

Highways Consultancy Group - Highways Research Group

Rock Slope Hazard Assessment Report

Task Reference: 652 (666) MTSC

Project Sponsor: David Patterson

Report Date: July 2010



Highways Consultancy Group Highways Research Group

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The companies from the supply chain contributing to this report are:

- Mott MacDonald

The nominated Task Manager is:

Christopher Jack

Tel: 0117 906 9500

Fax: 0117 922 1924

Email: chris.jack@mottmac.com

Address:

Mott MacDonald

Prince House

43-51 Prince Street

Bristol

BS1 4PS

Issue and Revision Record

Rev	Date	Originator	Checker	Approver	Description
B	July 2010	Chris Jack	Gareth Mason	Ian Duncan	Incorporating HA comments

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Executive Summary

The Highways Agency (HA) has a responsibility to ensure that its rock slope assets are safe and adequately managed. Furthermore it is necessary to monitor the slopes for signs of deterioration to allow for the efficient and economic maintenance of these assets.

However, the existing system used by the HA for rock slope hazard analysis has not been implemented for the HA's assets in a manner that is effective in the long term.

The HA's objectives for this project are to implement a system that:

1. Provides a consistent, appropriate and robust approach to initial risk assessment and identifies key actions.
2. Ensures that subsequent condition surveys target features which may be subject to change over time, contribute to risk assessment and trigger key actions.
3. Aligns the rock slope risk assessment process to that adopted for the earthwork asset.
4. Supports a more unified approach for wider infrastructure asset and Value Management processes.
5. Is viable for the long-term.
6. Is cost effective.
7. Is supported by appropriate resources and competencies.
8. Effectively links with other HA research including the rock anchors project and the risk project. Note that the rock anchors project is outside the scope of this work and will not be discussed further in this document.

This document outlines:

- The research that has been undertaken to allow this document and a related HA Area Maintenance Memorandum (draft AMM) to be produced.
- The different rock slope inspection systems that were considered.
- The options that were considered for implementation of the rock slope inspection system.
- The work that will be required for the draft AMM and the recommendations in this report to be implemented in the HA.
- Details of additional work that would further improve the HA's management of rock slopes.

Note: Subsequent to this document being prepared, the Highways Agency has decided that Option 2 in this report will be implemented as an intermediate step on the way to full implementation of Option 3. This is accepted as a necessary expedient and as a step towards improvement. It is intended that Option 3 will be implemented as recommended in this report once funding has been secured.

List of Contents

Executive Summary	2
1. Introduction.....	5
1.1 Background.....	5
1.2 Objective	5
1.3 Related documents	6
2. Research	7
2.1 Existing rock slope inspection systems	7
2.2 Initial selections.....	8
2.3 Rockfall Slope Hazard Index System (RSHI)	9
2.3.1 Description	9
2.3.2 Advantages	9
2.3.3 Disadvantages	10
2.4 Rock Hazard Rating System (RHRS).....	10
2.4.1 Description	10
2.4.2 Advantages	11
2.4.3 Disadvantages	11
2.5 Selection subsequent to Expert Group Meeting Nr.2	11
2.6 Decision	12
3. Options considered for implementation	15
3.1 Summary of options	15
3.2 Option 1.....	15
3.3 Option 2.....	16
3.3.1 Description	16
3.3.2 Advantages	16
3.3.3 Disadvantages	16
3.4 Option 3.....	16
3.4.1 Description	16
3.4.2 Advantages	17
3.4.3 Disadvantages	17
3.5 Option 4.....	17

3.5.1 Description 17

3.5.2 Advantages 17

3.5.3 Disadvantages 17

3.6 Recommendation 17

4. Amendments to existing HA systems 19

4.1 General 19

4.2 Area Maintenance Memorandum..... 19

4.3 Pocket GAD 20

4.4 HA GDMS 21

5. Implementation 22

6. Recommended future work 24

7. References 25

Annex A - HA Rock Slope Hazard Index AMM (Draft)..... 26

List of Tables

Table 1 Existing rock slope inspection systems..... 8

1. Introduction

1.1 Background

The Highways Agency (HA) has a responsibility to ensure that its rock slope assets are safe and adequately managed. Furthermore it is necessary to monitor the slopes for signs of deterioration to allow for the efficient and economic maintenance of these assets.

Recent practice has been to utilise the Transport Research Laboratory (TRL) Rock Slope Hazard Index (RSHI) system (McMillan & Matheson, 1997) for rock slope inspection. This process involves an initial prioritisation of all rock slopes followed by more detailed assessments of those slopes with identified problems. While this approach has been used in the past the experience of service providers has highlighted some shortcomings in the way in which the methodology is currently implemented in relation to the HA's rock slopes.

The key problems that have been identified with the use of the RSHI system on the HA network are:

- The system has not been effectively applied in the long-term.
- Diverse application between different service providers.
- Varying levels of competence between service providers.
- Lack of visibility to the assessment process, which is a problem as service providers change, meaning valuable data can be lost.
- The TRL RSHI system is currently a proprietary form of analysis and is currently reliant on a single organisation and its approved suppliers.
- Insufficient information on existing rock support and containment measures and their condition.

