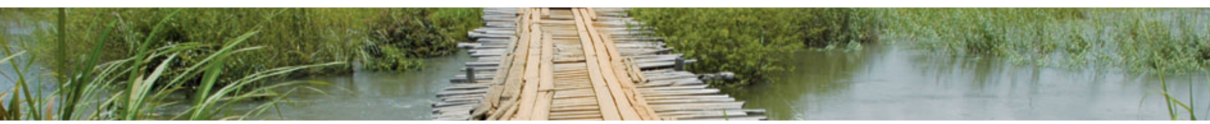
A Guide to

Road Clearance



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The Geneva International Centre for Humanitarian Demining (GICHD) works for the elimination of anti-personnel mines and for the reduction of the humanitarian impact of other landmines and explosive remnants of war. To this end, the GICHD, in partnership with others, provides operational assistance, creates and disseminates knowledge, improves quality management and standards, and supports instruments of international law, all aimed at increasing the performance and professionalism of mine action.

A Guide to Road Clearance, First Edition, GICHD, Geneva, July 2008.
ISBN 2-940369-11-9

Acknowledgements
The GICHD would like to thank the four mine action programmes whose work and experience is particularly reflected in this Guide – Afghanistan, Angola, Mozambique and Sudan; the Governments of Germany, Norway and Sweden for their financial support; and individuals who contributed to this GICHD review of road clearance techniques and procedures: Håvard Bach, Al Carruthers, Rune Engeset, Roger Hess, Maxwell Brent Jones, Klaus Koppetsch, Pehr Lodhammar, Alan Macdonald, Stuart Maslen, Sharmala Naidoo, Landon Shroder, Ted Paterson and Peter Renwick.

The GICHD would also like to thank the many professional, commercial and non-governmental organisations, and individuals, who generously contributed their time and expertise to help with this project.

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A GUIDE TO ROAD CLEARANCE

JULY 2008

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Clearing roads prior to the deployment of peacekeeping units, or in support of humanitarian, reconstruction or development work, is a prerequisite to a safe and successful operation.

However, road clearance is expensive and time-consuming. Equipment costs are high, especially in remote areas such as in Afghanistan, Angola and Sudan, where many roads remain contaminated by mines.

Confronted by these challenges, mine action operators are working to develop safer, more efficient and cost-effective road clearance systems. This Guide aims to contribute to that process by providing recent examples, data and methodologies from the field.

Methodologies and approaches used as examples in this guide were observed during field visits during 2006 and 2007. These should be considered to be snapshots: some procedures and equipment might have changed since then.

For the purpose of the guide we have generalised various methods and examples. However, in the field every scenario is unique and should be carefully assessed and interpreted within its own particular context.

Along with the information presented in this Guide, the GICHD has gathered supplementary technical data through visits to road clearance projects in four countries. This has been compiled in reference documents included on the accompanying CD-ROM. It is also published on the GICHD website (www.gichd.org).

DEFINITIONS

A wide range of terminology is currently in use to describe the elements of clearance or release of a road. While the aim is not to impose a set of terminology, it has been necessary to follow a standard set of definitions in this Guide. Readers may choose to adapt these terms or use alternative terms to describe the same process. It is, however, important to clearly define what each term means within the context of this Guide.

The term "*road clearance*" refers to tasks or actions taken to eliminate the hazard from landmines or ERW on existing and planned roads. "*General survey*" and "*technical survey*" are processes, together with "*road release*", that are sometimes included in the road clearance terminology.

A "*suspected hazardous area*" (SHA) refers to an area or segment of road that has been identified as potentially containing landmines or explosive remnants of war (ERW).

In this Guide the term "*danger area*" reflects the terminology used in the field to describe the part of a road subject to clearance, after survey has been carried out.

"*Land release*" is a generic term used to describe the process of freeing land previously suspected to be hazardous. This suspicion is eliminated by either some form of assessment or survey, or by full clearance. "*Road release*" is the application of certain land release principles to the clearance of roads. It should be noted that the concept of land release, and its application to road clearance, remained under discussion when this Guide was published in June 2008.

The term "*general survey*" is the process of collecting accurate and relevant information about the type and extent of explosive hazards in a SHA. A general survey does not involve the use of clearance or verification assets.

The term "*technical survey*" is used to describe a detailed physical intervention into a SHA, or part of a SHA, once all feasible general assessment activities have been implemented. A technical survey involves the use of clearance or verification assets. Terms like "*road proofing*" and "*risk reduction*" are also commonly used to describe the same process. Much of what, in the past, has been labelled as clearance is more correctly described as technical survey.

The term "*sampling*" is used to define a procedure whereby part, or parts, of a segment of a *cleared road* is taken as a representation of the whole road.

SUMMARY OF ROAD CLEARANCE GUIDELINES

Research for this Guide took place over a period of two years. During that time we investigated road clearance techniques and procedures worldwide. Particular attention was paid to road clearance operations in four countries – Afghanistan, Angola, Mozambique and Sudan. Detailed discussions were also conducted with road clearance operators in those countries. The following conclusions were drawn from the study.

1. Road clearance needs a layered approach

Road clearance needs a layered approach – a series of responses that together form a system designed to meet the various clearance challenges. The elements of such a system are:

- gather and analyse data on mine-laying so it can be fed back into planning
- select an appropriate mix of tools for different survey and clearance tasks

> combine demining technologies and methodologies that complement each other

> test them under realistic field conditions before finalising the approach

Many operators have already achieved important elements of such a coherent road clearance system, but (often despite bold claims) few individual operators have yet perfected such a system.

2. Road clearance is a highly specialised undertaking

Road clearance requires specialised technical, logistical and managerial skills, and tasks need to be executed in the correct order. For that reason, an accreditation regime should be in place for *all* assets engaged in road clearance, including mine detection animals, demining machines and applied detector systems. Road clearance is a *niche* activity – not one that all operators could (or should) undertake.

3. Operators should clear only what is needed

It is important to seek only to release or clear what is actually needed for road constructors and users. Defining the minimum road clearance requirement increases efficiency and effectiveness. This means the clearance operator should start, and maintain, a dialogue with the road constructor and with the potential beneficiaries (ie the future users).

4. Operators need to learn more from previous road clearance

Recording, analysing and sharing contamination data, (eg which mines were found, where they were found and how they were laid), should be given greater priority. Such information will ensure that clearance remains focused on contaminated areas and that decisions are based on evidence, rather than instinct.

5. Criteria are needed to release roads without clearance

Criteria to release roads without clearance should be agreed on the basis of internationally recognised standards and guidelines, (especially the IMAS), taking account of local realities. Whatever criteria are used, all decisions, (including the decision to release segments of road without clearance), must be carefully documented. Wherever general or technical survey finds clear evidence of contamination, follow-on clearance is always required.

6. Good information management is key to an effective road clearance system

The GICHD has found that, in general, Programmes pay insufficient attention to information management. All activities, decisions and information gathered should be recorded, analysed, shared and fed back into future planning. The logical – and systematic – way of sharing relevant information is to use a map. Modern technology has greatly facilitated this task, in particular through Geographic Information Systems (GIS).

Survey plays a critical role in this process. The purpose of general survey is to release roads or identify requirements for technical survey/clearance. This means that surveyors should be experienced and trained personnel who understand what information is required to release a segment of road. They should also be able to use Global Positioning System (GPS) technology. GPS has contributed to more effective general survey over the past five years.

Technical survey is the way to identify mined areas and then to focus scarce clearance resources on contaminated land. In the case of roads, full clearance can sometimes be as cost-effective as a technical survey, when working in a confirmed danger area. However, technical survey can be an efficient method to gather contamination data in areas where no other information is available.

7. Mechanical demining assets play an important role in road clearance

Road clearance will undoubtedly become cheaper, faster, more effective and safer if demining machines are applied on suspected or hazardous roads. In general, the better the general survey and technical survey processes, the more effective the deployment of mechanical equipment will be.

An important advantage of flails and tillers is that they also destroy minimum-metal mines, which are harder to locate using metal detection equipment. However, their potential for effective use is not universal. The following four principles should be observed when considering their application for road clearance:

- only machines with sufficient power to penetrate the road surface to the required depth should pass accreditation (but these machines have high running costs)
- only machines that can survive blasts from Anti-Vehicle Mine (AVMs) without the machine being damaged, or its capability degraded, should be used for road clearance
- machines should only be applied on dangerous segments of roads, as defined by general survey, or where it is impossible to disprove an area by non-intrusive means
- the road will need to be reconstructed or surface-repaired, as these machines destroy the surface of the road

The effectiveness of pneumatic-tyred roller systems in road survey or clearance is highly doubtful. However, there is some benefit from using a solid tyre or steel wheel roller. The use of steel wheels at wheel loads in excess of 3,000 kilograms of force will, in theory, when of similar width, improve the margin of safety of detonation of a mine, significantly above that of truck wheels. Where steel wheels are not acceptable (such as where they have to pass along tarmac roads), solid rubber tyres will give a lesser, but still worthwhile, improvement over pneumatic tyres.

8. Animal detectors are generally well-suited for road clearance

Normally roads contain little or no vegetation to hinder animals from effectively searching the surface. Animals also have the advantage of operating on the basis of scent rather than metal detection, or mechanical intervention. Animals, particularly dogs, may even find it easier to detect minimum-metal, rather than metal-cased, AVMs because of the greater seepage of odour through plastic.

The Remote Explosive Scent Tracing (REST) system provides a potentially flexible detection system that can be tuned to a wide variety of targets. REST systems are best viewed as methods for eliminating areas of road suspected of being mined, rather than for close-in detection of mines. They are therefore best applied on road lengths where there are no known minefields and information is being sought to support the hypothesis that the road is clear. Detection systems involving animals can also be used to quality assure part of an organisation's work with other survey or clearance tools.

9. Manual mine clearance is reliable, but slow and costly

Manual mine clearance is commonly used as a component in most road clearance projects. It is slow and costly but, depending on mine types, it can be a reliable method.

Manual mine clearance has been used as the only method to open complete roads, mainly because of the absence of more appropriate assets for road reopening. While manual mine clearance will always play an important role in reopening roads, an effort should be made to minimise the use of manual mine clearance to limited sectors and spots where there is a proven mine/ERW contamination, or where it is difficult to deploy other, more appropriate, assets.

