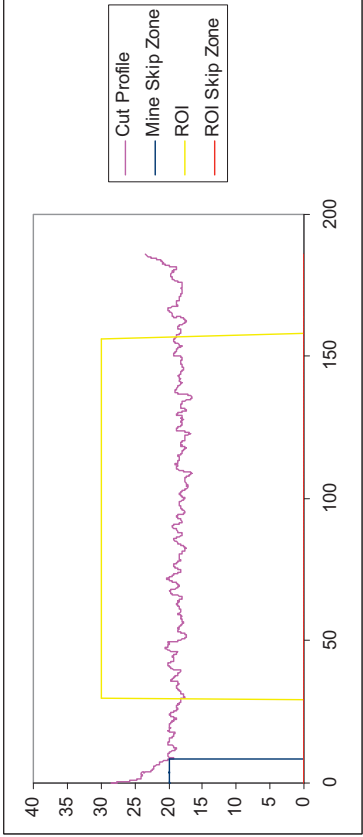
Appendix 5 – Samson 300



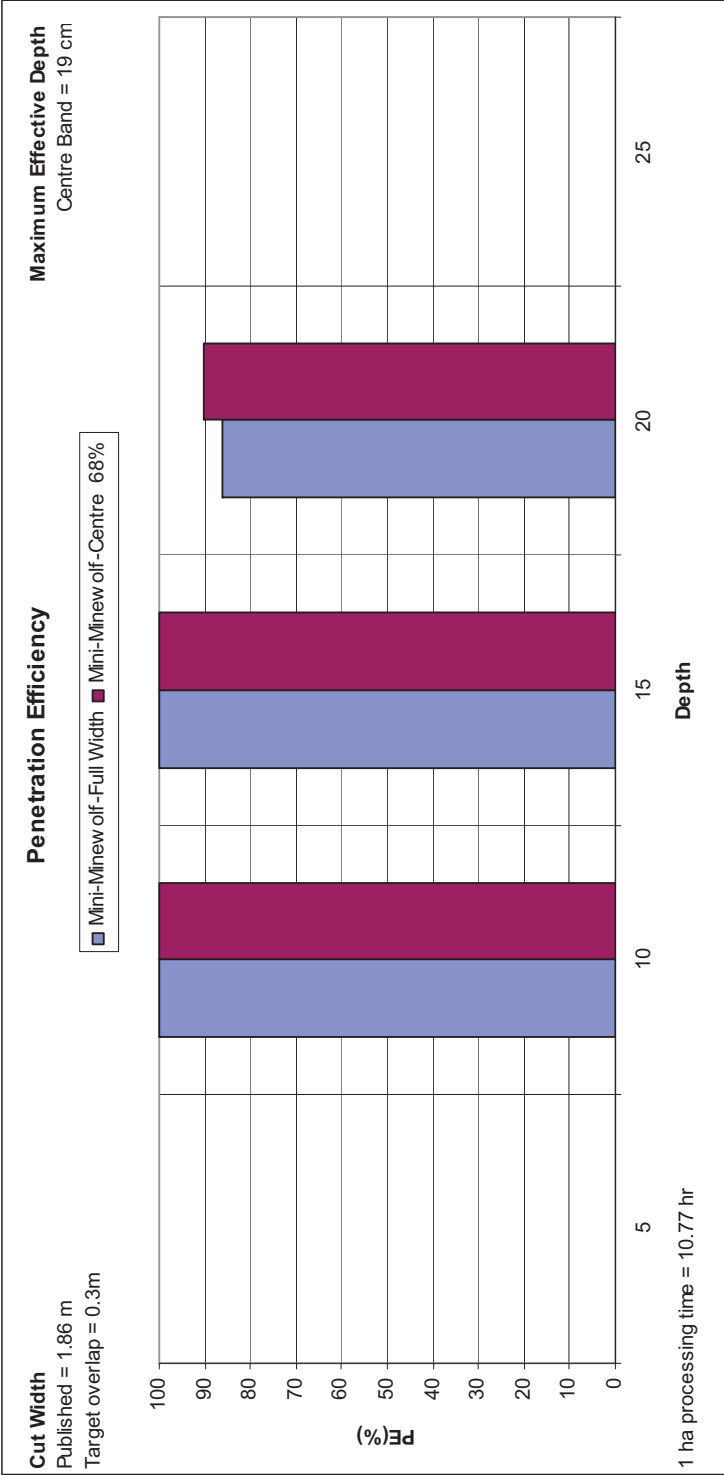
Appendix 5 – Samson 300



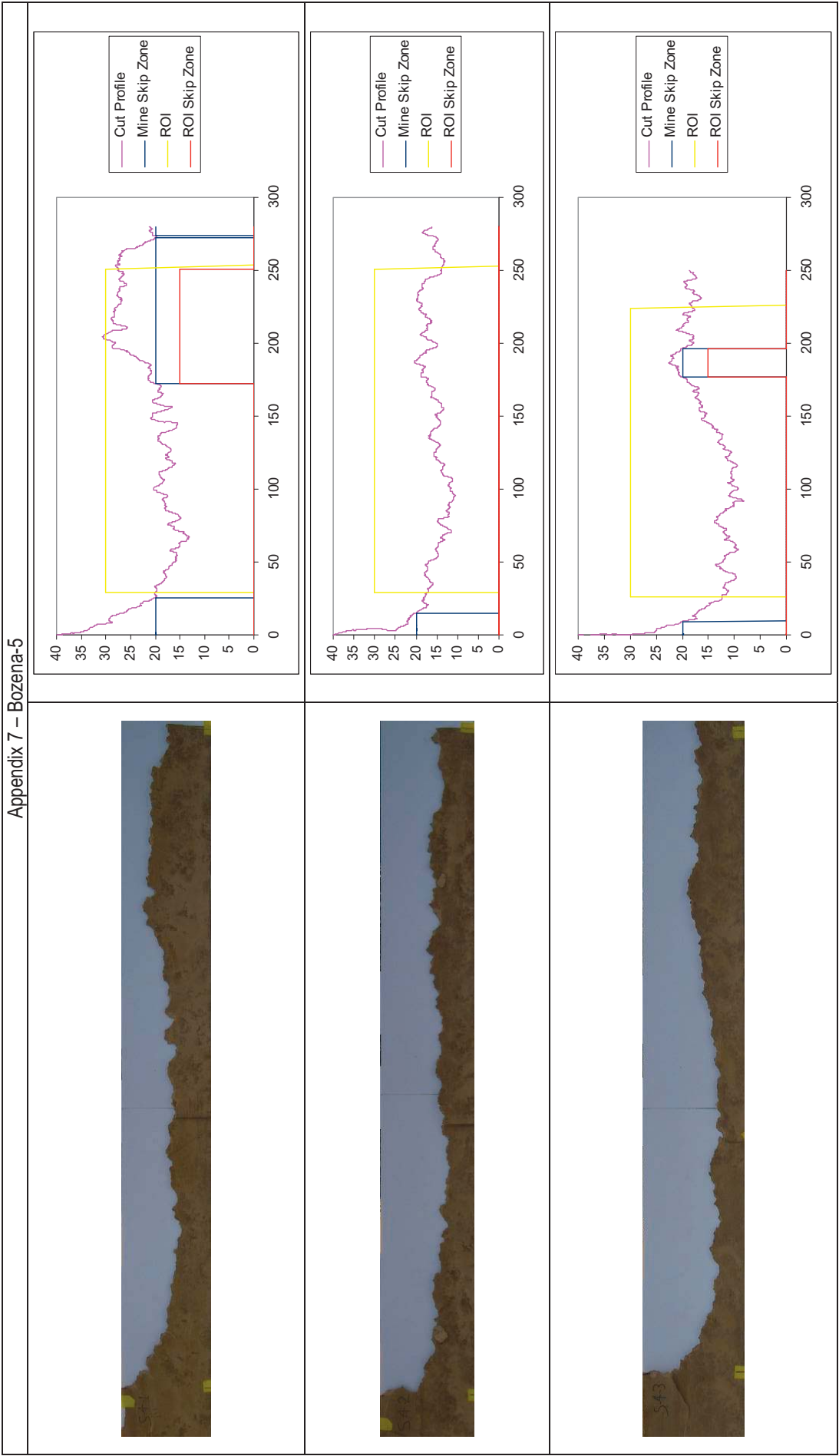
- Driver stopped briefly on return trip 3-4 times – probably a visibility issue. Huge dust cloud (partly caused by lack of shroud, partly because the machine worked to a shallow depth where the ground was dry). Apparently misunderstood requirement and thought depth of interest was only 15cm instead of 20cm.