1.2 Objective

The HA's objectives for this project are to implement a system that:

1. Provides a consistent, appropriate and robust approach to initial risk assessment and identifies key actions.
2. Ensures that subsequent condition surveys target condition features which may be subject to change over time, contribute to risk assessment and trigger key actions.
3. Aligns the risk assessment process to that adopted for the geotechnical asset
4. Supports a more unified approach for wider infrastructure asset and Value Management processes.
5. Is viable for the long-term.
6. Is cost effective.
7. Is supported by appropriate resources and competencies.
8. Effectively links with other HA research including the rock anchors project and the risk project.

It is intended that this system will be used throughout the HA and it is hoped that other organisations such as the HA's fellow roads agencies in the United Kingdom and will adopt the system.

Two Expert Group meetings were convened with experienced rock engineering practitioners during the duration of the project. The purpose of the meetings was to ensure the system implemented by the HA represented best practice. The first meeting occurred early in the project while the second meeting took place once draft versions of the documents were available for review and comment.

The following individuals were present at one or both of these meetings:

- David Patterson - HA Project Sponsor and HA Senior Geotechnical Advisor
- Alison Knight - HA Geotechnical Advisor
- Ian Duncan - Mott MacDonald, Senior Project Manager
- Chris Jack - Mott MacDonald, Engineering Geologist
- Richard Seddon - Mouchel, Senior Engineering Geologist
- Ian Nettleton - Coffey Geotechnics, Principal
- Anthony Butler - Network Rail Senior Earthworks Engineer

1.3 Related documents

A draft Area Maintenance Memorandum (AMM) has been produced which provides guidance on the rock slope management process. Note that the draft AMM assumes that the recommendations in this document are implemented. A copy of the draft AMM can be found in Annex A.

2. Research

2.1 Existing rock slope inspection systems

There has been a considerable amount of research into rock slope inspection systems by many different individuals and organisations. As a result of this research, a number of systems have been developed, some of which have been extensively used and refined in practice.

Therefore it was decided by the HA in conjunction with the Expert Group that was convened for the project that, if possible, an existing rock slope inspection system should be adopted by the HA rather than creating a new system. The advantages of adopting an existing system include:

- Time and cost savings.
- Ability to compare findings with existing and future results of other infrastructure managers.
- The reassurance provided by adopting a system that has been applied successfully elsewhere with consistent results.

Table 1 summarises the rock slope inspection systems that have been reviewed during the preparation of this report. It should be noted that there are many other equivalent systems but unfortunately it was not possible to review these due to a variety of reasons including:

- The relevant documents being written in different languages.
- The documents not being readily available.
- Time and budgetary constraints.

Furthermore, given that it is a key HA requirement that the system is viable in the long-term, it was considered that systems where the basis was difficult to obtain were unlikely to meet this requirement.

Table 1 Existing rock slope inspection systems

System	Comments
Principal Inspection as detailed in current version of HD 41/03	This is the system currently employed by the HA. The current Principal Inspection is very basic with regards to rock slope examinations. As a result it is considered that the current Principal Inspection system does not adequately assess the potential risk posed by rock slopes. For instance it is not currently possible to produce a list of rock slope assets using the current systems.
Rock Slope Hazard Index (RSHI)	Originally developed by TRL for the Scottish Office. Principal authors include Matheson and MacMillan (1997). The original intention of the system was to produce a database of the rock slopes in Scotland along with related hazard index values. The system has been used in Scotland, Wales and parts of the HA network. Modified versions have also been adopted by Network Rail and Tarmac.
Rock Slope Hazard Rating (RSHR)	Intended to be the detailed inspection follow up to the RSHI system. However development was abandoned by TRL before it was implemented, mainly due to complexity of trying to capture the information required for a detailed inspection in a system that scores rock slope features numerically.
Rockfall Hazard Rating System (RHRS)	Originally developed and refined by the Oregon Department of Transportation. Currently adopted in its present form by the Federal Highways Administration (FHWA) (1990) and States including California, Oregon, Kentucky, Nevada, Pennsylvania, Virginia, Wyoming, North Carolina, Utah and West Virginia.
Other modified versions of RHRS	Some States have decided to modify the RHRS systems to suit their particular requirements. These states include Arizona, Colorado, New Jersey, Vermont, New York, Tennessee, Idaho, Ohio, New Hampshire and in Canada; British Columbia and Ontario. These systems tend to be similar in many respects to the original RHRS.
Colorado Rockfall Hazard Rating System (CRHRS)	Based on the original RHRS system but modified to meet the requirements of the Colorado Department of Transportation. The most recent version was published by Russell et. al. (2008). This version of the RHRS has been singled out as it aims to ensure best practice by incorporating the most useful aspects of all of the various RHRS systems and aims to make the system less subjective and more quantitative.
Modified versions of Q system	The Q system was originally developed by Barton et. al. (1974) (also called the Norwegian Geotechnical Institute (NGI) system) for tunnelling applications. The purpose of modifications is so the system can be applied to rock slopes.
Modified versions of RMR system	Modified versions of the Rock Mass Rating (RMR) system originally developed by Bieniawski (1973). Again the purpose of modifications is so the system can be used on rock slopes.

