ScotlandTranServ
A Balfour Beatty Mouchel Joint Venture

A83 Tarbet – Lochgilphead – Kennacraig Trunk Road

A83 Rest and Be Thankful

Debris Slide Remediation

Geotechnical Desk Study

07/NW/0901/031

July 2008

Produced for
Transport Scotland

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1 Introduction

1.1 Synopsis of Failure

Scotland TranServ, as the appointed agents for Transport Scotland, acts as the Operating Company to supply emergency call out services in the North-West network that require geotechnical remediation.

In the early hours of 28th October, 2007, a debris flow event occurred on the hillside above the A83 trunk road near the Rest and Be Thankful summit (refer to Appendix A - Site Location Plans). Failure materials, comprising saturated, boulder laden soils, were deposited over the road to a depth of up to approximately 2.5m and in the Croe valley below the road.

On the hillside above the road, the debris flow material eroded a flow path channel up to about 4m in depth, extending from the failure source area down to the road and from there down to the old military road near the valley floor. On the slope below the A83 road, the debris flow created a new channel to the south-east of the existing drainage channel, leaving a scar in the hillside approximately 3m deep. Moreover, the downhill face of the road embankment was heavily eroded by scour, not only from the debris flow but from surface water redirected onto the embankment. The surface water was a result of failure debris blocking a culvert, which had previously directed the water from the hillside into an erosion channel down to a tributary of the Croe Water in the base of the valley.

1.2 Scope of this Document

The purpose of this desk study is to assess the potential geotechnical constraints affecting the design and construction of the proposed remedial measures and to allow a design to be prepared for the appropriate ground investigation. The following activities were undertaken for this report:

- Site walkover inspection of the debris flow area to establish the stability of the failure area material and the likelihood of further movement occurring;
- A review of historical maps to identify changes in land use and topography;
- An assessment of the ground conditions from a review of geological maps, plans, hydrogeological information, hydrological information and existing ground investigation information;
- Review of previous reports on studies conducted within the area;
- Scottish Environmental Protection Agency (SEPA), Loch Lomond and Trossachs National Park (LLTNP) and Scottish Natural Heritage (SNH) were contacted regarding possible environmental constraints of the site;

- An assessment of the site layout including identification of all salient features including watercourses, soil classifications, groundwater features;

- Review of previous monitoring data.

It is intended that the information contained herein will form the basis of the recommendations for a ground investigation within the vicinity of the existing culvert. The ground investigation will provide geotechnical data for use in the design of the drainage alterations and remedial measures. Although not a requirement of SH4/89 this project will use a Geotechnical Risk Register as outlined in HD22/02.

1.3 Scheme Details

The A83 within this area is susceptible to debris flows and has had numerous failures in the past which have resulted in temporary road closures.

It is intended that the proposed remediation works will provide stability to the undermined Inveraray-bound lane of the A83, a replacement for the existing culvert and measures to prevent any further erosion of the discharge channel in the hillside below the road. The alterations to this section of road to allow these improvements to be made are to be conducted in a geotechnically complex environment on steep unstable hillside slopes. The earlier Emergency Works Report[(1)] recommended that this scheme be conducted as a Category B scheme according to technical memorandum SH 4/89.

This report has been written under OI number 8400382 and scheme number 07/NW/0901/031.

2 Desk Study Information

The following sources of information were referred to in the production of this report:

2.1 Geological Information

The geological sheet for the area was referred to in order to assess the superficial and solid geology underlying the site surface:

- British Geological Survey (BGS) Solid Sheet 37E Lochgoilhead 1:50,000.

No other geological maps were available from British Geological Survey.

2.2 Hydrogeological Information

The BGS Hydrogeology map was referred to in order to assess the hydrogeology of the site:

- British Geological Survey Hydrogeological Map of Scotland (1988) Scale 1:625,000;
- Robins, N. S., Hydrogeology of Scotland, British Geological Survey, London: HMSO (1990).