Appendix 6 – Mini-Minewolf	
	
	
	

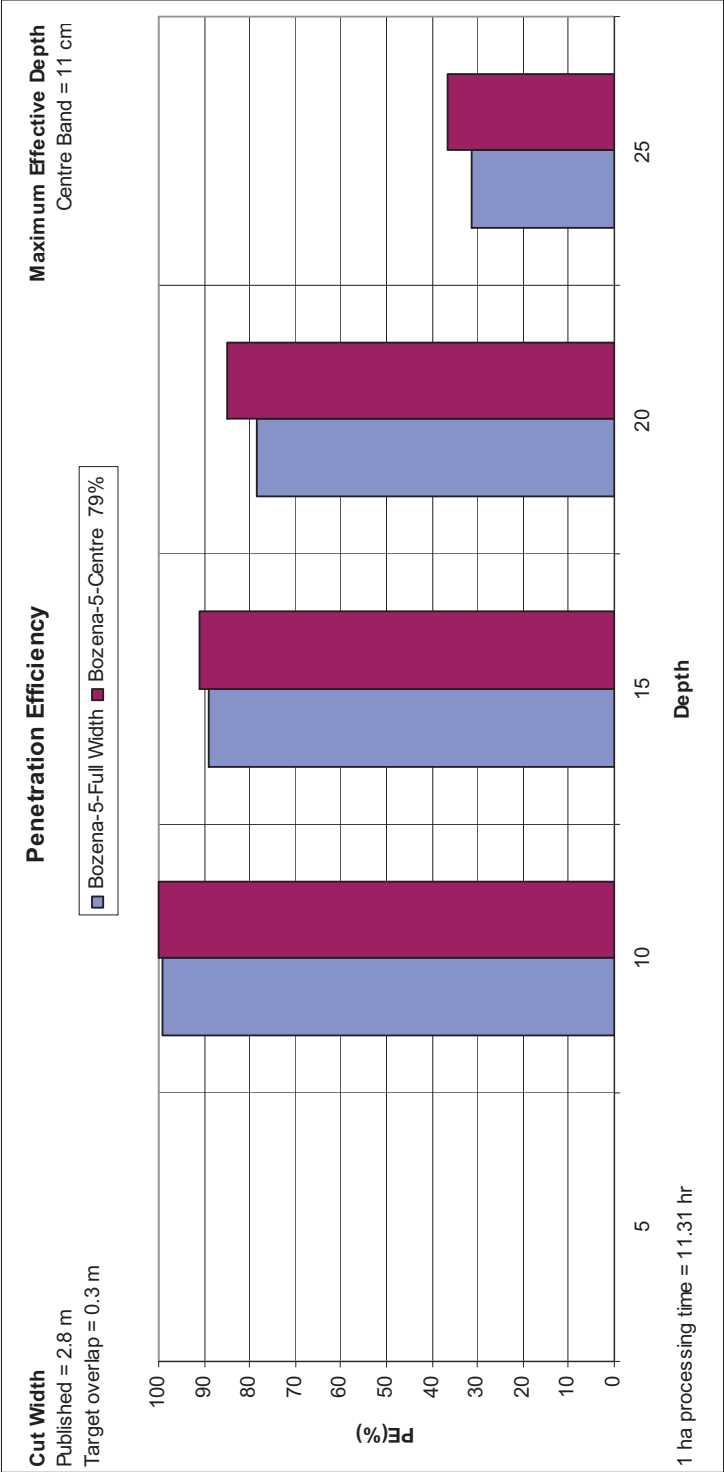
Appendix 6 – Mini-Minewolf



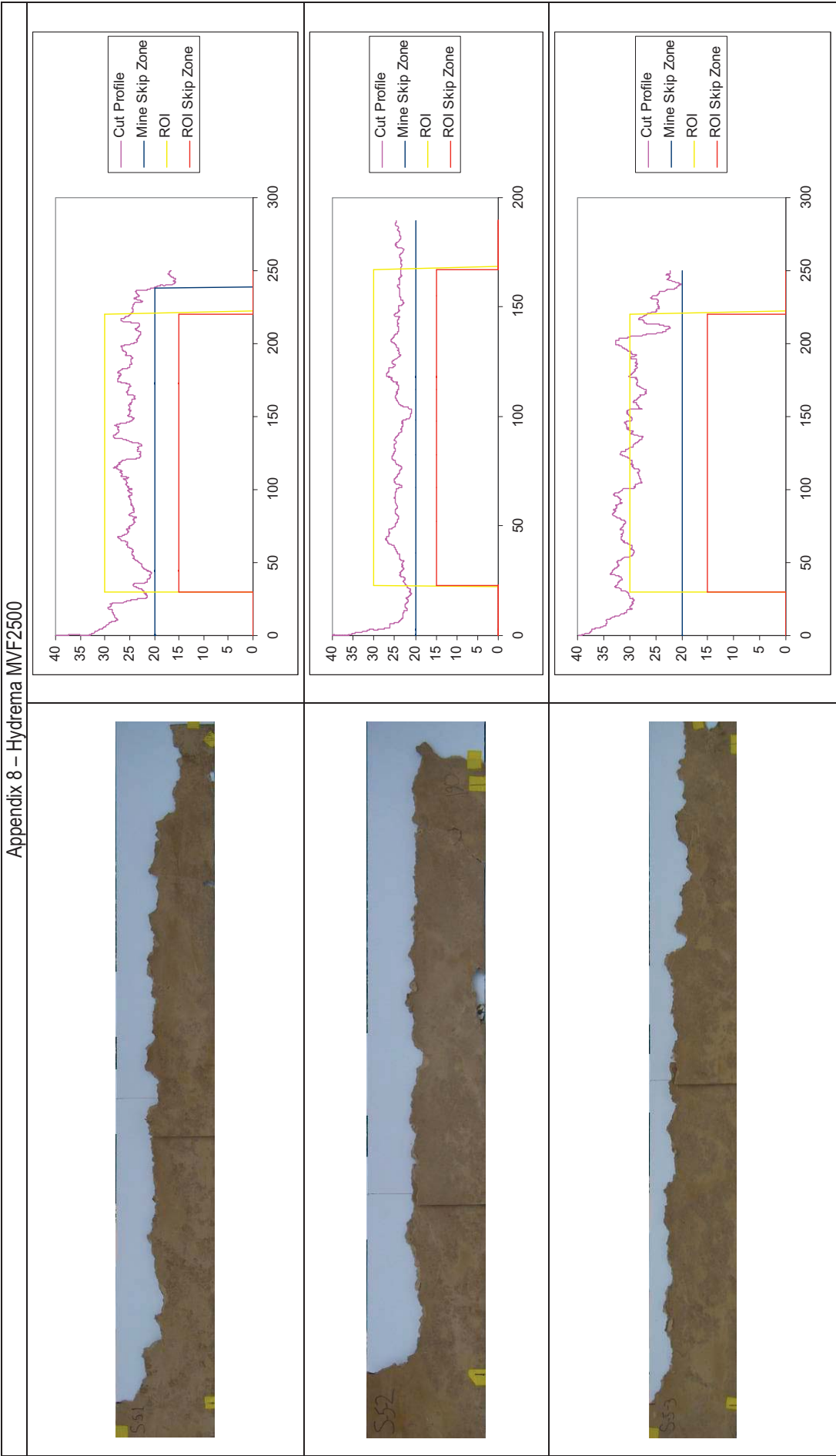
- Very little dust as soil is sliced, not pulverized. Soil only thrown a short distance ahead. From fibreboards, 30cm overlap not really achieved. Obviously a driver error issue not a machine performance issue.