2.2 Initial selections

It was decided by the Expert Group to carry the RSHI and 'standard' RHRS (as originally developed by the Oregon Department of Transportation) forward for further consideration. The reasons for this were:

- Both of these systems are well documented and information and training is available so that these techniques can be carried out consistently.
- There is experience of using these systems in the UK.

The other systems were not selected because:

- The current HD 41/03 process inadequately measures potential risk posed by rock slopes.

- The modified versions of the RHRS were ruled out because many of these have been developed to meet the geological conditions unique to particular States (although this is not the case with the recent version of the CRHRS which draws on best practice from former RHRS systems). In addition there is more evidence of consistent and ongoing application of the standard RHRS and as a result many more records of the application of this system should be available. This means comparison and confirmation with existing results is a possibility.
- The modified Q and RMR systems were ruled out as there is insufficient evidence of widespread, consistent and systematic application of these systems with regards to rock slopes. Also, it is difficult to determine what the accepted versions of these systems are. Therefore these systems currently do not meet the long-term viability objective which is one of the HA's key requirements. Furthermore, these systems generally require detailed measurements to be made before the assessment can be completed. This does not tie in with the level of detail currently required by HA Principal Inspections.

2.3 Rockfall Slope Hazard Index System (RSHI)

2.3.1 Description

The RSHI system was developed by TRL who still hold the intellectual property rights (IPR). The principal authors were Matheson and McMillan and the original work was carried out for the Scottish Office for use on roads in Scotland, particularly those in the north-west Highlands.

The RSHI system was designed for two main purposes:

- To populate a rock slope database
- To assign a 'hazard index' to each of the slopes.

A modified system has also been adopted for use on the railway by Network Rail and for use in quarries by Tarmac.

2.3.2 Advantages

- There is previous experience of use in UK, particularly in Scotland and on the Network Rail infrastructure. This means examiners exist who have experience in using the RSHI system.
- Versions of the system are in use by Network Rail and Tarmac which means the system should continue to be used in the future which should aid long-term viability.
- The system has previously been used by some HA Areas including Area 2. This means some existing slopes on the HA network have previously been rated, allowing the scores from new surveys to be compared with previous surveys.
- Relatively quick to complete inspection (typically 20 to 30 minutes per slope).
- Contains mainly quantitative measures which should reduce subjectivity and increase consistency.
- There is some ongoing development, for instance Network Rail are investigating how the system might better assess the hazards posed by weaker rocks.

2.3.3 Disadvantages

- The RSHI system was originally developed for slopes in relatively hard igneous and metamorphic rocks in Scotland. As a result it does not deal well with weak rocks and interbedded sedimentary rocks found throughout much of England. Network Rail is attempting to solve this problem by either modifying the RSHI system or introducing an alternative system for weaker rocks. However this system is still in development.
- The RSHI system is perceived to be a 'black-box' system as the results can currently only be processed by TRL's approved suppliers. The algorithm used to calculate the RSHI score along with the parameters and assumptions are not available in the public domain. Concerns about this aspect have been raised by the current service providers. The basis of the concern is that trained and experienced geotechnical practitioners are cautious of a system where they do not know how the result is derived.
- One possible way around the above disadvantage is an agreement with TRL. For example Network Rail has an agreement in place that recognises TRL's Intellectual Property Rights (IPR). This means that Network Rail has access to the algorithm, parameters and assumptions. The HA could conceivably put in place a similar agreement but this would not necessarily solve all of the concerns about the suitability of the system. There would likely be a cost implication associated with an agreement and publication.
- Presently it is necessary for inspectors to attend a course run by one of TRL's approved suppliers that is several days long before inspectors can use the RSHI system. However given the relatively simple nature of the inspections, combined with the fact that HD41/03 requires inspectors to be engineering geologists or geotechnical engineers, it is considered that the course may be too long, time-consuming and expensive for suitably experienced staff. On the other hand it is doubtful that a non-geotechnical engineer could reach the required understanding of geology and rock mechanics to reach an equivalent level of ability in the time offered by the RSHI course. The requirement for training that appears to be expensive and excessive could damage the long-term viability of the programme - especially given that inspections are often carried out by younger engineers who have a higher staff turnover rate.
- It is unclear what would happen to the system when the current trainers move on or retire. All of these factors contribute to uncertainties over the long term viability of the programme.
- TRL do not appear to be carrying out research to improve the system. Although, as discussed previously, Network Rail are thought to be developing the system and other organisations such as Tarmac may have modified the system.
- The RSHI system is significantly more complicated than the current HA Principal Inspection system and takes significantly longer to complete.