2.3 Flooding Information

The SEPA Flooding website was referred to in order to assess the likelihood of flooding at the site (www.sepa.org.uk/flooding).

2.4 Historical Information

Historical maps dating back to the first edition Ordnance Survey maps were purchased from the National Library of Scotland. The plans studied are listed below:

- Ordnance Survey Argyllshire Sheet CXXXIV Scale 1:10,560 (1874);
- Ordnance Survey Second Edition Argyllshire Sheet CXXXIV. SE Scale 1:10,560 (1900);
- Ordnance Survey Sheet NN20NW Scale 1:10,000 (1977).

In addition, reference was made to the Royal Commission on Ancient and Historical Monuments of Scotland website (www.rcahms.gov.uk) in order to establish if there were any sites of historical interest in the area.

2.5 Mining Information

The historical and current Ordnance Survey maps were inspected in order to assess any evidence of mining within the area.

The Coal Authority on-line Gazetteer was referred to in order to establish whether a Coal Authority Report was needed (www.thecoal.gov.uk/resources then follow links for Mining Reports Gazetteer, Scotland Gazetteer and "Areas where a mining report is not required").

2.6 Soil Information

The following Macaulay Institute Soil Survey Maps were consulted in order to assess the type and quality of the soils which could be encountered at the site:

- The Macaulay Institute for Soil Research, Soil Survey of Scotland, Sheet 4 Western Scotland Soil 1:250,000;
- The Macaulay Institute for Soil Research, Soil Survey of Scotland, Sheet 4 Western Scotland Land Capability for Agriculture 1:250,000.

2.7 External Consultation

Scottish Environment Protection Agency (SEPA) was contacted in order to assess the river and air quality in the area, contamination, hydrogeology, hydrology and any discharge or extraction licences.

Scottish Natural Heritage (SNH) was contacted in order to assess if there are any areas of Special Scientific Interest or protected species in the area.

Loch Lomond and the Trossachs National Park (LLTNP) were contacted in order to assess if there were any special requirements for working within the National Park area.

2.8 Slope Study and Assessment Reports

Reference was made to the numerous technical reports prepared as a result of the issues and events that have occurred since 1982. These have been referenced in Section 10 of this Desk Study.

3 Site Description

3.1 Site Location

The scheme lies approximately 400m south of the Rest and Be Thankful Car Park within the Croe valley and approximately 6 miles east of Inveraray, on the A83, within Argyll. The affected section of road is located at National Grid reference 223662,707106. Site Location maps are presented in Appendix A.

3.2 Site Description

3.2.1 Pre-Failure Site Description

Prior to the debris flow event in October, 2007, water from the hillside drainage channel was taken below the A83 road in a 450mm diameter pipe, referred to as Culvert 18. Water discharge from the culvert created an erosion channel that continued to progress uphill towards the road, resulting in collapse of pipe, sections and portions of the headworks. This problem, along with the inadequacy of the culvert to cope with water flow and debris from the hillside, had been identified by BEAR in a Culvert Assessment Report[2] prepared by the Babtie Group in April, 2003. Historical photographs of the culvert can be found within Appendix B.

3.2.2 Post-Failure Site Description

Debris flow material from the failure area was transported downhill to the A83 road following the path of an existing drainage channel. The debris flow deepened and scoured out the existing drainage channel to expose the underlying bedrock. Much of the failure material, estimated to be 600 tonnes, was deposited on the A83 road – blocking the road, the roadside ditch adjacent to the eastbound carriageway and the inlet to Culvert 18. The debris material continued to flow downhill of the A83 road, undercutting the embankment and creating a new run out channel which extended as far as the Old Military Road below. Following the slope failure, surface water runoff from the hillside, which previously flowed into Culvert 18, flowed over the A83 road and contributed to the undercutting of the downslope embankment. Photographs showing the consequences of the debris flow at road level are given in Appendix C.