Appendix 7 – Bozena-5

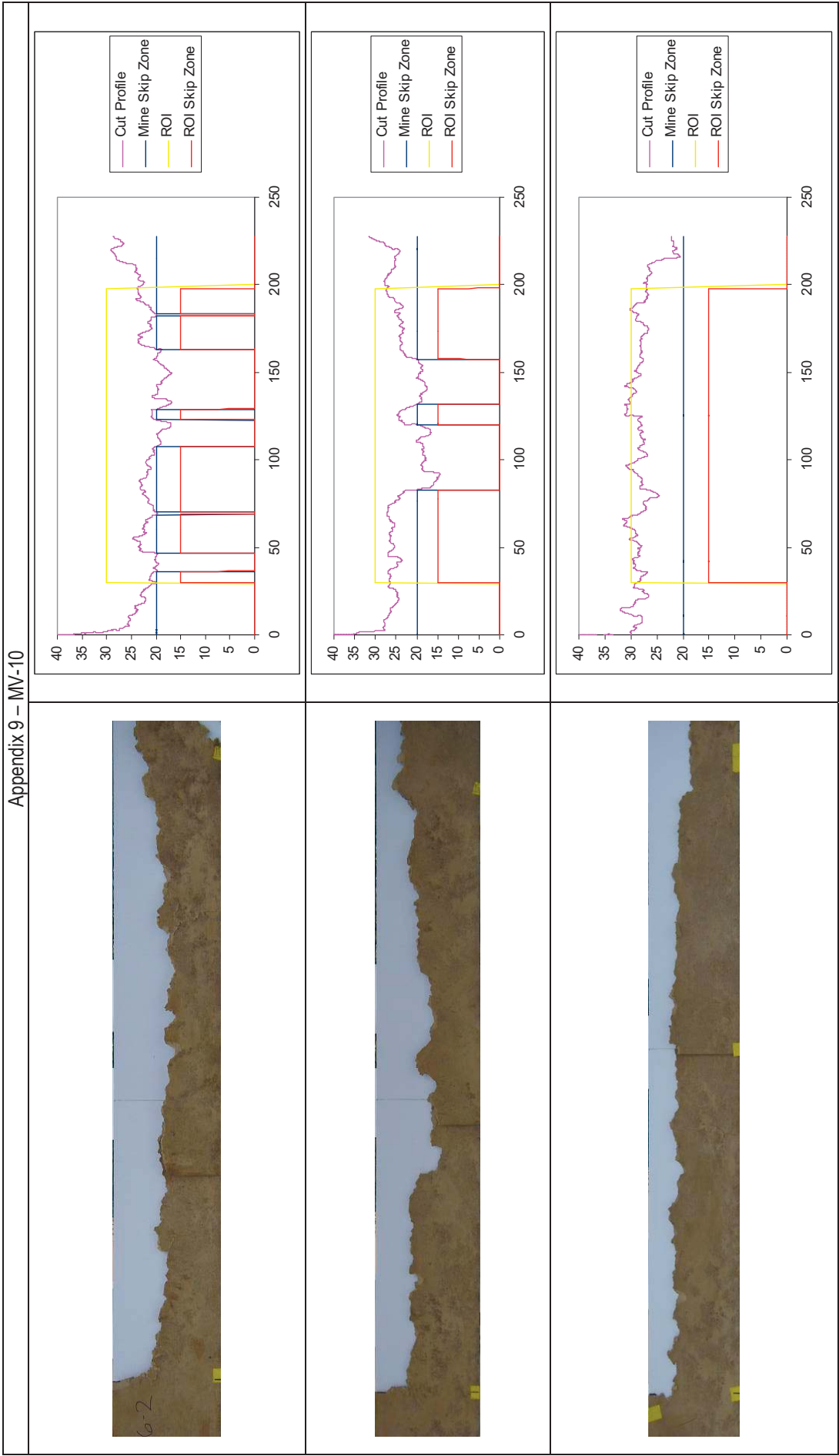


- Consistent speed control.