2.4 Rock Hazard Rating System (RHRS)

2.4.1 Description

The standard RHRS was developed by the Oregon Department of Transportation based on earlier work by Wyllie. The system was subsequently adopted by a number of other US and Canadian States and is currently promoted by the FHWA. This version of the RHRS is the most widely adopted and it has the most experience of use, is the easiest to find information on and the most widely cited.

2.4.2 Advantages

- Specialist knowledge of rock engineering not required. However, as a minimum, the inspector would need to be an engineering geologist or geotechnical engineer.
- Quick – typically takes no more than 5 minutes to fill out the proforma.
- Easy for engineering geologists and geotechnical engineers to understand – no need for external training course, all necessary training information is available online and an engineering geologist or geotechnical engineer would be able to train themselves via self-directed learning.
- Widely adopted – proposed system is recommended by the FHWA and adopted by a number of other US states.
- Process has been refined over many years to its present level of development.
- Designed to accommodate both harder and weaker rock slopes.
- The results of thousands of slope surveys in the US are available for comparison and calibration.
- The system is recommended by Hoek, Wyllie and Mah and is also cited in other publications.
- Research into the system is ongoing which demonstrates its wide acceptance, viability and potential for long-term improvement.
- Does not require any equipment that the examiner would not already have on a Principal Inspection.
- Similar in complexity to current Principal Inspection.
- All information and research is easily available. Scoring is open and transparent so the examiner can develop a feel for the weighting of the system.

2.4.3 Disadvantages

- The system is not considered to be perfect for all geologies, which is why some American and Canadian States have modified the process to a greater or lesser extent.
- Many of the assessment criteria are qualitative and subjective rather than quantitative. However this is not necessarily a disadvantage – as stated by Evert Hoek “the aim of a rock mechanics engineer is not to calculate accurately but judge soundly.”
- Does not include consideration of remedial works that may have been installed.

2.5 Selection subsequent to Expert Group Meeting Nr.2

On the basis of the above considerations a draft version of the AMM incorporating the standard RHRS was produced for review and comment at the Expert Group meeting Nr.2 on the 3rd of April 2009. The discussion at this meeting was wide ranging, however, a number of key points emerged.

- The HA still wanted a simple and quick system that tied in with their requirements for Principal Inspections.
- The HA restated that they did not want a proprietary system.
- RSHI was preferred by a number of members of the expert group. In addition, it was felt that the RSHI represented current UK practice.
- The standard RHRS was felt to be too subjective.

- Some members of the group felt that a training course would be required for the standard RHRS to achieve consistent results due to its subjectivity.
- The HA was willing to consider modifying an existing system as no system met the HA's requirements in its present form. Past precedent of scoring was considered to be desirable but not essential. There is a large amount of existing RSHI inspection data. Coffey Geotechnics have indicated that their database contains approximately 60 HA slopes and the Network Rail database contains a very large number of slopes.

As a result of the above considerations, it was felt on reflection that the Colorado RHRS (Russell et. al. 2008) should also be considered as an alternative to the standard RHRS. This decision was made after the Expert Group meeting Nr. 2 as the HA indicated that a system without a long track record was a possibility provided the system was adequate for the intended purpose.

If a long track record is not required, then the CRHRS offers some significant advantages over the standard RHRS:

- Incorporates best practice from several US and Canadian states.
- Still relatively quick and simple, although there are more parameters than the standard RHRS so takes longer to complete, but still not as long as the RSHI (probably 10 to 15 minutes per slope).
- Much more quantitative and less subjective than standard RHRS
- Separates Hazard from Risk - not done in either RHRS or RSHI

However the system at present is not adopted outside of Colorado, there is little prior experience of its use and it is not widely cited as yet. Therefore field trials would be required before the scoring could be calibrated for the HA.

2.6 Decision

Subsequent to the Expert Group meeting Nr.2 it became apparent that TRL would be willing to consider publishing the research, methodology and algorithm for the RSHI system.

This was a significant change, as previously a significant disadvantage of the RSHI system was the fact that it is a proprietary system and the background information was unavailable.

On the balance of all of the previous considerations it was decided by the Expert Group that the RSHI system should be adopted if available for the following key reasons:

- The expert group consensus is that this is the most appropriate system for initial inspections in the UK.
- There is previous experience of its use in the UK.
- It should be possible to obtain the previous inspection results and populate HAGDMS with the previous survey information.

However, it is recommended that the following shortcomings of the RSHI system are addressed before it is adopted:

- The HA would need to obtain full access to the research, methodology and algorithm.
- It would be desirable if the HA could gain access to existing RSHI databases and upload the information therein to HAGDMS.
- The requirement for a lengthy training course before inspectors can use the system should be removed.
- It would be desirable to access Network Rail's research on improving the system for inspection of weak and interbedded rock slopes. It is not certain what point this research is at and it may be that the HA could participate in this research.
- More detail is required on rock support and containment measures and the condition of these aspects. Note that this would also apply to the CRHRS system, if it were adopted. It will also be necessary to incorporate consideration of systems such as vegetation retention systems.
- More information is required concerning weathering to allow deterioration to be monitored in the long term.