10. Beware migrating mines

As a part of general survey it is important to assess the topography in relation to known mined areas. Mines and ordnance from higher ground can potentially be washed out from their original location and travel relatively long distances. Normally heavy seasonal rains form creeks and *wadis*, in which mines and ERW can travel. It is important to identify the correlation between higher lying minefields close to roads and water channels. If there is a possibility for washouts, actions should be taken to clear and take measures to prevent recontamination of the cleared area.

The obvious solution to this problem is to clear the source of the hazard. If short on resources or time, mitigating measures such as a grille or heavy duty metal mesh in culverts and trenches can be used to catch washouts. Such mitigation systems should be monitored to avoid clogs and subsequent wash-outs over the road.

11. Test all approaches in realistic conditions

All approaches must be tested in realistic field conditions in an environment similar to the roads to be cleared. A performance test should be carried out on applied equipment, operators and processes as a key part of accreditation, to ensure that the equipment and methods are fit for purpose. For further information on performance testing see Reference Documents 8 and 13.

12. Technology challenges for future road clearance

The layered road clearance methodology described in this Guide would certainly benefit from new detection technologies to further improve overall performance. Such technologies should focus more on cancellation of larger areas than the classical close-in detection capabilities, and can be either tailor-made for road clearance or fielded as part of broader land release.

New detection technologies must fit in as an additional component to existing approaches. They need to be of rugged, modular design, cost-effective and fast. Any new detection unit should be able to be fielded as a stand-alone system or as an integrated part of other road clearance systems. What will be key, however, is the ability to detect minimum-metal AVMs and possibly smaller anti-personnel mines (APMs) – the mines that current detector systems are struggling to find.

New technology is needed to:

> detect the explosive filling, the casing or other materials that make up a minimum metal AVM; or

> be able to react to the lowest common denominator that distinguishes the AVM or other munition from the materials used in road construction.

Preferably, the technology should not physically engage the ground as this would inevitably reduce efficiency and increase cost. The highest accuracy level in detection might not be needed as long as it is complemented by other systems.

CHAPTER 1

DEFINING THE CLEARANCE REQUIREMENT

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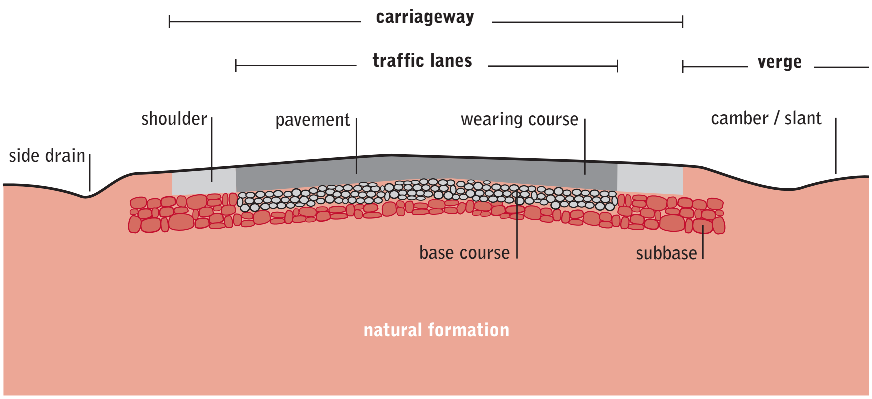
WHAT IS A ROAD?

Understanding the usage and features of a road is integral to effective road clearance.

Figure 1 | The features of a road



A road typically comprises the following features, as illustrated in Figure 1:

- traffic lane or lanes, over which people and/or vehicles travel
- shoulder, where people and/or vehicles pass or stop
- side drains, into which water on the carriageway (i.e. the traffic lane and the shoulder) drains and is carried away. A road would normally have a camber, which means the carriageway is highest in the centre of the road and slopes away on each side towards the drains.

Example of a road in Angola

In essence there are four typical road types:

- asphalt/paved
- gravel (paved)
- dirt (earth)
- degraded

Different road types may require different responses, survey or mine clearance.

IMPORTANCE OF ROAD CLEARANCE

A road, as a line of communication, is generally critical to the communities it serves. From governance and commerce perspectives, the network of roads that make up the infrastructure of a country is vital for economic development and prosperity. It therefore follows that when a road is blocked by mines the consequences are usually greater than when an area of land is blocked.

Landmines, especially minimum-metal anti-vehicle mines (AVMs), can be a major problem during, and following, armed conflict. They endanger emergency relief operations, block rehabilitation projects and impede development. Ensuring that roads are accessible - or can be rebuilt - is a priority immediately after conflict, during the most intense period of international intervention and humanitarian assistance.

Post-conflict road clearance is therefore urgent and important.

CHALLENGES OF ROAD CLEARANCE

Despite its importance, road clearance remains one of the least understood and least developed aspects of mine action. When clearing land, the integration of manual deminers, mine detection dogs (MDDs) and demining machines is well understood, and guided by long-established norms (see Box 1 for a discussion of some of the differences between road clearance and clearance of land). However, there are no universally accepted methods for rapid and efficient demining of roads.

DEFINING THE CLEARANCE REQUIREMENT

Box 1 | Road clearance and clearance of land: two sides of the same coin or two different coins?

Clearing a road is different to clearing an area of land. This is due to the scale of the function of length and width of the area potentially to be cleared, the type of ordnance typically encountered and its impact, and decisions on the depth of clearance needed.

In terms of size, the areas of road suspected to be hazardous are potentially vast – amounting to thousands of kilometres in length and thousands of square kilometres, if the width is factored in. The linear length of a road presents a challenge – in terms of square metres, a road of 60 kilometres long x 24 metres wide is 1,440,000 square metres – i.e. just short of 1.5 km^2 of area. The length factor means that the survey of a road as an entity cannot be treated as a single hazardous area.

Consider the road in its entirety. Then divide it into a series of manageable segments with an identifiable start point, eg a junction, or the edge of a town, and an identifiable end point – A to B. This has important implications for how to survey it, report the findings, plan and conduct work, and record what has been done.

There are two elements to consider regarding the width of the road: the width of the actual features of the road, and how wide to employ demining resourses.

AVMs are the type of ordnance most often encountered on roads. Their explosive effect can cause multiple victims and have very significant social and economic impact (including on circulation of goods and labour, peacekeeping operations and delivery of food aid or emergency medical supplies) – as will any mistakes in clearance. Determining the impact is usually much harder than it is for suspected land. It also means additional precautions must be taken when surveying a road.

During survey, find people or organisations with particular knowledge of any segment to try to understand the challenge of the road along its total length. (Clearly there will be overlap of informants between segments.)

A final consideration is depth. But depth of what? Do we mean depth in terms of the construction of the road or in terms of what hazards might be found in the road? The answer is both. Ignoring depth as a dimension of the road will inevitably have negative consequences.

Addressing road clearance requires a wider variety of technologies (some specific to roads), a greater level of coordination and discussion, (ie with the construction company as well as future users), and a more complex set of decisions than is normally the case with land clearance.

Clearing a segment of road can be relatively straightforward, but clearing or opening an entire road or significant length of road is more complex. When there is limited time available for clearance, demining programmes often struggle to meet the demands of road constructors, while attaining clearance standards.

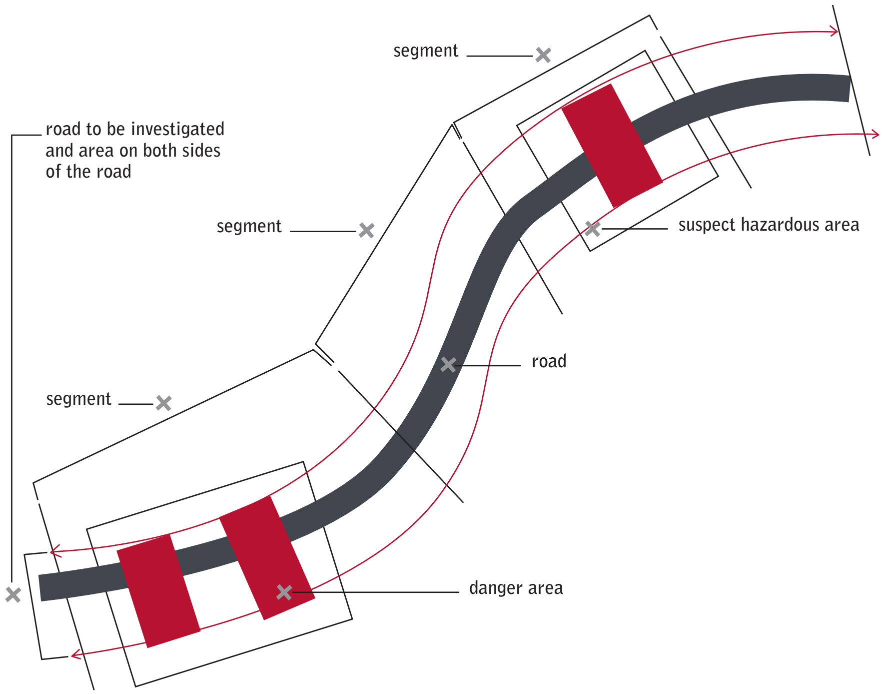
There are five main challenges in road clearance:

- cost
- speed
- safety

> coordination with road construction programmes
> current available technology and its suitability for road clearance.

This Guide suggests ways to meet and overcome these challenges.

Figure 2 | Segment SHA



Basic principles of road release

1. view the "mine-contaminated" road as a single entity. The road will have an identifiable start point, and an identifiable end point – A to B. This concept of complete linear length is important when considering the impact of a road being blocked because of mines, and also because of the implications for the planning and conduct of survey, clearance, recording and reporting.
2. decide on the width of clearance required, based on the intended future use of the road (eg is it for trucks, peacekeeping operations, emergency access, etc.?) and its current features.
3. define depth of clearance: it is necessary to decide the depth of excavation based on what will actually be needed for construction or reconstruction of the road.

4. record the impact of vegetation on, and beside, the road, noting any constraints it will impose on the clearance operation.
5. establish a common terminology between the various stake holders: for example, a road reconstruction company tasked with "rehabilitating" the road after it has been demined. Box 2 discusses the semantic differences between a road and a route.

Box 2 discusses the differences between a road and a route.

Box 2 | Roads and routes: a brief discussion of terminology

A **road** is an open, generally public way for the passage of vehicles, people, and animals.

The definition of a route encompasses a road, but also refers to a course or way for travel from one place to another. The concept of a route is generally considered to be broader than that of a road. It is also used widely in military contexts.

Generally, contracts are issued for road clearance rather than route clearance. In Sudan, however, UN contracts have been issued for the clearance of routes.

