Risk Assessment and Asset Management Applied to Geotechnical Hazards within Roading Networks

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Summary: Terrain evaluation, hazard and risk mapping all aim to provide clients with a visual indication of risk level for a particular hazard in relation to a particular asset. However, in a road environment these excellent visual tools do not provide a proactive means of monitoring and ranking deformations over time.

As part of the Transit Performance Specified Maintenance Contract 002 in Northland, a 10 year maintenance contract operated by Works Infrastructure Limited in conjunction with MWH (NZ) Ltd, a means of listing and monitoring ground instabilities was identified at an early stage as being an essential tool to manage the plethora of slips existing, and continuing to occur, within the network.

Drawing on international approaches to asset listing, monitoring and management, MWH have developed a geotechnical hazard database which catalogues all ground instabilities (overslips, underslips, scour and landslides) within the network, provides a means of monitoring them over time and, through an evaluation and assessment process, provides inputs into a specifically designed risk matrix, from which sites are ranked.

INTRODUCTION

Ground instability is a problem that affects most roading networks. Transit New Zealand's Region 1 (Northland) is considered to have one of the largest number of ground instabilities on the State Highway network, with approximately 225 ground instability sites that affect the safety and/or serviceability of the network.

In the Performance Specified Maintenance Contract (PSMC 002) a high level of ownership has provided the motivation to ensure a high level of safety and service is delivered to the road user. The PSMC 002 team has developed a process to manage the risk exposure to the road user with respect to ground instabilities affecting the road. This is achieved by undertaking a risk assessment of each ground instability and then analysing the effectiveness of different risk mitigation strategies. The process enables the prioritisation of individual ground instability sites in terms of safety and serviceability of the roading network. This tool provides a 'live' management system, which allows continual assessment of the network to be done whilst permitting the finite resources of Transit New Zealand/Transfund to be used effectively.

This paper demonstrates how an innovative ground instability risk management process can be used to assist in the development of proactive risk management strategies to efficiently manage road user's exposure to risk associated with ground instability.

THE RISK ASSESSMENT PROCESS

The risk assessment process for each ground instability site has been developed utilising AS/NZS 4360:1999: 'Risk Management', modified to take into account TNZ Z/10, shown schematically in Figure 1.

The process provides an efficient strategy aimed at preventing the road user being exposed to unacceptable risk. The adopted strategy provides a method of managing an unacceptable site in an 'acceptable' low risk manner whilst best utilising Transit New Zealand's limited resources.