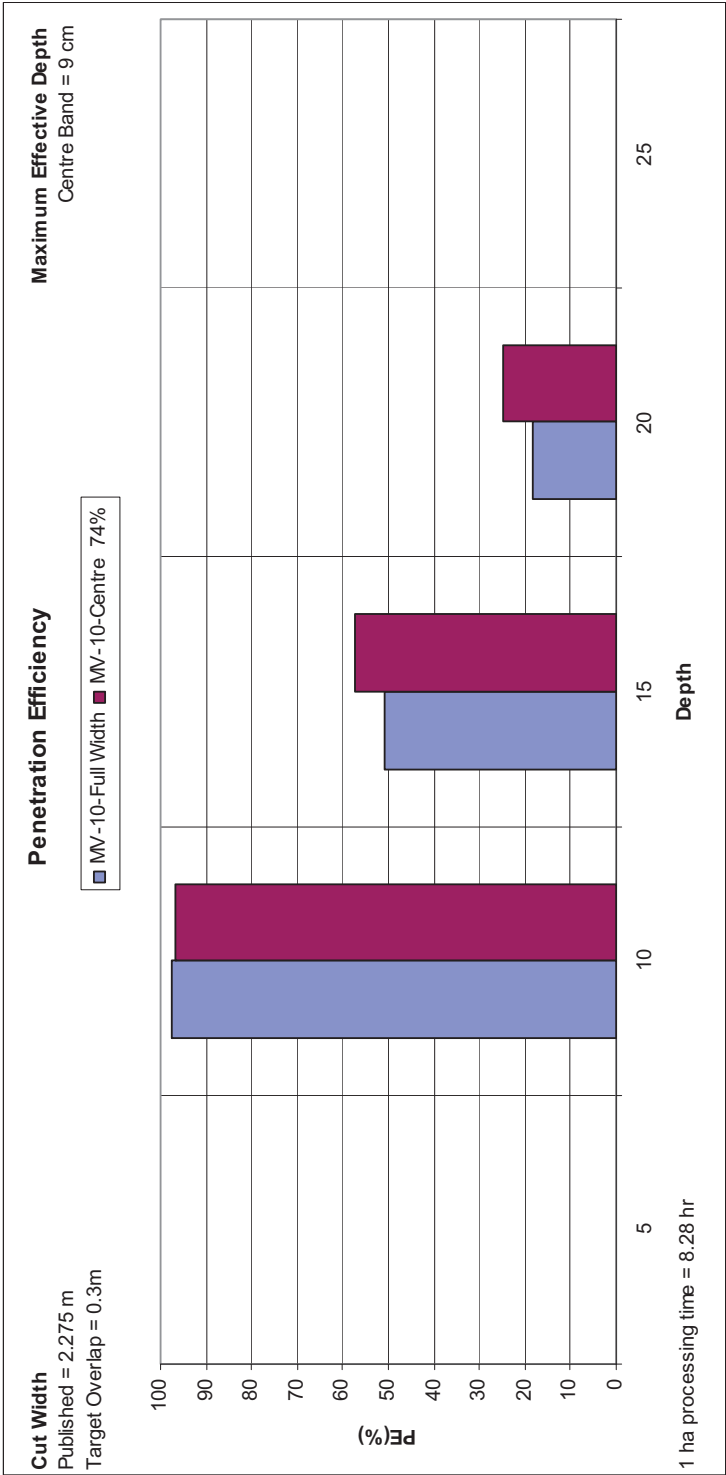


Appendix 8 – Hydrema MVE2500

<div><div><div>Cut Width Published = 2.50 m Target Overlap = 0.3m</div><div>Penetration Efficiency</div><div>Maximum Effective Depth Centre Band = 7 cm</div></div><div><div>■ HydremaMFV2500-Full Width</div><div>■ HydremaMFV2500-Centre 76%</div></div><div><div>PE(%)</div><div>100</div><div>90</div><div>80</div><div>70</div><div>60</div><div>50</div><div>40</div><div>30</div><div>20</div><div>10</div><div>0</div></div><div><div>5</div><div>10</div><div>15</div><div>20</div><div>25</div><div>Depth</div></div><div>1 ha processing time = 12.27 hr</div></div>		<div><div></div><div><ul style="list-style-type: none">• Exact PE(20cm) and MED values may be slightly off since the middle fibreboard was hit so far across the board that only 190cm of the cut could be captured. The difference should be minor.• Great variations in speed. Slowed visibly near board/decoy strips 1 and 2. Flail head stalled near strip 5. Machine stopped moving while trying to restart flail engine. Lots of smoke on restart of the flail engine. Happened again near strip 6. Slowed several times on return trip.</div></div>
---	--	---