An asphalt or tarmac/paved road

Types of roads and the implications for clearance

As mentioned above, there are four basic road types: asphalt or tarmac/paved, gravel (paved), dirt (earth) and degraded. The characteristics of each have particular implications for the clearance requirement.

A gravel road

With an asphalt or tarmac/paved road, it is normally clear where (a) the course of the road is, and (b) where the features of the road are. Thus it is possible to define the traffic lanes and the shoulders (which together make up the carriageway) as well as the side drains.

With a gravel (paved) road, it might be less clear where the traffic lanes and shoulders meet. Paved roads can present challenges in terms of clearance, but there is no problem defining where the road is, unless vegetation has grown up over many years.

A dirt (earth) road

On a dirt (earth) road, it is probably less clear where the traffic lanes and shoulders meet – and the physical course of the road might not be clear. This is partly because there may be "*spread*", i.e. lateral movement of the carriageway across a wider area then would be normal for a typical paved road. This may result from road users creating deviations or detours because of flooded or soft ground. This sort of road presents a number of problems in survey, clearance and reporting, the central issue being "*where exactly is the road?*"

A degraded road

A degraded road is one where the carriageway and drains are completely blocked by vegetation, (possibly as a result of mines rendering the road impassable, restricting its maintenance and repair), or where much of the original road structure has disappeared due to erosion, washouts or other natural occurrences. When this type of road was constructed it was probably a dirt road or a gravel/paved road.

Vegetation brings further complexity to the demining of all road types. The major challenge is to match resources to the amount of vegetation needing to be cut, since this can significantly affect the speed of the operation. For example, if manual deminers are required to clear the shoulders of a road to a width of two metres beyond each side of the traffic lane, along a length of 50 kilometres, then there are 200,000m^2 of vegetation to be cut.

A vegetation cutter, mounted on an armoured tractor, requires prior clearance of the traffic lane to be used by the tractor. This could involve significant extra costs. Additional mechanical assets will also require maintenance and support.

Vegetation should only be cut if it hinders the ability to remove a hazard or obstructs movement. This will typically result in a road released for use to a width of eight metres (four metres either side of a centre line, which allows two trucks to pass each other).

Understanding the needs of the road user

It may appear obvious, but operators must understand the intended use of the road before road clearance operations commence. In essence, three uses of a road potentially require a mine action response:

> emergency access on an existing known road

> improved access through the reconstruction of an existing or previously known road

> new access, through the building of a completely new road

In each of the three cases the mine action response may be different. For example, if the intention is to allow emergency access to demobilisation sites, to provide food and shelter to former soldiers, there is little point in clearing hazards out to eight metres or more from the centre line of the road, (sometimes requested in the context of peacekeeping operations).

A bridge in need of reconstruction

Similarly, if the aim is to rehabilitate key bridges between two towns, (or even two countries), to foster trade or enable displaced people to return to their homes, then the clearance response is again about access along the road's traffic lanes to facilitate bridge-building. However, this work must be supplemented by localised clearance at the bridge sites, and the bridge engineer should be consulted, to understand exactly what his/her needs are.

If, on the other hand, the operational intent is to rebuild the road then it is likely that the whole width of the road (traffic lanes, shoulders and drains at a minimum) will need to be demined. Clarify to what width (and measured from where!) clearance needs to take place. The road constructors might also have other requirements, such as specific locations of borrow pits, (a pit created to provide earth and gravel that can be used as fill for the construction of the road), for the construction material needed.

Another aspect to consider is the potential difference between the needs and wishes of the various stakeholders. For example, if a road is cleared to an eight-metre width to facilitate the movement of peacekeepers (as occurs, for example, in Sudan) this will help the peacekeepers but may not help cattle herders who traditionally move their cattle on the shoulders of the road. All potential usage of the road must be considered as it is being surveyed.

Coordinate with the road constructor

There may also be a requirement to clear borrow pits for road rehabilitation material, or to clear a construction camp site. This again calls for dialogue between the road constructor and the demining operator and/or funder. Try to agree a reduction in the width of area to be demined, for example in return for an increased number of cleared borrow pits. Minimising the width of road to be cleared will significantly speed up the process. For instance, reducing the width subject to clearance of five kilometres of road from 50 to 16 metres will reduce the total area to be surveyed and cleared from 250,000 to 80,000 square metres, (a reduction of 68 per cent).

Another issue is the setting of the centre line of the road. Common sense suggests that the course of the road will be set by the road construction company's civil engineers – and that any required demining will be measured out from that centre line.

However in one country (where funding for clearance and reconstruction have previously been uncoordinated), the centre line, from which clearance was occurring, was set, in at least one case, by the demining agency. This meant that any follow-on reconstruction could deviate slightly from cleared areas, if the engineer designated a different line. The driver of a grader or bulldozer following the line designated by the engineer, would be put at risk.

In sum, close coordination between the demining effort and the civil engineers is critical to efficient – and safe – road reconstruction operations. In practice, this has not always occurred, as Box 3 illustrates with an example from Afghanistan.

Box 3 | The dangers of poor coordination in road reconstruction: an example from Afghanistan

During the course of clearance in support of road rehabilitation in Afghanistan a demining agency surface-cleared an area adjacent to the road, which had been selected as a borrow pit by road reconstruction engineers. The perimeter of the area was marked with painted stones.

A construction crew was then dispatched by the road construction contractor to begin excavating base materials for the road. These materials were trucked to the part of the road being rehabilitated. When workers began manually spreading the material anti-personnel mines were discovered.

The subsequent investigation into the incident discovered that the construction crew had misidentified minefield markings as the borrow pit area, and had therefore begun excavation in a minefield. Had the crew driven a further 500m they would have seen another marked area, the designated borrow pit area.

What went wrong? Although demining and construction were essentially ongoing on the same road at the same time, coordination between the contractor and the demining agency was weak. Such risks are even greater where demining precedes reconstruction by months and physical coordination between those directly involved is not feasible.

Integration with reconstruction and development

Effective communication and coordination between mine action actors, national, regional and sector government authorities, and relevant humanitarian and development agencies, is vital to improving cost-effectiveness. To further enhance the developmental effectiveness of mine action, programmes need to ensure that mine action planning and priority setting are aligned with national, sub-national and/or sector development priorities and plans. In practice, this can be a major challenge for the mine action programme. Box 4 illustrates the example of road clearance in Mozambique.

Box 4 | Integrating road clearance into reconstruction and development: the case of Mozambique

Mozambique is an example of a country that has actively sought to integrate road clearance into its national reconstruction and development programme. Mozambique's National Administration for Roads (ANE) first encountered serious problems with landmine and unexploded ordnance contamination during its Emergency Road Programme (1994–1996). Under intense time pressure, it worked with the UN Development Programme and donors to make arrangements for stand-alone demining services – typically mechanical "treatment" followed by survey and clearance - so as not to delay the work of the civil engineering firms selected as prime contractors for each rehabilitation project. This proved extremely unsatisfactory, as many explosive devices were missed, causing the road work to stop, with ANE bearing the cost of delays.

As a result, ANE has developed a system in which the prime contractor assumes complete responsibility for demining services. Tender documents make it clear that the bidders must include a specialised sub-contractor for mine/ERW survey and clearance. After the award of contract, the prime contractor is not allowed to mobilise the road-works crews until the demining sub-contractor produces a certificate from the country's National Demining Institute (IND) that the roads, bridges, gravel pits and other worksites relating to the roads rehabilitation project have been cleared. Subsequently, any missed devices incidents are the responsibility of the prime contractor and, after mobilising the heavy equipment and work teams, delays due to missed devices would be extremely costly. ANE does not require external quality assurance – it leaves this responsibility to the prime contractor.

Financing for the requisite demining works is provided in the budget for the road rehabilitation project. A provisional two to five per cent of the total budget is allocated for demining services, but ANE pays for actual and reasonable expenses. ANE's planned work programme over the next decade is US$1.7 billion, implying that the budget provisions for demining should be between US$3.4 million and US$8.5 million per year on average.

ANE maintains close contact with IND, with two of its engineers serving in a liaison role. It sends all its project plans to IND and requests all the relevant contamination and clearance records. However, even if IND certifies that a road segment has been entirely cleared, ANE still requires the prime contractor to sub-contract a demining firm to complete another survey and clearance operation. Given its costly experiences with missed devices in the past, ANE wants to put all responsibility for clearance on the prime contractor.

[1] This section is adapted from GICHD, A Review of Ten Years Assistance to the Mine Action Programme in Mozambique, October 2005.

Where feasible, road clearance assessments should be undertaken in collaboration with other stakeholders, especially the road constructor or contractor, representatives of affected communities and (where relevant) peacekeepers. It is also desirable that the results of assessments be disseminated to humanitarian and development organisations working in mine-affected areas, to ensure that communities are provided with the skills, inputs and support required to effectively and productively use cleared roads.

Where appropriate, post-clearance assessments should also be conducted to monitor post-clearance road use, and ensure that cleared roads meet the needs of the target beneficiaries. Such a process strengthens accountability to communities, mine-affected states and donors, for the achievement of developmental results and the proper use of funds. It also allows valuable lessons to be learned and incorporated into future planning.

Contracting for road clearance

Contracting road clearance has been problematic in the past because decisions about whether to survey, clear or release, need to be taken during implementation and obtaining the necessary approvals may entail considerable bureaucracy. It is important for the contracting agency (for example, the United Nations) to ensure that high levels of safety are maintained, while still allowing demining operators sufficient flexibility to define the clearance requirement based on the changing circumstances. An appropriate balance has not always been achieved in the past.

Road clearance contractors often complain that the contract is all penalties with no incentives. A more positive approach could be to promote speed and safety with carrots (i.e. financial bonuses) as well as sticks (i.e. financial penalties).

In terms of the technical aspects of a contract for road clearance, the process is normally initiated through a Request for Proposals (RFP). This might consist of the following documents:

- the RFP itself
- a Statement of Work (SOW), which normally divides responsibilities and reporting requirements under the contract
- a Proposal Submission Form
- a Sample Contract in draft, including the General Conditions used by the contracting agency

The technical component of a proposal should be concisely presented and normally structured, in the following order. Including, but not necessarily limited to:

- a description of the bidder and the bidders' qualifications
- the requirements for services, including assumptions
- the proposed approach, methodology, timing and outputs
- the proposed team structure

The bidder should include a detailed implementation plan in the technical proposal. Failure to carry out thorough logistical planning has probably been the single biggest cause of project failure in the past. Bidders are normally required to demonstrate that they are able to meet the deadlines indicated in the SOW. A field trip to the site is often required to provide the necessary inputs for proposals.