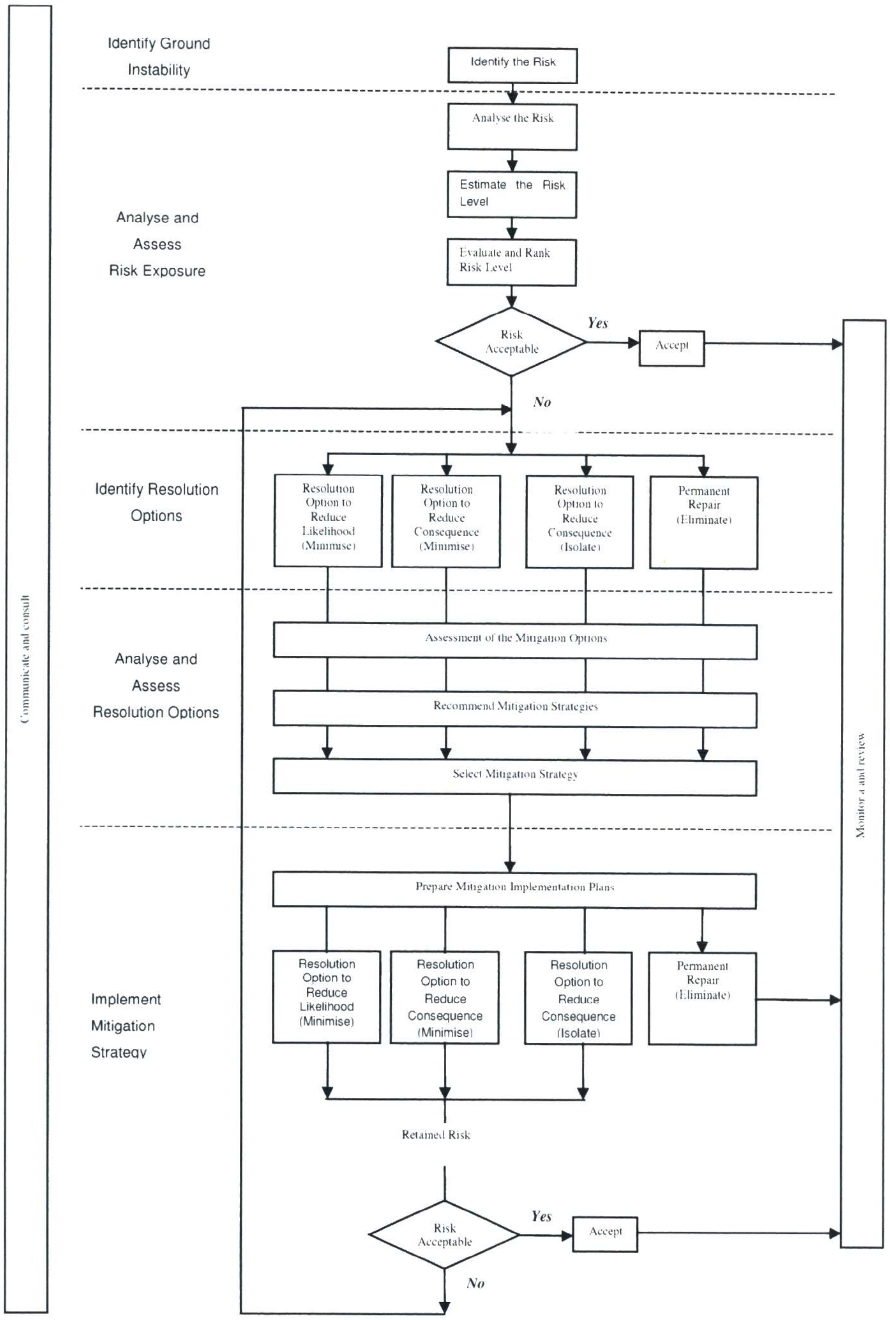

Figure 1: The Ground Instability Risk Management Process

DATA COLLECTION

A standard process of data collection has been adopted covering the key parameters needed for the determination of the risk exposure. The information gathered during the site inspection is entered into a specially designed database that consists of six key fields: Location, Background, Geotechnical, Safety, Progress Log and Mitigation.

Four of the database fields (Location, Background, Geotechnical and Safety) are used for the analysis of the field data, while the other two (Mitigation and Progress Log) allow for additional data to be included and utilised in the management process. The Progress Log field has been developed to allow a detailed account of all activities to be recorded.

The database also incorporates tools for the assessment and reporting of deformations, which includes the determination of mitigation strategies, facilities for calculating rough order costs for remedial works and links to documents (reports, site photos, etc.) and data associated with the individual site.

The identification of ground instability utilises the four fields; Location, Background, Geotechnical and Safety, with the parameters within these fields providing the base data for determining the risk exposure.

Input Fields

The location field covers the key basic properties identifying a site, including site name, location (State Highway, Route position, left or right side), form of carriageway at that position (embankment, cut, fill) and the date of inspection.

The background information field (see Figure 2) deals with the basic properties of the deformation in terms of dimensions, relationship to the carriageway, the type and current movement activity, date of initial occurrence, and the description of the defect and the currently proposed remedial option.

The geotechnical field (see Figure 2) deals with the physical properties in terms of the influence of surface/ground water and drainage, movement (horizontal and vertical scarp movement), frequency (events/year) and likelihood of catastrophic failure (partial or full closure).