As some of these aspects involve significant additional research, or are dependant on the work of outside parties, it may not be possible to incorporate all of these aspects within the scope of the current Task Order. However, it is recommended that all of these aspects are eventually implemented.

If the TRL RSHI method does not become available then the CRHRS would also be a very good system. The key reasons for this are:

- All of the information on the system is available in the public domain.
- The system is simpler and quicker to use than the RSHI, reducing the amount of training required and saving time during Principal Inspections.
- The system is closer in the level of detail required to the current Principal Inspection than the RSHI system. This will mean there is less of a mismatch between the level of detail required during inspections and the system can be more easily incorporated into the HA's existing systems such as Pocket GAD and HA GDMS.
- The CRHRS system is better at assessing sedimentary and interbedded geological formations which are more common than harder rock formations on the HA's assets.

An additional reason why it would be beneficial to adopt the modified CRHRS system is that the use of two systems in the UK (RSHI and the newest version of CRHRS) would likely help to provoke discussion, debate and research in the topic of rock slope inspection systems. Ultimately this may lead to better versions of both systems being developed.

The following modifications would need to be made before the CRHRS could be used by the HA:

- Change parameters from imperial into metric.
- Change some of the terminology to that used in the UK.
- Modifications of the guidance to suit the UK and the HA's requirements
- Additional data on rock dowels, bolts and anchors.

A completely bespoke system has not been developed as the requirement for a completely new system does not appear to exist. Furthermore, developing such a system to the level where it was of a similar system to those existing would likely take several years.

The remainder of this document and the associated draft AMM (contained in Annex A) assumes that the RSHI system is adopted by the HA.

3. Options considered for implementation

3.1 Summary of options

The following options were considered for the implementation of the RSHI system within the HA.

- **Option 1** – do nothing.
- **Option 2** – publication of the AMM without any further work. The RSHI data would be captured on paper forms and in inspection reports but not in Pocket GAD. The records would need to be scanned and uploaded to HA GDMS manually.
- **Option 3** – publication of the AMM with Pocket GAD and HA GDMS being modified to include a 'Rock Slope' observation in which the RSHI information could be recorded. However in this scenario the RSHI information could not be easily manipulated in the manner that much of the other data on HA GDMS can be.
- **Option 4** – publication of the AMM along with amendments to Pocket GAD and HA GDMS to fully incorporate the RSHI system.

3.2 Option 1

The HA's existing systems do not allow effective preliminary assessment of the hazards and risks posed by rock slopes. This is because rock slopes often present little or no visible indication that a failure is about to occur while the present Principal Inspections record visible defects or those that have already occurred. Therefore the current system generally misses the main hazards posed by rock slopes. Furthermore the observations and defects that can currently be recorded during a Principal Inspection do not cover many rock slope aspects and do not provide nearly enough information to allow any kind of meaningful assessment of rock slope condition.

Another significant problem with the current system is that it is not possible to determine from HA GDMS how many rock slope assets the HA have or the condition of these slopes. Therefore it is currently very difficult, if not impossible, for the HA to quantify the hazards and risk their rock slope assets present or to estimate the required budget for inspection, assessment, maintenance and remediation of these assets.

Note that the costs for remedial works to rock slopes following failures tend to be very high due to difficulties in access and the requirements for traffic management. Often the slopes are steep and roped access techniques are necessary. This means that a regular and consistent inspection regime is very cost effective as potential problems can be identified and resolved before significant costs are incurred.

The consequence of ineffective assessment of these slopes is increased maintenance and remediation costs and increased risk of disruption and injury to the road user.

For all of these reasons it is recommended that Option 1 (do nothing) is not selected.

3.3 Option 2

3.3.1 Description

This option could be considered as a way of minimising the changes that would need to be made to existing HA systems to incorporate the RSHI system. Under this option an AMM would be issued detailing how the RSHI system should be carried out within the HA. No changes would be proposed to other documents or systems such as Pocket GAD and HAGDMS.

In this scenario, the inspector would need to take additional paper proformae with them when carrying out Principal Inspections to record the RSHI information as the data would not be captured by Pocket GAD. The RSHI would be included in an inspection report which would need to be scanned and manually uploaded to the reports database on HAGDMS.

3.3.2 Advantages

- Relatively quick and inexpensive to implement.

3.3.3 Disadvantages

- Potential for system to be ineffectively implemented or for information to be lost. Requires inspector to remember to bring RSHI paper forms to site, these could get damaged by rain, blown away or otherwise lost. Inspector then needs to incorporate RSHI forms into an inspection report which would then need to be uploaded to HAGDMS.
- Related to the above point, it is possible that inspectors may forget to bring the required forms and therefore the inspections would need to be repeated. This would incur unnecessary cost, add inertia to the inspection system and could potentially lengthen the inspection process of rock slopes.
- In addition it would be more difficult to ensure an auditable information trail obtained for quality assurance purposes.
- Possible for RSHI part of the system to be unknown, forgotten or ignored by Managing Agents and could also lead to confusion. Considered that this may compromise long-term viability.