CHAPTER 2

MANAGING INFORMATION IN SUPPORT OF ROAD CLEARANCE

MANAGING INFORMATION IN SUPPORT OF ROAD CLEARANCE

A road is rarely cleared over its full length: more usually it will be surveyed and cleared in a combined operation. Road clearance is mainly a process of general and technical survey, with some limited clearance requirements. Effective operations therefore depend on *survey* to gather data and *effective analysis* of the data recorded during clearance or stockpile destruction operations.

In most countries where roads have been cleared, data collection and analysis has often been inconsistent. If a survey only captures a small percentage of the required information, (typically because of a perception that there is no time for proper data collection during the emergency stage), a valuable opportunity to facilitate future planning has been wasted. This chapter looks at how to manage information to make planning more efficient.

BASIC PRINCIPLES OF INFORMATION MANAGEMENT

Data collected during road survey and clearance should be structured in such a way that it can be incorporated into the database and analysed adequately. Some argue that collecting too much information slows the demining process. However, the time taken to collect information can reduce the need for clearance and enable efficient survey and clearance approaches. It is normally better to collect too much information than leave out information that may prove vital later.

To support effective general and technical survey, it is important to analyse the original tactical reasons for laying mines on the road, as well as available historical records and relevant empirical experience. When this process has been completed, it may be possible to make assumptions that can be used in survey. So be careful not to be seduced by "urban mine myths" (see Box 5). All hazard claims must be verified.

Box 5 | Mine myths!

As with other aspects of mine action, many claims have been made about the type and location of hazards confronted in road clearance operations. Some of these are myths.

Claim: several AVMs are stacked on top of each other.
Reality: although this has happened, it is very rare that several mines are double or triple stacked.

Claim: wooden sticks are set above AVMs, emplaced 70-100cm below the surface, to detonate the mines.
Reality: in rare cases and only in a few countries, deep buried mines with sticks have been found. It is normally possible to predict when this is likely to occur on the basis of survey or empirical experience. They may, however, be difficult to detect.

Claim: AVMS and APMs are equipped with anti-handling devices.
Reality: AVMs and APMs may indeed be equipped with anti-handling devices, although this is much rarer than generally believed. Care is obviously needed when dealing with hazards so that the risks of this occurring are taken into account.

The IMSMA template for recording data linked to road contamination and clearance is attached as Reference Document 9. For a non-exhaustive list of data that needs to be collected for road clearance, see Reference Document 10.

DATA COLLECTION AND STORAGE

A range of information about the road is collected from relevant actors, such as local authorities and individual informants. There are many other primary and secondary sources of information, such as the military (all parties to a conflict), police, hospital professionals, hunters, herders, villagers and pedestrians. Of course, attention has to be paid to the credibility of both the informants and the information they are providing.

The state of the road will dictate how information can be gathered along it. The factors to be considered are:

- the surface of the road
- weight classification
- bridge status (complete, collapsed, bypassed, etc.)
- vegetation

Technology can assist in the collection of quality data (see Box 6). Basic digital cameras and GPS recorders are inexpensive and now readily available for most survey and clearance teams. The value of pictures in planning or preparing road clearance operations should not be underestimated.

Box 6 | The application of Geographic Information System (GIS) technology to general survey.

GIS technology is extremely useful for all mine action, but especially for primary road assessments. Maximising efficiency requires developing a sequence for GIS/GPS technology, which can be integrated into any standing operating procedure for advanced survey or area reduction.

It is essential that roads be mapped by waypoints (points between major places on a road, which are recorded digitally). Waypoints are streamed by a hand-held receiver at an interval determined by the user (distance, time, or frequency). This process can begin as soon as the GPS hand-held receiver can obtain a satellite fix.

A Garmin GPS, for example, comes loaded with the appropriate mapping software (MapSource), which can be integrated, both in application and process, with the receiver itself. For example, through use of the "Track" function the user can track the road being verified, mapping all subsequent targets, and have all of the information uploaded onto mapping software for analysis at the click of a button ("receive from device" button).

This flow of information and data is not impaired by one-way operation, but can support the mutual exchange of data from the information already intrinsic in MapSource. Through desktop analysis of the information available on MapSource Tracks, maps and waypoints can be created and downloaded from the mapping software straight to the GPS hand-held receiver.

For example, MapSource provides basic base maps, which have been overlaid with shape files delineating roads, rivers, lakes, towns, etc. If a road is to be surveyed a Track can be overlaid on the mapping software by inserting waypoints at whatever interval is conducive to the user. Any additional waypoints, which have already been catalogued along a specific road, can be added to this base map and downloaded straight to the GPS handheld receiver.

The most effective way to analyse and manipulate the data captured is in an intermediate mapping programme, such as ArcView GIS. A simple conversion to a DXF (*.dxf) file will allow users to export the MapSource Track data and import it into ArcView. Waypoint information should be catalogued in Excel spreadsheets. Each piece of information captured should have its own Excel spreadsheet, which can be converted into a DBF 4 (dBASE IV) file and exported into ArcView as a data-set. Every piece of information thus becomes a layer, which can be analysed and cross-referenced in ArcView.

Box 6 | The application of Geographic Information System (GIS) technology to general survey.

This data, once exported into ArcView can be overlaid on a plethora of different maps, such as base, detailed, topographical and satellite imagery, etc. Once the user is comfortable with the data-sets that have been layered into ArcView, the data and information can be manipulated to fit the specification of the analysis. Maps can be put to scale for distance, polygons can be overlaid to delineate dangerous areas/suspected hazardous areas or reduce their size by "footprinting" community-based development data and cross-referencing with an IMAS standard. Vector based data can also be added to determine distance/extent of path and road based networks with targets mapped to specification. The visual representation of these data-sets, which are geo-referenced and built to scale, will provide the most accurate and reliable format for analysis and cross-reference.

* Information provided by Landon Shroder, Community Liaison Manager MAG, Angola.

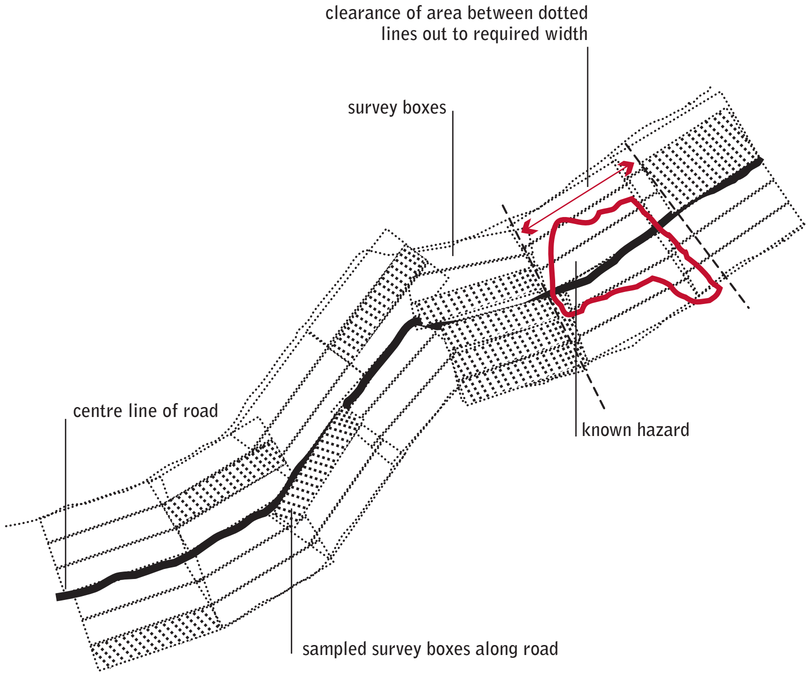
A GPS in use on roads in Angola

GENERAL SURVEY

A general survey typically combines information gathering from available literature and key informants at national, regional or district level. The outcome will be enhanced if the survey team contains representatives of a mine action agency, the local community, the road constructor or contractor and perhaps police and/or the military. This requires more organisation and coordination but results in improved information.

As mentioned in Box 1, a road should always be subdivided into logical segments, defined by the natural features of the road. Each segment should be treated as a single subject or a single suspect hazardous area. The approach is not one of segmenting the road for purely geographical purposes, but rather to find informants with particular knowledge of the segment and identify which areas require technical survey and which require clearance. Clearly there will be an overlap of informants between segments.

Figure 3 | Segments, suspect hazardous areas and dangerous areas on roads



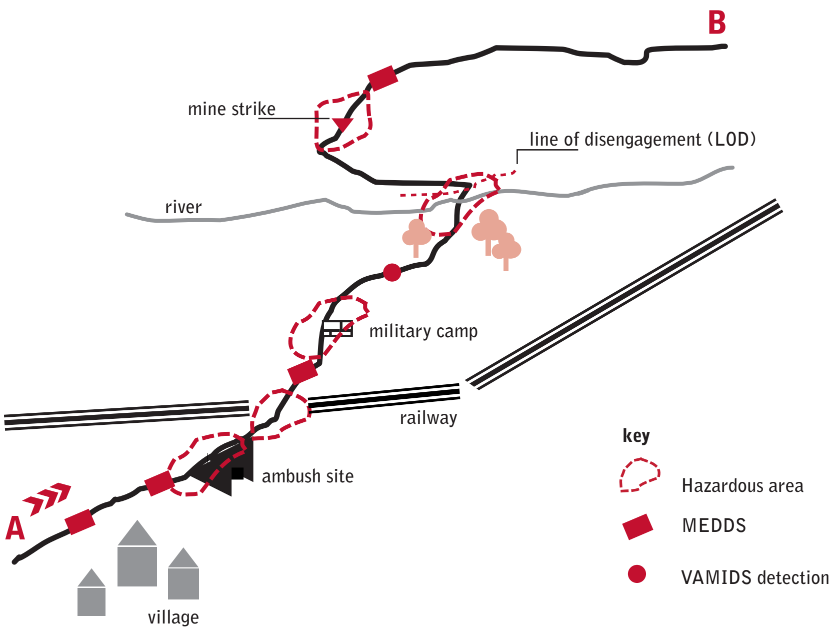
TECHNICAL SURVEY

Technical survey of roads, in comparison to general survey and full clearance, seeks to identify the location of mines and other explosive ordnance, as well as the technical information necessary for clearance. Experience, focused through good information management, should direct technical survey towards identifying the most likely locations of landmines and ERW. So if there is no evidence that plastic-cased AVMs have been used, it makes sense to look for metal-cased AVMs during technical survey. Likewise, if there is no evidence that AVMs are buried deeply, a technical survey may first look for shallow buried AVMs.