Appendix 9 – MV-10

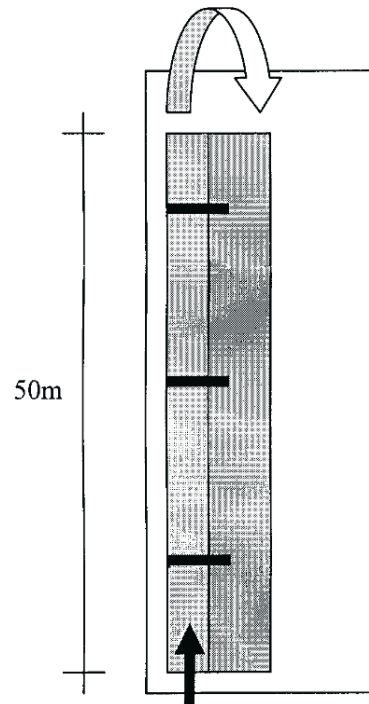


- Head was lifted a couple times between the first and second fibreboard/decoy strips. Reasonably consistent speed throughout run but may have been a little slower on the return trip.

Appendix 10 – Instructions issued to Machine Operators

INSTRUCTIONS FOR THE DEMINING MACHINES OPERATORS

a) Layout of the test lane



b) Activities of the machine operator

- Drive the machine to the line-up line. Machine will face the bleachers (spectators stand). The operator stands on the left side of the work tool.
- Upon signal – drive the machine from the line-up line to the start line, 3 m before the start line of the test lane.
- Upon signal – start the work tool, lower the work tool to the foreseen depth and start moving the machine.
- **Machine operates in 50 m test lane, at the end of lane lift the work tool, turn the machine around, set the overlap of soil treatment to 30 cm, lower the work tool and drive the machine back down the lane (50 m).**
- **Machine must operate in a continuous movement and constant soil treatment.**
- Time required of driving through the lane (outbound + turning + inbound), and depth of the soil treatment will be measured.
- If machine is operated from the cab, the operator will remain in the cab for the whole duration of operation (and will not leave the machine at any time, even

during the malfunction or stall of the machine), especially when on the test lane.

- If machine is remote control operated, the operator must wear protective equipment during operation, and stand at least 50 m behind the machine.
- Upon passing the finish line, drive the machine to the line-up line, turn off the engine, and stand next to the machine.

c) Disqualification possibilities

- Driving backward is not allowed
- Change of the speed is not allowed in the test lane
- It is not allowed to stall the machine, dig with the work tool on the spot, and then continue with operation
- If there is a malfunction of the machine or work tool during operation, the results will not be taken in account
- Operating outside foreseen lane or changing of direction is not allowed

INTERNATIONAL SYMPOSIUM “HUMANITARIAN DEMINING 2007”

24 - 27 April 2007, ŠIBENIK, CROATIA

Summary Remarks³⁷

This is the 4th Symposium in a series of meetings hosted by Croatia. The first concentrated on the achievements of CROMAC and HCR-CTRO and the second concentrated on machines. The third focused on metal detectors and we have returned to machines for this Symposium.

This time we reached the highest attendance and had excellent representation from the field (176 attendees from 35 different countries.)

The aim was to provide a forum for the use and management of machines in mine action to be discussed and to share experiences.

Did we achieve the aim?

The Symposium followed a two day meeting of the CEN Working Group on follow-on procedures behind machines in mine action and gave those attending an excellent chance to realize the issues involved and to start the exchange of information. We have heard some valuable experiences of both CROMAC and CTRO and ways by which to evaluate cost effectiveness of machines. We have had some stimulating and informative discussions in plenary and certainly a great deal of side meetings and exchanges in the corridors.