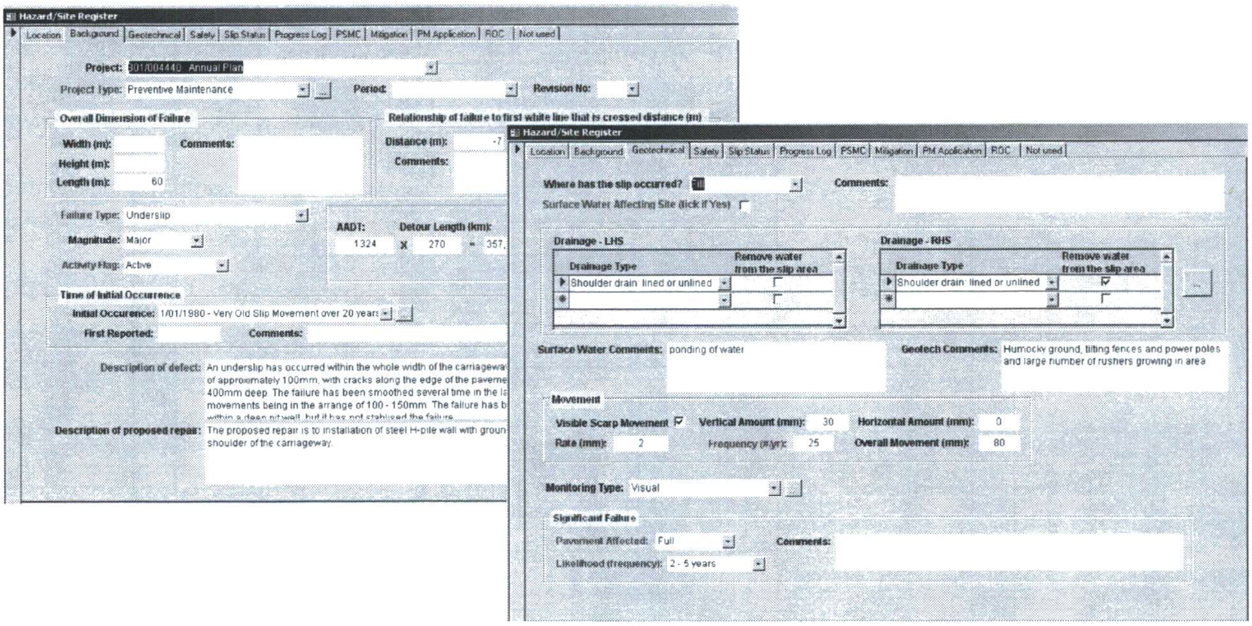

Figure 2: The Background and Geotechnical Input Screens

The safety field (see Figure 3) focuses on the road user's safety, driveability and perception of the site. The safety and serviceability contributors are the roughness of affected pavement, deflection within the pavement, driveability of the affected area, delay incurred due to reduction of the carriageway or a detour, alignment of the carriageway at the affected site, speed reduction incurred (due to the defect), permanent speed environment, current warning signage, safety features (warning devices). From this the current user hazard is evaluated and a prediction of the future hazard made.

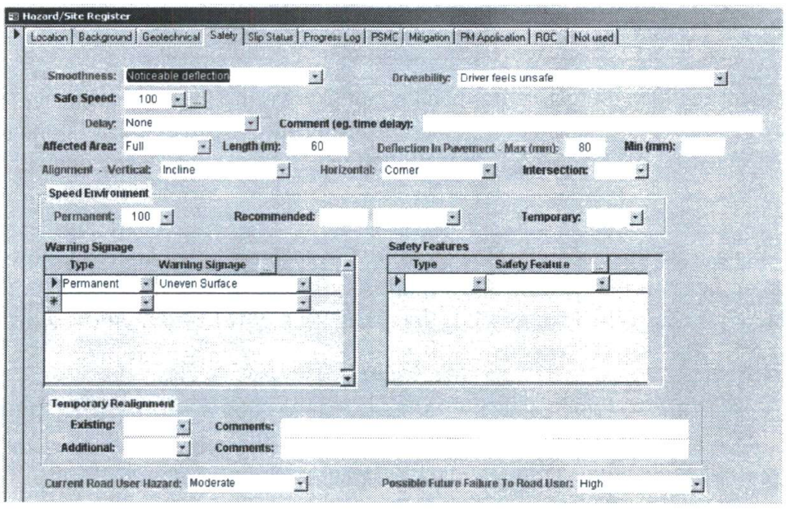

Figure 3: The Safety Input Screen

DATA ANALYSIS AND RISK EXPOSURE ASSESSMENT

A risk matrix is utilised in the calculation of a risk rating and is based on the analysis of field data in terms of consequence and likelihood.

The analysis of the field data results in the determination of sites that have a risk exposure that is either acceptable or unacceptable to the road user.

The risk exposure influences the strategy required to manage the ground instability. Sites that have an unacceptable risk exposure must have a mitigation strategy implemented to reduce the risk to an 'acceptable' level, whilst sites that have an acceptable risk exposure are monitored to ensure they do not progress into the unacceptable category.