This approach can be expanded. If it is thought unlikely that mines are laid in isolation on shoulders, technical survey may look for mines in the road lane first and only check shoulders where mines have been found in the lane.

Additional data may be obtained by using a Remote Explosive Scent Tracing (REST) system (see Chapter 4 for details), such as the Mechem Explosives and Drug Detection System (MEDDS – see www.mechemdemining.com/MEDDS.htm). If this layer of sensory data is added, the results of general survey and another layer of sensory survey can be mapped, as shown in Figure 2.

Figure 4 | Stylised general survey results incorporating REST data



Assume that Figure 2 represents an 80 kilometre road suspected to be mined. After a general survey, supported by additional layers of information, it has been converted from a single linear SHA into 11 designated dangerous areas. The other areas have been released because there does not appear to be evidence of mines or ERW. If each of these dangerous areas is 200m long and 26m wide, the clearance requirement is 57,200m^2 (or 2.75% of the original SHA). This provides a potentially huge saving in time and costs.

Remember also that a general survey is normally based on both discussion and observation. If a road is not used by vehicles and is heavily overgrown, it is clearly inappropriate to force a passage without a mine-protected vehicle. If, on the other hand, the road is regularly used by cars, trucks and buses, a vehicle survey may be appropriate, but there will be staff health and safety considerations. In particular, it may not be acceptable to use an unprotected vehicle on a road that might still have mines in the traffic lanes, even though it is in regular use.

The length of the road will also affect decisions. If a blocked road is an overgrown, tertiary dirt road, walking the road on an existing footpath may be a reasonable action if the road is not too long. If the road is very long, some sort of transport will be required.

Box 7 describes one approach to technical survey, which has been developed by Norwegian People's Aid (NPA) in Angola.

Box 7 | An approach to technical survey in Angola: Norwegian People's Aid

NPA has been clearing landmines in Angola since 1995. NPA's focus has gradually shifted to reopening the tertiary road network between isolated smaller communities and the larger access networks. This box describes the method NPA plans to use.

A joint team produces a detailed task order and an implementation plan based on a general survey report and a detailed task map. The road is divided into segments on the map. A segment is defined based on specific geographical or demographical characteristics. The plan details the requirements for personnel and equipment as well as a proposed time schedule.

NPA uses several technical survey and clearance approaches. A mine-protected vehicle with steel or rubber wheels was used in the past but has now been abandoned for road clearance work. NPA now uses the Aardvark flail, wide-array detectors, or manual deminers, depending on the type and location of road and the available assets. During technical survey, the flail may be followed by visual inspection.

If the flail or the visual inspection does not indicate the presence of mines, this typically justifies release of the segment. If mines are found, full manual mine clearance is required behind the machine. The wide-array detector may be used in cases where there is a high probability that most of the AVMs are metal-cased. If the wide-array detector does not find any mines, the segment of road may be reclassified for release by technical survey, but this depends on the initial classification in the general survey report.

In pocketed areas around trees and boulders, in trenches, ditches and potholes, manual deminers are often easier and more effective to deploy than a machine. Verges and terrain that cannot be easily cleared by mechanical means are cleared manually.

NPAs teams often operate far away from the nearest operations base and machine breakdowns occur regularly. NPA has eight Aardvarks but they aim to keep four of them operational at any time under a rotation scheme. The field teams are supplied by a central logistics base. The timing of fuel and food delivery is critical to productivity.

SAMPLING

In a number of countries, a sampling approach is applied to the technical survey process and to the clearance of roads. For example, in Afghanistan, a road is subject to *both* clearance within the identified SHAs and to a process of 33 per cent sampling. In contrast, in Sudan, suspected areas appear to be cleared systematically, with no sampling being conducted of those lengths of road surveyed as having "no evidence of mines".

Sampling has obvious benefits for efficiency. Perhaps a good generic approach would be to complete a random sampling process, so that an unadulterated data set is collected, and then to conduct an additional layer of "skewed sampling" on top. This effectively becomes a layer of internal quality control.

CHAPTER 3

APPLICATION OF MACHINES TO ROAD CLEARANCE

APPLICATION OF MACHINES TO ROAD CLEARANCE

Appropriate application of mechanical demining equipment leads to cost-effective road clearance and, ultimately, to returning safe roads to communities.

An additional benefit is that mine clearance machines destroy or excavate all types of AVMs and APMs, whether plastic or metal cased. Machines do not differentiate between metal-cased and plastic-cased mines.

A variety of assets can be used for road clearance. But a well-managed mechanical component is essential for an effective road clearance programme. This chapter reviews the use of mechanical demining equipment for road clearance, including some of the major mechanical systems currently in use.

AN OVERVIEW OF DEMINING MACHINES

In general terms, demining machines are used for three purposes in a mine action programme: to find and destroy mines; prepare ground, including vegetation cutting (while often, but not always, also destroying mines); and to act as a platform for another application. These three tasks are also applicable to, and can be assigned for, road clearance. (See Reference Document 12.)

Mine clearance machines are those machines whose stated purpose is the detonation, destruction or removal of landmines. For example, a front-end loader, armoured and adapted to excavate mined ground, can be designated as a mine clearance machine because the definition includes the removal of all mines to a certain specified depth.

Bozena 5 in action

The use of a mine clearance machine may mean that follow-on processes can be reduced or eliminated. Not following-on a mine clearance machine with a secondary process, to finish the removal and destruction of all targets is unusual, but circumstances do exist where the machine used will have cleared all mines.

Rigorous testing against target mine types in specific conditions will help to establish whether a machine is capable of clearing all mines. For example, a flail, engaging a specific mine type may detonate or destroy all functioning mines of this type without the machine being damaged or its capability degraded. If it is known that the contaminated site, or road, contains only the specific mine type which the machine is known to detonate, there may be no requirement to follow-on with a secondary clearance process. A simple visual inspection of the road may be sufficient.

The main mine clearance machine designs are:

- flails
- tillers
- combined tiller and flail systems, or those with interchangeable flail or tiller tools
- civil or military plant, agriculture or forestry machinery adapted for mine clearance or removal (such as the grill bucket on a front-end loader)

An example of a mine clearance machine | the Scanjack 3500

An example of a combined tiller and flail system | the MV10

All of these machines can be used for road clearance. Mine clearance machines always destroy the road surface. Road reconstruction will be required after clearance has been completed, to make the road useable again.

APPLICATION OF MACHINES TO ROAD CLEARANCE

TO FLAIL OR TO TILLER?

In ground processing and clearance of SHAs and technical survey tasks, the most commonly used mechanical tools are flails and tillers. Similarly, in road clearance, these assets have been applied more and more often as their reliability and effectiveness have gradually increased over the last five years. An important advantage of these machines is that they will also destroy minimum-metal mines. However, their potential for effective use is not universal. The following four principles should be observed when considering their application for road clearance.

1. Only machines with sufficient power to penetrate the road surface to the required depth should pass accreditation.
2. Only machines that can survive blasts from AVMs without the machine being completely damaged, or its capability degraded, should be used for road clearance.
3. They should only be applied on dangerous segments of roads, as defined by a general or a technical survey.
4. Coordination with a road constructor will be needed as the road will have to be rebuilt or surface-repaired, as these machines destroy the surface of the road.

In general, the better the general survey and technical survey process, the more effective the deployment of mechanical equipment will be.

Both flails and tillers have their strengths and weaknesses. In most scenarios the preferred option is to use a combination of both, depending on the road surface and the hazard. Typically, a tiller system might be more cost effective when there are no mines encountered, while a flail demands less repair and downtime when detonating mine targets. Table 1 summarises the strengths and weaknesses of the two mine clearance systems.

APPLICATION OF MACHINES TO ROAD CLEARANCE

Table 1 | Advantages and disadvantages between flails and tillers

Advantages of tillers	Advantages of flails
> Lower operating cost when no AVMs are encountered.	> Lower operating costs when AVMs are encountered.
> Higher production rate due to less downtime for maintenance and repair.	> Lighter prime movers can be used as the base vehicle which often results in a lighter machine.
> Easier to control and to measure penetration depth.	> More target impact in loose soil and sandy conditions due to no "slipstreaming"* phenomena.
> Less maintenance needed.	> Less expensive to buy.
> Generates less dust, which increases operator's visibility and reduces wear and tear on engine and moving parts.	> Demands less engine power to operate the tool.
> Easier to ensure overlap with previously cleared lanes.	> Less likely to be blocked by debris, such as concrete elements and vehicle parts, encountered during operation.
> Uses commercially available steel teeth that last longer than chains and hammers and are easier to replace with new ones.	> Chains and hammers can be locally manufactured in countries with a steel industry capacity.
Tiller disadvantages	**Flail disadvantages**
> Larger repairs often required when detonating AVMs.	> Higher replacement costs of hammers and chains compared to tiller teeth.
> Often based on heavier prime movers.	> Generates more dust, which leads to decreased visibility and more wear and tear on engine and moving parts.
> Demands more engine power, which often leads to higher fuel consumption.	> Demands slow operating speed to break through tough surface layers of ground.
> Larger elements of worksite debris and rocks can block, and potentially damage, the clearance tool.	> Can throw out mines, in particular polycarbonate/ ABS plastic-cased APMs like the VS-50.
> The tiller tends to be blocked by mud when working in sodden conditions.	> Not as effective as tillers when deployed on hard ground.
> Particular types of tillers are subject to "bow wave" and "slipstream"* phenomena.	> Can generate "skip zones"* when not properly operated.

* For an explanation of the reported phenomena of bow wave, slipstreaming, ridges/skipped zones and soil expansion, see Reference Document 11.

APPLICATION OF MACHINES TO ROAD CLEARANCE

Table 2 summarises the advantages and disadvantages of flails and tillers over other mechanical clearance tools like rollers and loaders.