On the basis of the above considerations, Option 2 could serve as a useful step to full implementation that would be relatively easy to implement in the short-term.

3.4 Option 3

3.4.1 Description

In this option a 'Rock Slope' observation would be added to Pocket GAD and HA GDMS. The RSHI data would then be inputted directly into this observation in Pocket GAD (simply as raw factual data that cannot be manipulated) or a scan of the paper forms could be uploaded to HA GDMS. However, the actual RSHI data could not be manipulated in any way and the slopes would have to be scored separately. This option solves many of the concerns of Option 2 without requiring significant and potentially costly modifications to Pocket GAD and HA GDMS.

3.4.2 Advantages

- HA GDMS could be interrogated to produce a list of rock slopes, greatly improving the HA's ability to quantify their rock slope assets and aiding the planning of repeat inspections and long-term asset management.
- All of the RSHI information could be easily and reliably stored and retrieved, aiding asset management, repeat inspection and deterioration assessment.
- Provides a much more reliable audit trail for quality assurance purposes.
- Relatively easy to implement in Pocket GAD and HA GDMS relative to Option 4.

3.4.3 Disadvantages

- RSHI information cannot be manipulated in a sophisticated way, meaning that the potential benefits associated with assessing whole-life costing, cost modelling and scenario modelling would be considerably more difficult to realise.
- It would be more difficult to calculate the RSHI scores as this would have to be undertaken as a separate exercise once the inspection was complete.

3.5 Option 4

3.5.1 Description

In this option the RSHI system will be intimately built into Pocket GAD and HA GDMS.

3.5.2 Advantages

- Would result in a consistent and integrated system which stands a greater chance of being viable in the long-term.
- RSHI data could be manipulated and a score would be generated automatically.
- Would provide an excellent audit trail for quality assurance purposes.
- Data would be used to populate central data reporting, allow inclusion in whole life costing modeling, scenario modeling and long term trend analysis.

3.5.3 Disadvantages

- Significant additional work required to modify Pocket GAD and HA GDMS.

3.6 Recommendation

On the basis of the above considerations, Option 3 is recommended. The key reasons for this are:

- Option 1 leaves the HA at significant risk of unplanned expense and possible road user injury as a result of rock slope failure.
- Option 2 is not considered to improve on the HA's current management of rock slopes as this option is likely to have a number of fundamental and ongoing problems with consistent application. This threatens consistency and long-term application.

- Option 4 would be the ideal solution. However, given the relatively modest number of rock slopes thought to be present on the HA network it is considered that this option would be disproportionately expensive and would not represent a cost effective solution.

Therefore, Option 3 is recommended as this option would significantly improve on the HA's current management of rock slopes. This option would ensure that the RSHI system was consistently applied and the required information was reliably captured. It is considered that the modest amendments required to Pocket GAD and HA GDMS would represent a cost effective way of significantly improving the HA's management of its rock slope assets.

As detailed in the draft AMM (see Annex A) the implementation of the RSHI system would allow a score to be derived for each rock slope. This RSHI score is directly related to actions that service providers have to undertake to manage and maintain the rock slope asset. In this way the RSHI system will significantly improve unified risk assessment.

The draft AMM explains how the RSHI system fits within the existing HA geotechnical asset management system from inspection planning through uploading and reviewing the data on HA GDMS and onto repeat inspections.

The remainder of this document assumes that Option 3 is selected.

4. Amendments to existing HA systems

4.1 General

None of the proposed changes fundamentally alter the HA's existing earthwork management systems. Rather, these changes aim to improve the existing system with regards to the inspection of rock slopes.

4.2 Area Maintenance Memorandum

The draft AMM that is linked with this document (see Annex A) has been prepared to allow the implementation of the RSHI system in the HA in the short to medium term. Ultimately, to achieve the goal of widespread, consistent and long-term implementation it would be necessary for the information in the draft AMM to be incorporated into an updated version of HD 41.

The following comments supplement those already in the draft AMM.