Risk Analysis

The purpose of the risk analysis is to provide a structured methodology for assessing, evaluating and ranking each site.

A risk matrix, see Figure 4, is used to establish the risk level (to the road user) of the site is established (ranging from negligible to extreme).

Likelihood						
	A (Almost Certain)	**H**	**H**	**E**	**E**	**E**
	B (Likely)	*L*	**H**	**H**	**E**	**E**
	C (Possible)	*N*	*L*	**H**	**E**	**E**
	D (Unlikely)	*N*	*N*	*L*	**H**	**E**
	E (Rare)	*N*	*N*	*L*	**H**	**H**
		1 (Insignificant)	*2 (Minor)*	*3 (Moderate)*	*4 (Major)*	*5 (Critical)*
		Consequence				

N = Negligible, L = Low, H = High, E = Extreme

Figure 4: The Risk Matrix

Consequence Assessment

The levels and descriptors adopted for the analysis of ground instabilities are shown in Figure 5.

Level	Descriptor	Description
5	Critical	Sever the highway and/or extreme risk to road users
4	Major	Close the highway for more than 24hours and/or major risk to road users
3	Moderate	Close half the highway for more than 24hours and/or an unacceptable risk to road users
2	Minor	Reduce available road width and/or low risk to road users
1	Insignificant	Minor delays during clean-up and/or insignificant risk to road users

Figure 5: Likelihood Descriptors and Descriptions

The qualitative measures of consequence are based on the analysis of field data and include consideration of the following:-

- The type of failure – scour/underslip/overslip/landslide ;
- The original alignment of the carriageway of the site;
- Original speed environment of the site;
- Safety features installed (warning signs, barriers, speed reduction posted);
- any temporary realignment;
- Deformation to the pavement (deflection, smoothness);
- Driveability over the affected area;
- Delay in travel time;
- The strategic importance of the road (including political awareness);
- Road user hazard exposure that exists now and until the next movement;
- Road user hazard exposure that could be experienced in the event of a catastrophic failure (partial or full closure);
- Length of detour route and time delays associated therewith.

The consequence assessment is driven by road user safety and serviceability factors. Each of the contributors has been assigned weightings to distinguish the relative influence that a contributor has on the consequence. For example, the following are considered to be the major contributors:

- The alignment of the carriageway of the site;
- The change in speed environment of the site;
- The type of failure – scour/underslip/overslip/other;
- Pavement defects;
- Driveability.

The rating of each contributor is multiplied by the given weighting and added to give an overall score that is converted into a consequence level for a site (Level 1-5).

Likelihood Assessment

The levels and descriptors with descriptions adopted for the analysis of ground instabilities are shown in Figure 6.

Level	Descriptor	Description
A	Almost certain	Expected to occur in most circumstances
B	Likely	Will probably occur in most circumstances
C	Possible	Might occur at sometime
D	Unlikely	Could occur at sometime
E	Rare	May occur only in exceptional circumstances

Figure 6: Consequence Descriptors and Descriptions

The contributors for the likelihood are collected from the field data and include the following:-

- Whether the ground instability is currently active or not;
- Whether the existing drainage removes water from the site or not;
- The influence of surface/groundwater on the instability;
- The rate/depth and frequency of movement; and
- An assessment of the likelihood of a catastrophic failure occurring.

The evaluation of the likelihood of occurrence focuses on these five different contributors, which are physical properties that drive the rate of progression of further deformation. Each of the contributors has been assigned a weighting to distinguish the relative influence a contributor has on the consequence.

The ranking of each of the contributors at a site is multiplied by the given weighting and added to give an overall score that is converted into a likelihood level (Level A-E).

Using the risk matrix (Figure 4) the level of risk for each site can be determined: negligible to extreme.

Internally, the following definitions for the level of risk have been adopted:

E: Extreme risk: immediate action required as this risk is unacceptable. Resolution strategies require development to manage this risk.

H: High risk: unacceptable and resolution strategy required to manage this risk.

L: Low risk: acceptable, however, review and monitor to ensure site does not deteriorate to High or Extreme category.

N: Negligible Risk: acceptable, review to ensure it does not deteriorate further.