Table 2 | Advantages and disadvantages of flails and tillers over other mechanical clearance tools

Advantages

> when well-managed, flails and tillers are the most cost-effective clearance tool for larger sites or demining tasks

> fast and reliable

> the performance of many machines has been tested and evaluated in accordance with the protocol described in CEN Workshop Agreement 15044

> performance and output is easy to measure, quantify and document

Disadvantages

> "soil expansion" (overburden) can be a problem for follow-on activities (manual or MDD)

> demands a professional logistical set-up to ensure productivity

> high initial capital investment costs – and relatively high running costs

GROUND PREPARATION MACHINES

Ground preparation machines (light, medium and heavy systems) are primarily designed to improve the efficiency of demining operations by reducing or removing obstacles. Ground preparation may or may not involve the detonation, destruction or removal of landmines. Ground preparation machine tasks in road clearance might include:

> vegetation cutting and clearing

> removal of tripwires

> loosening the soil for follow-on activities

> removal of metal contamination

> removal of building debris, boulders, rubble, defensive wire obstacles

> sifting soil and debris

> repairing the surface of the road following a ground engaging machine

An example of a ground preparation machine | the MineWolf Bagger

Vegetation cutters are used to assist manual clearance, mine detection dogs and other detector systems on roads. Vegetation cutting commonly occurs where the road is overgrown by vegetation, or vegetation partly blocks traffic lanes. If the clearance contract states that the clearance task has to clear the road up to an extended width on both sides of the road, vegetation cutting may be required before manual or MDD clearance operations can start.

In most cases machines used as vegetation cutters are based on commercial off-the-shelf equipment which has been adapted for demining operations. The most commonly used configuration is to install a cutting tool, such as a slasher or a mulcher, on the arm which normally has a backhoe bucket fitted to it. The chassis can be a medium size, wheeled tractor with a protective operator cab or fitted with a remote control. Such machines provide a flexible, mobile platform which can be used for a variety of functions and tasks.

An example of a vegetation cutter

An example of a soil loosener, attached to a Pearson Minefield Tractor

Graders are successfully used in ground preparation roles in road clearance. The graders are well suited to surface preparation of roads and to assisting other clearance activities. MDDs will have easier working conditions following a grader operation, since the removal of the top layer will enable odour from the mine to evaporate, and other demining tools will be guided by the cut made by the grader's blade on the road surface. A grader can also be used to improve the road surface after other machines have worked on it. Graders in a standard configuration need an armoured cab to protect the operator from an AVM blast. *(See the Voodoo description (page 45) for an example of graders used for road clearance as part of an integrated system.)*

DETONATION TRAILERS AND MINE ROLLERS

Mine rollers or detonation trailers are used to prove the safety of roads that have been cleared of AVMs. There have been a variety of rollers used on roads, varying from the (rarely used) steel rollers, through to the solid-tyred rollers, the pneumatic tyres used on the Chubby system and the HALO Multidrive.

The Chubby system

The towing vehicle is fitted with low pressure tyres (to avoid setting off a mine) and detector arrays (shown stowed at an angle to the side of the engine). Towed behind are a series of trailers fitted with pneumatic truck tyres and ballasted to load each wheel with approximately 1.8 tonnes.

This type of vehicle was originally deployed during earlier conflicts in Southern Africa. They are now being used by demining operators, principally in Angola. There is concern as to how effective these detonation trailers are when employed in humanitarian mine clearance operations because they have not yet detonated any mines. It is not certain whether this is because there have been no mines in the road or because the Chubby has developed insufficient force to activate the fuse. It is unfortunate that the wheels of these detonation trailers have only been loaded to about 36 per cent of the typical wheel loads of the heavy trucks.

Research has concluded that:

- the benefit of adding extra weight to pneumatic tyres is disappointing, as much of the additional force is lost due to the tires distributing the load more widely: but there is significant benefit to using a wheel that is harder than a pneumatic tyre
- using steel wheels at wheel loads in excess of 3,000 kilograms force, will improve the margin of safety of detonations significantly above that of truck wheels
- where steel wheels are not acceptable, solid rubber tyres will give a lesser, but worthwhile, improvement
- the effectiveness of mine rolling diminishes with depth

MINE PROTECTED VEHICLES

Mine-protected vehicles (MPVs) are vehicles specifically designed to protect any occupants, and equipment from the effects of a mine detonation. In mine action, the designation MPV is normally associated with vehicles originally designed as armoured military personnel carriers. MPV are commonly used during survey and detection operations, often on roads. They can carry equipment such as detector arrays or vapour sampling devices, or push or pull a roller. They are often equipped with steel wheels that can be used for hazard reduction, technical survey and area reduction on roads.

An example of a mine protected vehicle | the RG31 Mk6

APPLICATION OF MACHINES TO ROAD CLEARANCE

A variety of vehicle-mounted detector systems have been developed over the years. The South African military developed a number of vehicle-mounted systems, eventually producing the Meerkat vehicle as part of the Chubby system. This vehicle also used an under-body detection array and was followed by engineers to clear any suspect signals.

The Meerkat

HALO Trust acquired a Chubby system and employed the Meerkat in Eritrea. Recognising drawbacks with the under-body mounted detection system, HALO contracted Ebinger to design a front-mounted system, incorporating the UPEX-740 detector that could be operated by one person. The system incorporated a single detection loop mounted on a wooden fold-up frame, wired to a control and warning box in the cab.

The Chubby Meerkat LLD front detector

After calibration, the operator would simply drive at a pace of between five and seven kilometres per hour until the warning bell sounded. The operator would immediately stop the vehicle and try to centre the front-mounted coil over where the signal would be the strongest, without driving over that point. Once the spot was identified, a clearance team could be brought forward to clear that point.

INTEGRATED SYSTEMS

There are a remarkably small number of integrated road clearance systems in operation today. The best known is the Voodoo System.

The Voodoo System

Developed by MgM (Menschen gegen Minen), the Voodoo System has been used successfully in Angola for about ten years.

The Voodoo System is *not* designed to be used on all-weather paved or asphalt/tarmac roads. In the provinces of Angola where MgM is conducting clearance, the hazard exists on roads where their use can be expected to be interrupted by wet weather and the rainy season. These roads simply make use of the local soil and – during good dry weather – can be used by heavy transport vehicles, buses and lighter vehicles. Nevertheless, these roads are part of the national secondary road network, and their clearance does have a large impact on the local population.

A motor grader used on roads

In Angola, the major mine hazard on the roads is from AVMs. The most difficult mine to deal with is generally said to be the South African No. 8 minimum-metal mine. This was designed with all its metal components in the base of the mine, which makes it undetectable by metal detectors under most circumstances. The density of mines laid is extremely low – usually only a few AVMs and APMs in an entire length of road of 50 kilometres or more. The location of these mines can often be predicted by experienced technical survey teams and by the assistance of the local population.

In spite of the very low density and the predictability of the location of the mines, the work agreed between the National Inter-Sectoral Commission for Demining and Humanitarian Assistance (CNIDAH) and MgM will stipulate that the entire length of the road should be graded. This is to ensure that the entire road is processed by the blade of the grader during the process, and that the road surface is considerably improved, allowing much more effective use of the road.

Statements of work further stipulate that the road must be left in such condition that the mine action authority can easily traffic the road to conduct quality assurance inspections. This means that road construction becomes a significant part of the road clearance process. Culverts and expedient bridges are built, and so on, all at the expense of efficient mine clearance.

However, this work means the road can be used immediately. Movement of displaced persons, humanitarian aid and normal transportation of goods and people can take place as soon as road clearance in completed. The economic and social benefit of this process is considerable and therefore this "road construction" element is an integral part of the road clearance work.

The HEC Rotar sifter

The Voodoo system is a process that combines many elements including planning; survey; clearance using machines, dogs and manual deminers; quality assurance/control; and record management. (Operating procedures for the system are detailed in Reference Document 1 on the CD-ROM with this Guide.)

The effectiveness of the Voodoo System

The motor graders are the key element in the Voodoo System. This is the equipment which sets the pace for the entire operation and will have the greatest effect on productivity. It is the preferred vehicle for road clearance, most notably when mine clearance goes hand-in-hand with road construction.

The grader will perform well if it operates on a flat, sandy road. The grader/ Voodoo system also works well on highland roads, jungle tracks or just about any secondary road surface, except rocks. Rainfall can be a limiting factor but not a debilitating one. Team leaders always seek solutions to any challenges that may prevent operations from continuing.

The berm (a ridge, or mound of earth) that is created provides a distinctive marking method for defining the edges of the cleared area. Deep potholes (filled with rain) and large obstacles on the road require particular investigation, and slow down the mine clearance process. But, deep potholes on asphalt/tarmac roads are not generally filled with water for the whole year. Dry potholes can quickly be checked by the MDDs.

Roads with a low density of expected mine hazards are preferable for the Voodoo system. However, MgM reported that the density of mines is sometimes very high in hot spots. In one case, the Voodoo system found nine AVMs within 100m of each other.

The Voodoo system is not designed to work on the traffic lanes of a paved asphalt/tarmac road. The threat along an asphalt/tarmac road that has been undisturbed is negligible. But the Voodoo system, including the grader, can work effectively along the sides of paved roads, where hazards are most prevalent. Culverts are easily checked for explosive charges set under roads. Clearance of the sides of the roads will also reveal planted mines, emplaced directional mines and command cables, set to charges or pipe mines laid in holes from the side to lie under the asphalt/tarmac road. Therefore there is no need for a system to dig up the entire asphalt/tarmac road in order to find charges set under it.

The Voodoo system performs well if the combination of tools is operated in accordance with the conditions on the ground. The possible time-lag between the grader in use and the follow-on MDD, as well as manual mine clearance can become the main weakness of the system. A high density mine threat can dramatically slow the process of road clearance. The right combination of tools and their appropriate application on the ground are the key contributors to good performance.

CHAPTER 4

MINE DETECTION METHODOLOGIES FOR ROADS

MINE DETECTION METHODOLOGIES FOR ROADS

BASIC PRINCIPLES OF MINE DETECTION METHODOLOGIES

Technical intervention on roads is a mix of technical survey and clearance. The latter should be limited to small segments, or spots, where hazards are likely to be found. There are, of course, a variety of detection tools, some of which are specifically designed for roads. No system has proved to be either foolproof or universal in application; therefore the toolkit principle of demining is especially applicable to road clearance.

Given the typical length of roads to be cleared – many kilometres – manual demining using traditional detectors needs to be focused on confirmed or localised high-risk areas, such as bridge heads and junctions. Of far more widespread application are mobile detection systems, such as the Wide Area Detection System, the Vehicular Array Mine Detection System or the use of mine detection animals. These are described below.