We discussed the necessity of management input and requirements to make sure that machines are used to the best advantage and we had an excellent field demonstration of some machines in realistic circumstances. Here, special thanks must go to the manufacturers for putting their machines on test and to the staff of CROMAC and CTRO for the organization of a demonstration which does not happen easily.

The demonstration gave us a good opportunity to see the machines closed up and to ask questions of the manufacturers and operators. What you may have not seen was the huge line up of logistical support vehicles in the adjoining field and which gave an indication of the broader consequences and considerations of using machines.

On the final day we had the results of the demonstration very clearly explained as well as some interesting thoughts on the US System of Systems approach which is aimed at proving that machines

can achieve confidence even when used in the clearance role. We also heard some interesting approaches on innovation and the production of cheap solutions which will be particularly relevant to smaller programmes. Finally we were reminded of the medium of the Journal of Mine Action, from The James Madison University, which can help us spread information about technology and experiences.

However, there are some general thoughts we should take a way with us:

Machines are not perfect. They are good but still need some follow-on procedures to confirm quality control.

Machine operators are a large influence on the performance of machines.

Tillers are certainly good for some conditions and threats but flails can be better in other conditions and perhaps the ideal is to consider the availability or interchangeability of both.

A machine is not the answer to all problems.

A huge change in management thinking and planning is required in order to avoid the purchase of machines which simply stand and rust.

However, the introduction of machines, if properly managed, will save time and money in most programmes.

If a programme is interested in using machines they should seek advice and assistance from those who have experience – perhaps even considering hosting advisory exchange visits.

So, in summary, we hope that you have enjoyed your visit to Croatia. We hope that you have learned something new and that you have made contacts that will help you in the future. And finally, we hope that we will see more machine use in the future of mine action.

The next Symposium, if you agree that we should have one, will try to build on this one and be even better. Current thinking is that we could concentrate on the issues of a National Mine Action Authority and responsibilities and have a shorter period directly on the use of machines, as well as retaining the demonstration in the field.

Please fill in your comment sheets and let us know what you would like. This Symposium is for your benefit and so your constructive input is essential. Thank you all for coming and we wish you a safe return to your home locations.

³⁷ Summary remarks made by the International Program Committee at the end of the Symposium, presented by Mr. Noel Mulliner (UNMAS)



SCANJACK AB - SWEDISH TECHNOLOGY IN LANDMINE CLEARANCE

- Certified for Humanitarian Demining in Croatia
- The choice of the Swedish- and the Royal Netherlands Armies for international missions
- Used by NGO's for UN Demining missions in Sudan

Scanjack AB • Norra industriområden, 776 70 Vikmanshyttan, Sweden • www.scanjack.com • info@scanjack.com • Tel: +46 225 633 50



TOOLS FOR EOD AND DEMINING



- Personal Protection
- Deminer's Tool Sets
- Marking

....
....

For more information please contact
www.forceware.de



UXO & MINE DETECTORS

⇒ Pinpointing Feature
(VMH3-series)



VMH3CS

⇒ Dual-Sensor-Detector
GPR and
Metal Detector



VMR2

For more information please contact
www.vallon.de

WITH **MV-4** TOMORROW ALWAYS COMES



 **DOK-ING**

INPEX 2004 AWARDED DEMINING MACHINE and MINI-DOZER



MV-4



MVD



MV-20

**small dimensions
excellent maneuverability
high engine power
low track-ground pressure
easy maintenance
low operating costs
simple to operate**



EOD

our satisfied customers include -

- US ARMY - SWEDISH ARMED FORCES - IRISH MILITARY -
- CROATIAN ARMY - FSD - NPA - CROMAC - MECHEM - CROATIAN DEMINING COMPANIES

www.dok-ing.hr



DURO ĐAKOVIĆ
SPECIJALNA VOZILA d.d.
SLAVONSKI BROD • HRVATSKA

STROJ ZA RAZMINIRANJE RM-KA-02



Dr. Mile Budaka 1
HR-35000 SLAVONSKI BROD
Republic of Croatia

tel: +385.35 / 218.219
fax: +385.35 / 218.824
e-mail: dgrbac@ddsv.hr