Exposure to **high** and **extreme** risk is deemed to be an unacceptable risk to the road user. Sites that meet this criterion require mitigation to reduce and then manage the risk at an 'acceptable' level. The **low** and **negligible** risk sites are considered to be an acceptable risk requiring monitoring to ensure the risk profile does not regress to a high or extreme level.

From the numerical assessment undertaken for both consequence and likelihood, a numerical risk level is also obtained. This value, the *Risk Level Priority Ranking* enables sites to be ranked overall to provide a ranked list of all deformations. This listing is then adopted to assist in selection of sites for both Emergency Works and annual Preventative Maintenance Sites for Transfund consideration.

IDENTIFICATION OF RESOLUTION OPTIONS

Any ground instability that has **high** or **extreme** rating is required to have a resolution strategy implemented for the site. Typical resolution strategies adopted for a site would be:

- Permanent stabilisation of the ground instability (eliminate);
- Barricade off the affected slip zone and unsafe area, and realign road for two-way traffic to remove the road user from the unsafe area (isolate);
- Temporary smoothing of the pavement to reduce the consequence of the movement to the road user (minimise); and
- Partial repair of the slip to reduce the likelihood of failure (minimise).

The resolution options can be utilised independently or in conjunction with one another to develop strategies to manage ground instability sites in an effective manner within available fiscal resources.

ASSESSMENT OF THE RESOLUTION OPTIONS

The assessment of each resolution option is undertaken in terms of cost/benefit to determine the effect it will have on the risk exposure. The benefits of differing options are considered over short, medium and long term, to take into account the changing safety and serviceability of a site over time.

The effect of a particular resolution option has on mitigating the risk varies from site to site, because of the different conditions at each site. Hence the effectiveness of a particular resolution option is dependent on site conditions and the resulting 'risk exposure' to the road user from applying that option.

Once each resolution option has been evaluated, a recommended strategy is developed which may be one or a combination of options to manage the risk in an efficient manner. The resulting strategy will look at the effectiveness of mitigating the risk, and the cost associated to achieve this over the life cycle of the asset and/or resolution option(s) adopted. Adjustment of the strategy may be required to take account of the objectives of Transit New Zealand.

THE IMPLEMENTATION OF THE MITIGATION STRATEGY

The resolution strategy will be implemented once it has been accepted as the method to manage a site. An important aspect is to continue to monitor and review the implemented mitigation strategy to ensure that it continues to mitigate the risk effectively over time. Mitigation strategies are susceptible to a reduction in effectiveness over time due to the dynamic nature of the ground instabilities and driver familiarity.

Mitigation strategies most susceptible to reducing effectiveness are the minimisation options, since sites can easily progress to an unacceptable risk level over time. Managing the unacceptable sites to an 'acceptable' level through minimisation and isolation (i.e. the hazard has not been eliminated) is not an ideal long-term solution. Ground instabilities by their nature can move unexpectedly and without warning, resulting in deterioration of the site despite the minimisation and isolation strategies undertaken. Also, the natural deterioration of sites invariably results in higher repair costs, with continual smoothing of the sites adding dead load (mass) to the driving force of the slip, potentially accelerating deterioration. However, this has to be balanced against available financial resources.

Even though an unacceptable risk can be managed in an efficient manner, it does not eliminate the ultimate need for a permanent repair. The strategy merely manages the risk envelope within the available funding.

CONCLUSION

The developed ground instability risk management process is summarised by the following five steps:

1. Identify Ground Instability;
2. Analyse and Assess Risk Exposure;
3. Identify Resolution Options;
4. Analyse and Assess Resolution Options;
5. Implement Resolution Strategy.

The key contributors to the analysis of risk exposure are determined from the consequences to the road user and the likelihood of occurrence of the ground instability deforming further. The assessment results in either acceptable (low and negligible) or unacceptable (high and extreme) risk to the road user, with the unacceptable sites requiring a resolution strategy. A resolution strategy utilises resolution option(s) to:

- Eliminate
- Isolate
- Minimise

the hazard/risk.

Once a resolution strategy has been accepted for the ground instability as the method of management, the implementation of the strategy requires continual monitoring and review. This enables the dynamic nature of the problem to be managed to ensure it does not regress outside the risk mitigation level.

Development of resolution strategies for all sites enables the network to be managed through the developed strategies combined with on-going monitoring and review of each individual site. In this way the management system permits the finite resources of Transit New Zealand/Transfund to be effectively used.

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