- The draft AMM has been written in a format similar to that generally employed by the HA.
- It is not intended that the final version of the AMM will be released until all of the appropriate changes have been made to Pocket GAD and HA GDMS. All aspects of the system will then be simultaneously implemented.
- The draft AMM has been prepared to supplement the guidance in HD 41/03 and should not contradict anything in HD 41/03.
- In addition it has been written to fit within the processes outlined in HD 22/08.
- The document has been written to try and make it applicable to other Overseeing Organisations (OO) such as Scotland, Wales and local authorities; rather than just the HA.
- The draft AMM does not explain specifically what changes have been made to Pocket GAD and HA GDMS – these will be obvious from the systems themselves once they have been changed.
- Section 3 of the draft AMM describes how the RSHI system will fit within the HA's existing systems. This implementation document explains the details of how the system will be implemented.
- Section 4: the detailed inspections and assessment section has been left as simple as possible so as to not restrict practitioners unnecessarily. In addition, good guidance is already available and the draft AMM and this document could not hope to recreate the scope of existing guidance.
- Draft AMM Section 4.1: it has been left open for the Designer's Geotechnical Advisor(DGA)/Managing Agent's Geotechnical Liaison Engineer(MAGLE)/Overseeing Organisation (OO)/HA to determine who qualifies as a suitably experienced rock slope inspector.
- Draft AMM Sections 4.9, 4.10, 4.11, 4.12 and 4.13 have been included to ensure that this is a requirement for considerations beyond the basic rock slope.
- The risk elements in the RSHI (traffic, sighting etc.) could be used to help make decisions at the Value Management stage. However, this will need to be carefully considered as there is potential to conflict or confuse if these have already been included in a RSHI numerical assessment.

- Once the RSHI score has been calculated and the 'Rock Slope' observation added to HA GDMS it is intended that the MAGLE will have the opportunity to approve the RSHI score and the suggested Risk Level. If the MAGLE does not agree they will be given the opportunity to adjust the Risk Level, although justification will be required.

4.3 Pocket GAD

At present, the recommendations on how to incorporate the system within Pocket GAD are general in nature. Technical details of how the system will be incorporated will follow after consultations with the system developers.

Some trials would also be required on a beta version of the system before it went live for the HA network. In Section 6, it is suggested that all of the HA's rock slopes are inspected in one complete round – this would be the ideal opportunity to do this.

It is intended that the following changes will be made to Pocket GAD if Option 3 is implemented. However if Option 2 is adopted by the HA as a interim step towards full implementation of Option 3 then many of the proposed modifications to Pocket GAD will not initially be made. Reference should also be made to the HD41 Guidance Note, dated 2010 for further information.

- A 'Rock Slope' observation would be added.
- The RSHI system would be incorporated into Pocket GAD. However, the information would be 'dead' i.e. it would not be possible to manipulate the information or use it to derive the RSHI score.
- The inspector will be required to identify whether the slope is a soil or rock slope. The definition of rock used will be as in the draft AMM. If necessary, the examiner will be able to call up the definition to help them decide. If the slope is indicated to be a rock slope then the RSHI data would become available and would need to be completed in addition to the normal Principal Inspection information.
- Data from previous RSHI inspections, where these exist, will be attached/completed as observations in Pocket GAD.
- During subsequent inspections the inspector would be able to check the information in previous observations and compare it to the present condition. This should generally speed up the process considerably and potentially allow changes in long-term condition to be monitored.
- In relation to the above point it is recommended that after the initial inspection that most of the factual RSHI data (whether in the form of scanned paper copies or raw factual data) becomes locked and can only be altered by the MAGLE. The information that would remain available for change would include aspects that are likely to change over time such as weathering condition. This would mean that data is not unnecessarily changed.
- The guidance on the RSHI system available in the draft AMM should also be made available in Pocket GAD if possible. This could take the form of a help menu or a Portable Document Format (PDF) file.
- Within the observation an input box would be required for the RSHI score. This would need to be calculated from the inspection data as a separate exercise. Once the score was calculated it would be entered and the Risk Level would be automatically allocated. It is likely that the

score will generally be entered directly into HA GDMS rather than Pocket GAD. However if the score is entered into Pocket GAD then the inspector will be able to see the assigned Risk Level. If the inspector does not agree with the Risk Level they will be given the opportunity to comment on this and provide their assessment of the risk, but they will not be able to change the actual Risk Level (although it is proposed that the MAGLE will be able to do this in HA GDMS, see Section 4.4).

4.4 HA GDMS

At present the recommendations on how to incorporate the system within HA GDMS is general in nature. Technical details of how the system will be incorporated will follow after consultations with the system developers. Reference should also be made to the HD 41 Guidance Note, dated 2010 for further information.

All of the changes required to ensure the RSHI system is fully incorporated into Pocket GAD (Section 4.3) would also need to be made to HA GDMS. In addition the data form Pocket GAD would need to be easy to upload to HA GDMS and vice versa.

It would also be necessary to ensure all of the relevant RSHI could be inputted manually into HA GDMS if need be, for instance if the actual inspection was done on the paper form.

5. Implementation

Details of how the RSHI would fit within the existing HA geotechnical asset management systems, how it would work and be used in practice and how the RSHI scores relate to Risk Level and the maintenance strategy are provided in the draft AMM (see Annex A).

This section assumes that Option 3 is implemented. However if the HA decide to adopt Option 2 as a step towards full implementation of Option 3 then some of these proposed stages will not occur until later.

Note that all of the following items, with the exception of Stage 2, are outside the scope of the current project scope.