WIDE AREA DETECTION SYSTEM (WADS)

Based on the experiences of UXB (a commercial demining company) with a similar road clearance system in Eritrea in 2001, DanChurchAid (an NGO) contracted Regis Trading (South Africa) to construct a modular wide area system for road clearance tasks in Angola. The system was completed in late 2004 and named the Wide Area Detection System.

WADS can be used effectively on roads where metal-cased AVMs are suspected. Standard metal AVMs, such as the TM-46/57 series, can be consistently located at depths of one metre or more, as can common UXO items. However, its application for detecting minimum-metal AVMs is less efficient and there are a high number of false positive readings that result from a more sensitive setting.

WADS employs the Ebinger UPEX-740 large loop as the detection system. The synchronisation of the UPEX coils is controlled through standard Ebinger hardware and software, and fed into a standard laptop computer. Tracking of the detection and vehicle progress is done by an OmniStar wide area DGPS system. The WADS is mounted on a Mine Protected Vehicle (MPV) (South African Samil 20 "Rhino") as the prime mover.

The WADS

A modular mounting system has been constructed that allows the WADS to use up to eight UPEX coils in various configurations and sensitivities. A series of electric winches raises and lowers the unit with minimal effort. The mounting system is quickly adjusted to cover search widths as small as 3m, or up to 8m if needed, including extending the detection swathe into a road verge. Search speed ranges between five and 10 km/h, depending on the terrain and vegetation.

The system can be retracted into a travel position in approximately 30 minutes, as illustrated below, which allows self-transport at speeds up to 80 km/h on improved roads and 30-50 km/h on unimproved roads. This has greatly reduced the transport time between survey sites, and so improved the productivity of the system.

The WADS in travel position

VEHICULAR ARRAY MINE DETECTION SYSTEM (VAMIDS)

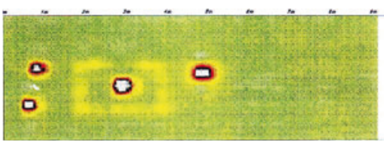
As part of a United States demining research and development project in the mid-1990s, Schiebel detection systems developed the Vehicular Array Mine Detection System (VAMIDS). The original version was mounted to a skid-steer vehicle for prototyping and has since been mounted on MPVs. The system works on electromagnetic principles, incorporating PSS-19/2 mine detector heads in a modular array.

Early versions were mounted to the front of a vehicle, with the data from each detector head fed into an on-board computer. The hardware assembly can accommodate between eight to 48 detector heads in the array, allowing it to be expanded or reduced as needed. The system underwent considerable testing and upgrades, both at the US Army R&D organisation of night vision and other sensor technologies called NVESD, and with Mechem.

The NVESD version was mounted to a skid-steer for prototyping

Earlier versions of the geophysical mapping were quite cluttered and difficult to discriminate between clutter and a suspect item. Considerable progress on data processing was made on later versions and the maps became much easier to understand (see Figure 3).

Figure 3 | More recent VAMIDS mapping results



The measurements at the side of the map makes progress easy to follow, once the baseline was correctly established. This allows for an effective area reduction process that accelerates the clearance, with less labour. The software and data-recording system requires specialised training to operate, but does not require a trained geophysical specialist to analyse the survey results - a substantial benefit.

Mechem adjusted the power supply to the detection coils and mounted them on a two-metre-wide piece of durable rubber matting (expandable up to eight metres if needed). The entire detection array is mounted on a well-designed swing-arm assembly that allows employment to either side or directly behind the vehicle.

This system offers many advantages, such as contouring to the road surface and minimising the stand-off between the detection coils and the ground. This provides better reception of the eddy currents being returned, and therefore increased sensitivity when searching for smaller items. Search speed ranges between five and 10 km/h, depending on terrain. The disadvantage is that, because the handheld detector heads are used as the coils, the detection depth is limited to between 50 and 70 centimetres against larger items such as metal-cased AVMs.

Both Mechem and NVESD have mounted the VAMIDS on protected vehicles. The Mechem system has been working in Eritrea, DR Congo and in Sudan for several years.

THE USE OF MINE DETECTION ANIMALS

This section describes indirect and direct use of mine detection dogs (MDDs) during road clearance. This includes Remote Explosive Scent Tracing (REST) and Mechem's Explosive and Drug Detection System (MEDDS). These last two are systems suitable for technical survey, to release roads without undertaking clearance, whether with MDDs, manual deminers or demining machines.

A mine detection dog

When animals are used for detection of explosives, defined changes in the animals' behaviour indicate the presence of odours that correlate positively with the presence of that ordnance.

A number of animal species have been used in the detection of landmines. The list includes dogs, rats, goats, pigs, and bees, although dogs are by far the most commonly used. The remainder of this section focuses on the use of MDDs in both direct detection and remote detection roles. There is also a brief discussion of the use of mine detection rats (MDRs).

A mine detection rat

Dogs and rats have been preferred over other animals in mine detection. Both animals are known to possess a keen sense of smell. Given that mines in minefields cannot be seen, heard or touched, sensing their odour is the only way they can be detected by animals. A dog's ability to detect an odour against a background bouquet has been estimated at between 10,000 and 100,000 times that of a human's. The sensory abilities of both animals for the odours emanating from mines are far better than those of any existing electronic device.

Training techniques used in the military, police, civil defence and customs have also been used to train mine detection animals. Both dogs and rats are relatively easily socialised with humans, meaning that most aspects of their behaviour can be managed by people.

Animal detectors are generally well-suited to the demining of roads because roads contain little or no vegetation to limit the surface area that can be searched.

REMOTE DETECTION

There continues to be a need for a detection technology that can improve the efficiency of demining. Few technologies rival the potential efficiency of remote detection by animals, and MDDs in particular. This approach involves systematically collecting samples of air or dust/sand from defined sectors of road and presenting those samples to animals trained to emit a clear response when they sense mine-related odours. As the term 'remote detection' implies, these animals inspect the samples in a laboratory that is remote from the sites from which the samples were taken.

REST describes a set of procedures which evolved from Mechem's Explosives and Drug Detection System (MEDDS). The system was originally developed to detect conventional explosives, small-arm weapons and illicit drugs at border-crossing checkpoints. In the mid-1990s, Mechem applied their system to the detection of landmines. The general method was subsequently used by NPA, who called it *Explosives Vapour Detection*, and organisations from the US, where it was known as Checkmate. The two systems are based on the same operating principles and used for the same purposes. For the sake of clarity, the generic term, REST, (which has also been adopted in IMAS), is used to refer to all methods of remote sensing using animals.

REST is not a method in itself, but a set of methods for identifying areas of land that are contaminated with the explosive ingredients of mines/ERW, and areas that are not. Therefore, REST is better viewed as a sub-system within an organisation's overall detection system, because numerous complex phases are involved:

- surveying and marking
- sample collection (*sampling*)
- sample *analysis* and *follow-up* in the field

REST is to be used as a technical survey system and is not intended for direct detection, or as a primary clearance tool.

The first phase in REST (surveying and marking) generally involves the following:

- dividing the roadway into equal-sized segments (e.g. 100-200 metre portions)
- marking the boundaries of each sector with semi-permanent distinctive stakes and/or coloured rocks
- recording the GPS coordinates of each marker so that the sectors can be drawn on maps

It is assumed that operators have previously defined and mapped the centreline of the road at regular intervals, using a GPS. This step not only facilitates any later follow-up searching but also defines the area the organisation has searched, and declared safe at project completion.

In the second phase of REST, samples of air and dust are collected from each sector. This phase is known as *sampling*. Organisations are using different methods for sampling (eg vehicle-mounted suction pumps or manual versions). Coded containers holding either filters or dust samples from each sector are then transported to remote laboratories, where they are presented to MDDs that have been trained to emit a defined response when they detect mine-related odours in a filter or container of dust. This phase is known as *analysis*.

Samples are then designated as either *positive* or *negative*. Positive samples are those that were indicated either by a minimum number of animals, or by one animal a minimum number of times (depending on the organisation's SOPs). These represent road sectors that are suspected of containing landmines. The sectors from which those samples came are searched in a *follow-up* phase by field operators using a different method, (or *layer*), of detection and a method that has finer resolution than REST (e.g. MDDs, MDRs or manual deminers with metal detectors).

Negative samples are those which either none of the animals responded to, or those which occasioned the indication response from less than a minimum number of animals. The road sectors represented by these samples are generally declared free of mines and no further searching is undertaken in them. However, a small proportion of them might be searched more thoroughly during a quality control process.

REST systems are best viewed as strategies for eliminating areas of road suspected of being mined, (i.e. a technical survey approach), rather than as strategies for pinpointing locations of mines. They are therefore best applied on road lengths where there are no known minefields and information is being sought to ensure that the road is mine-free. To be used efficiently, REST should follow general survey, but precede the more thorough searching offered by MDDs or manual deminers.

REST systems have several major advantages over more conventional methods.

1. By seeking to identify negative sectors of road, REST has the potential to reduce, substantially and quickly, the area of road that needs to be inspected by more expensive and slower detection methods, or cleared, either manually, or by machine. This potential for rapid *area reduction* offers a guaranteed improvement in operational efficiency because detection and clearance resources can be deployed in areas where actual hazards exist.

2. By using MDDs as the primary detection agents, REST provides a potentially flexible detection system that can be tuned to a wide variety of targets. The set of targets that the MDDs are trained to respond to might include a set of landmines that are common in that area, or a mix of landmines and IEDs. Whatever elements make up the set, it is relatively straightforward to capture and present to MDDs the odour signatures of each element. The MDDs can quickly learn to distinguish and indicate different targets.
3. The most common AVMs are metal cased (e.g. the TM57) and are relatively easy to detect by systems involving arrays of metal-detectors mounted on armoured vehicles (e.g. VAMIDS). However, some AVMs are largely plastic (i.e. minimum-metal mines) and cannot easily be detected using metal detectors. Fortunately, chemists have discovered that plastic mines are more likely to leak their explosive-compound ingredients into surrounding soil than metal ones: it is the odour of these compounds that animals can detect and be trained to indicate. REST can, therefore, potentially fill a gap in an organisation's detection system when they are tasked with clearing AVMs from roads.

Whereas the use of MDDs in the field is constrained by environmental factors, (particularly hot and dry climates or very rocky terrain), the use of a laboratory for REST analysis greatly enhances the accuracy, reliability and endurance of animal detectors. The animals can work most days and for longer periods each day. REST animals can be less likely to miss positive samples, can be more stable in their detection accuracies and can sustain that stability for longer periods of time than their field-operating counterparts. (Environmental conditions on the road itself are, however, important variables determining the effectiveness of sampling, and so must be considered relevant factors in the REST SOPs of any organisation.)