- | | |
|---------|--|
| Stage 1 | HA to reach agreement with TRL that allows the HA access to the RSHI research, methodology, guidance, algorithm and database. |
| Stage 2 | Finalise documents required from this Task Order (draft AMM and this report). However, these documents will not be issued at this point although they will be available to those beta testing the RSHI system. |
| Stage 3 | Make required modifications to Pocket GAD and HA GDMS so beta versions of the system can be used in subsequent initial inspections. |
| Stage 4 | Undertake desk based exercise to pre-populate HA GDMS with existing TRL information. Sources of information would include existing information on HA GDMS, rock slope records provided by MA's, data from existing TRL databases such as that maintained by Coffey Geotechnics (if available). |
| Stage 5 | Plan a round of inspections to populate the RSHI database. The aims of this exercise would be to beta test the RSHI system and allow a baseline of data to be inputted into HA GDMS. To ensure cost effectiveness the inspections would prioritise rock slopes that have not been inspected or have not been inspected in a long time and/or are high risk. |
| Stage 6 | Assemble team to inspect the rock slopes identified in Stage 5 in one complete round to populate the RSHI data in HA GDMS using the beta version of Pocket GAD and HA GDMS. It is envisaged that the inspections will be carried out by two man teams from a variety of organisations. One member of the team will be trained in the RSHI system and will be drawn from an HA area that has a relatively large number of rock slopes. The other member of the team will be from the geotechnical team's local HA area. The inspector trained in the RSHI system would ensure that the baseline data was reliable and consistently obtained and would train the local team member. The local inspector would ensure that all of the appropriate quality, health and safety aspects were in place and items such as traffic management was arranged and in place. This approach should ensure that the systems are carried out safely and to a high standard. It will also assist the dissemination of the knowledge of the system and help ensure that a wide base of knowledge is quickly established. |

- Stage 7 Inspection data to be uploaded to HA GDMS and RSHI scores to be calculated.
- Stage 8 Data to be reviewed in HA GDMS and approved or otherwise by MAGLEs. As detailed in the draft AMM, the RSHI scores are related directly to Risk Level which provides the MAGLEs with the maintenance actions that they have to perform. These actions will be the responsibility of the MAGLE.
- Stage 9 Carry out feedback review to HA and:
- Review and amended scoring if required.
 - Provide final suggestions for improvement.
- Stage 10 Based on the information from the feedback review, make final improvements to draft AMM, Pocket GAD and HA GDMS.
- Stage 11 Formerly issue AMM and simultaneously release the versions of Pocket GAD and HA GDMS that contain RSHI onto the live system.
- Stage 12 Subsequently, rock slopes are to be reviewed at intervals established by RSHI inspections by local MAs as part of their Principal Inspections. Local MAs will also be responsible for any maintenance actions if required. It is considered that these tasks will be made easier by the baseline of reliable information that will have been established by the above process.

If all of these stages are carried out then the system should be consistently applied and viable in the long-term.

Having trialled the system, it is not considered that inspectors who meet the HA's requirements for Principal Inspections will need additional training to carry out the inspections. However the course that the HA GDMS support team currently provides on Principal Inspections and Pocket GAD could include training on the system if required.

6. Recommended future work

Note that the following work is outside the scope of the current Task Order.

- The draft AMM has been significantly modified following on from the Expert Group meeting Nr.2 to incorporate the RSHI system. It is recommended that a final meeting of the Expert Group is carried out to review the remaining details.
- As discussed earlier in this report, the RSHI system currently does not deal very well with weak and interbedded rocks. It is recommended that additional work is carried out to improve this aspect. One possible approach would be to find out if Network Rail research in this area has made progress.
- There may be scope to undertake a collaborative research effort to establish an improved and definitive version of the RSHI system to ensure best practice and consistency across UK practice. Such a system would address the weak/interbedded rock issues and the effort could involve the HA, Network Rail and TRL amongst others.
- To further aid consistency and long-term application, it is recommended that the contents of the draft AMM are incorporated into the revised HD 41 when it is issued.
- In the medium to long-term it is recommended that Option 4 in Section 3 of this report is eventually implemented. This will further ensure consistency and long-term application and will resolve the fundamental lack of elegance associated with Option 3 which will be the inability of Pocket GAD and HA DGMS to automatically calculate the RSHI score or manipulate the data.
- Update the Network Maintenance Manual (NMM) and the Route Maintenance Management System (RMMS) to ensure the whole of the HA asset management system is operating in a holistic manner to manage the hazards and risks posed by rock slopes.
- Additional guidance documents could be produced for rock slope assessment and design. Network Rail have documents that cover these aspects and work could be undertaken to provide similar documents for the HA. This would help with the overall aim of ensuring the HA's rock slope assets are safely, effectively and efficiently managed.
- Research could be undertaken into the long-term condition assessment of rock masses using work such as that of Nicholson (2004) as a basis.
- Research could also be undertaken into the long-term deterioration of rock support (dowels, bolts, anchors) and rock containment measures (mesh, netting etc.)

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Annex A - HA Rock Slope Hazard Index AMM (Draft)