SAMPLING IN MEDDS & REST

The manner in which samples of air and/or dust are collected from suspect roads is critical to the overall effectiveness of the REST system. Different collection techniques result in different quantities of target compounds (e.g. soil contaminated with explosives) being taken to the analysis phase, and the accuracy of animal detectors is unavoidably limited by the strength of the target odour in a sample. The overall aim of any sampling technique is to maximise the collection of explosive compounds in positive samples taken from mined sectors – and minimise any transfer of these compounds to the negative samples taken from non-mined sectors.

Considerable resources have been spent on developing procedures and equipment to optimise the sampling component of REST. Perhaps the most important finding is that the concentration of explosive compounds and their by-products in the surface sand/soil above a mine is around one million times higher (and considerably more stable) than the concentration of these chemicals in an adjacent odour plume. This has led a number of organisations to develop equipment and protocols for collecting dust samples from roads. This work is still in progress, but it is likely that the sampling phase of REST systems will change dramatically. The aim will be to bring representative samples from road sectors into the laboratory for close inspection by animals.

Similarly, the analysis phase of REST has undergone dramatic changes and differs markedly across organisations. Variations in method include: how the samples are arranged for inspection by animals, how the samples differ from, and might be interspersed with, training samples, (i.e. known positive and negative samples), how rewards are arranged for indications on operational and/or training samples, how an animal's performance is measured and analysed, and how the responses of individual animals are used in the categorisation of operational samples.

For further information on procedures used in REST and MEDDS, see Reference Document 3 on the CD-ROM included with this Guide

DIRECT DETECTION BY MINE DETECTION ANIMALS

Direct detection is the use of detection technologies in the field to identify areas of ground containing signals that correlate positively with the presence of buried landmines or concealed IEDs. MDDs can be used for intensive searching of a suspect road. The resolution of this searching is generally fine enough to enable the animal's indications of a mine to be followed up by manual searching by a deminer.

The efficient use of MDDs generally requires that they are deployed following the use of a wide array detector system, or REST, to reduce the search area. This position in a detection system means that MDDs can also serve as a useful quality assurance function. Specifically, by systematically selecting areas of road to be searched by MDDs, the detection accuracy of the technology before it in the sequence (i.e. VAMIDS or REST) can be assessed. This requires that all sectors of road declared positive, and some negative, by the preceding detection technology must be searched by the animals.

MDDs searching areas declared positive by REST provide opportunities for identifying hits and false-alarms of that technology. In contrast, MDDs searching areas that have been declared negative provide opportunities for identifying correct rejections and misses of that technology.

USE OF MINE DETECTION ANIMALS FOR QUALITY MANAGEMENT

Detection systems involving animals can be useful for quality control. By deploying REST occasionally on roads that were declared safe by other urveying techniques, (such as interviewing locals), their accuracy and reliability can be assessed. The logic behind this process is that the follow-up detection system is applied to more sectors of road than declared necessary by the detection system under scrutiny.

This might seem like a waste of time and resources. However, without accurate and informative assessments of each component of an organisation's detection system, deploying components that add no value to the overall system wastes more time. Even worse, if one component is systematically missing mines or providing false-alarms at a high rate, then that component could be reducing the accuracy of what could otherwise be a reliable overall system.

MDDs can also be used effectively in a follow-on role behind mechanical demining machines to ensure that all mines have been cleared. The MDDs can also be deployed for direct detection in support of a mechanical demining operation, to cover areas that were not accessible to the machines, such as areas around buildings, bridges, trees, etc.

APPLYING LAND RELEASE PRINCIPLES TO ROAD CLEARANCE

APPLYING LAND RELEASE PRINCIPLES TO ROAD CLEARANCE

BASIC PRINCIPLES OF APPLYING LAND RELEASE TO ROAD CLEARANCE

As mentioned earlier, roads are best released by applying a "layered" approach. There is, however, a need for clear criteria to define when roads can be released by general and technical survey. These criteria should comply with internationally recognised standards and guidelines, taking local realities into account. The basis of any decisions made to release segments of road without clearance must be carefully documented. Wherever general or technical survey finds evidence of contamination, follow-on clearance is *always* required.

LAND RELEASE METHODOLOGY AND ITS APPLICATION TO ROADS

The vast majority of suspect roads demined today are proven, in retrospect, to contain no landmines or other explosive ordnance. Efficiency requires investing more time and resources in the activities undertaken prior to clearance, including general and technical survey.

There is, today, a set of broad generic principles and requirements that are widely understood throughout the mine action sector. Their application to roads has yet to be fully explored in practice, but land release methodology offers useful insights on how to maximise efficiency in road clearance. The following five elements would comprise a road release methodology.

1. Start a formal, well-documented investigation process into any mine problem

A precondition for any release of roads using general approaches is to establish a credible investigation into the risk of the presence of mines or ERW. In some countries, land has been released as a result of re-analysing old survey information more thoroughly. However, it is more common to undertake a new survey.

There are several types of survey. The general survey is a hazard identification process. Its output is based purely on the collection of information from a variety of sources, coupled with visual field inspection. General survey is the first step for mine action organisations to build an approach and make decisions on whether a particular segment of road can be released.

For a road to be released through general survey there needs to be a documented high level of confidence in the collected information. Factors that will influence this process include:

- a thorough and well described methodology ensuring objective assessments
- sufficient number of credible informants (with names and contact details recorded)
- survey information quantified if possible

A general survey should ensure that not only are major informants with knowledge of the conflicts or community leaders involved, but that other relevant respondents are also included in the process of data collection and information cross-checking.

2. Set well-defined and objective criteria for reclassification of roads

The criteria used for the reclassification of suspected roads need to be clear and universally understood. If a road is released as a result of a general survey, the detailed process allowing that release should be described and, to the degree possible, quantified.

Reclassification can be based on qualitative and quantitative measures. The first implies clear criteria for measuring the confidence in survey information. Information provided by soldiers who laid the mines may be considered more credible than information provided by a villager who recently moved back into an area. Quantitative measures may involve the type of information and the number and variety of information sources.

3. Ensure a high degree of community involvement

There needs to be a high level of confidence in the process, which should be genuinely accepted and agreed between the operators and the population with the local authorities. Effective local participation in major decisions will ensure that a road is effectively used after it has been released. Local participation should be fully incorporated into the main stages of the process in order to render the entire process more accountable, manageable and ultimately cost-effective. The community should ideally be involved in any handing over process or procedure.

4. Ensure ongoing monitoring after release

Post-clearance and post-release monitoring must be properly planned and agreed between the different parties. This will help measure the impact that road release has had on local life – and clarify issues related to liability in case of accidents. This approach is important especially when it effectively uses current social and political structures to carry on the work of monitoring and information updating.

5. Support a formal national policy on liability issues

The absence of a national policy that addresses issues related to liability is likely to impede the process of effectively releasing roads. It is therefore important that the national mine action authority, on behalf of the national government, develops a policy that details the shift of liability from the survey organisation to the government or local authorities.

The shift in liability may be tied in with the requirements for an open survey and assessment process. An organisation failing to demonstrate that it has followed the national policy may, for example, be liable in the case of accidents or evidence of mines in previously released land. If it is demonstrated that the organisation undertaking the survey and assessment has used a methodology which has been endorsed by the government, liability in case of later mine accidents typically lies with the government.

CHAPTER 6

CONCLUSION: FIVE GUIDELINES FOR ROAD CLEARANCE

CONCLUSION: FIVE GUIDELINES FOR ROAD CLEARANCE

This final chapter summarises the lessons of the guide in five key points.

1. **Only areas that are absolutely necessary for the road constructor and end user should be cleared.**
   This is the first step in any road clearance project – defining as restrictively as possible the clearance requirement. It is essential to clearly understand the intended use of the road before starting operations, as this can help to reduce the width and depth of clearance. Dialogue with the road constructor may, for example, enable the operator to agree to a reduction in the width of area to be demined, in return for an increased number of cleared borrow pits.

2. **Road clearance needs a layered approach.**
   Survey, allied to a systematic analysis of all data gathered, is crucial to the success of a road clearance project. A mixture of appropriate tools, combining different suitable demining technologies and methodologies, should be used for survey and clearance of roads. Prior to fielding any equipment, their performance should be field tested under realistic conditions.

3. **Agreed criteria are needed to release roads without clearance.**
   It will always be possible to release segments of road without undertaking clearance of the road surface. This demands prior agreement on the standards and guidelines for information gathering, documentation and adjustment to local realities that must be followed. But when general or technical survey finds clear evidence of mine contamination, follow-on clearance is always required.

4. **The difference between road clearance and clearance of land needs to be understood by demining operators.**
   Not all demining operators have the necessary capacity and knowledge to undertake survey and clearance of roads. For instance, standard manual demining drills and the use of rollers, which are usually used to clear land, may not be appropriate when clearing roads. Specific road conditions and time pressures need to be taken into consideration when determining approach and technology. Mine clearance operators are encouraged to further develop methods and technologies that are specifically suited to the survey and clearance of roads.

5. **Quality management is an important element during road clearance**
   As with any demining task, quality assurance and quality control are integral to each operation. It is essential to document the various processes in an auditable document trail (starting with the survey report and leading up to the handover documentation of the road cleared and released).

   Quality assurance should be carried out on all aspects of the road clearance operation. Quality assurance and quality control should not only be internal but also conducted by an external partner, or the contracting agency, if possible. Quality assurance and quality control should ideally be carried out while the operation is ongoing.

LIST OF REFERENCE DOCUMENTS ON THE CD-ROM

1. THE VOODOO SYSTEM, MPV, WADS AND VAMIDS
2. THE USE OF ANIMALS AND ENVIRONMENTAL FACTORS
3. ANALYSIS PHASE IN MEDDS AND REST
4. DETONATION TRAILERS AND MINE ROLLERS
5. CONTRACT MANAGEMENT
6. CHECK-LIST FOR ROAD CLEARANCE
7. CEN WORKSHOP AGREEMENT 28 AND 29
8. IMAS 09.50 (AND IMAS 07.10 ADAPTED TO ROAD CLEARANCE)
9. IMSMA ROAD CLEARANCE FORM
10. DATA NEEDS
11. BOW WAVE, SLIPSTREAMING, SKIPPED ZONES AND SOIL EXPANSION
12. CATEGORISATION OF MINE CLEARANCE MACHINES
13. PERFORMANCE TESTING

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