3.2.3 Subsequent Changes to the Site

After the debris flow the road remained closed to traffic until failed material on the road had been removed, the roadside ditch adjacent to the eastbound carriageway had been cleared and the undercut section of the northbound carriageway embankment had been temporarily reinstated with coarse granular fill. Concrete barriers were placed on the edge of the carriageway adjacent to the uphill slope and a Varioguard barrier located near the westbound verge to limit the effects of traffic loading on the now weakened downslope embankment. Traffic management remains in place due to the restricted width of this section of the route.

At Culvert 18, a flexi-pipe was used to divert the hillside waterflow away from the road and undercut embankment, towards the adjacent downhill culvert. Culvert 18 was eventually cleared and now functions normally again, allowing removal of the flexi-pipe and reduction in pressure on the adjacent downhill culvert. Photographs taken after the debris flow event showing embankment reinstatement are presented in Appendix D.

4 Field Studies

4.1 Previous Site Walkover Information

Prior to the debris flow event, the hillside was subject to quarterly monitoring to help identify potential areas of risk for instability. The source area of the debris flow materials had been recognised as part of a potentially unstable area that was being monitored for movement. A diagram showing the areas previously recognised as having the potential for failure and included in the quarterly pin monitoring survey is shown in Appendix E.

Visual monitoring surveys were also conducted in conjunction with pin monitoring surveys above and below the road to establish the quantitative movement of particular areas at risk. The most recent survey findings were presented in the 2007 Annual Slope monitoring Report[3].

4.2 Emergency Site Walkover

A site walkover was carried out at the debris flow source area and the undercut road embankment on 28th October shortly following the debris flow. A sketch plan of the flow site and a cross section along the alignment of the flow are presented in Appendix F.

4.3 Subsequent Slope Monitoring Since Debris Flow Event

Visual inspections are conducted of the debris source area and the reinstated road embankment. During site visits, photographs were taken of predominant features (tension cracks, soil rafts, boulders, etc) within the source area and of the road embankment.

5 Desk Study Information

5.1 Geology

5.1.1 Drift Geology

The superficial deposits at the site are recorded to comprise glacial tills. During the site walkover, exposed soil horizons were logged and found to comprise very sandy clayey silt with gravel, cobbles and boulders. The drift deposits are likely to comprise both glacial till deposits, colluvium (slope debris moved downslope by gravity) and, within the flood plain of the Croe valley, alluvial material is likely to be present.

An extract of the geological map for the area is given in Appendix G.

5.1.2 Solid Geology

The geological map records the site to be underlain by quartz mica schist, grit, slate and phyllite of the Ben Bheula Schist in the Argyll Group. The Ben Bheula Schists are of Upper Dalradian age and are recorded to be strongly deformed and metamorphosed with none of the original sedimentary structures preserved. The Ben Bheula Schists are recorded to be 2km to 3km thick and consist dominantly of semi-pelitic (very fine grained sediment) schists interbedded with lenticular schistose grits. The rock was metamorphosed during the Caledonian Orogeny and has been affected by several folding episodes since then.

An extract of the geological map for the area is located in Appendix G.

5.2 Hydrology and Hydrogeology

5.2.1 Watercourses

There are several unnamed watercourses in the vicinity of the recent debris flow. The recent debris flow was largely contained in a small unnamed watercourse channel. This and other unnamed watercourses are culverted under the A83 and flow into a tributary of Croe Water in the valley floor.

5.2.2 Aquifers and Water Resources

The Hydrogeological Map of Scotland indicates that the area underlying the site comprises Precambrian concealed aquifers of limited potential without significant groundwater. The region is underlain by impermeable rocks generally without groundwater except at shallow depth.

The crystalline basement offers little potential for groundwater storage and transport other than in cracks and joints which may be associated with tectonic features or near surface weathering. Groundwater emanating from springs is recorded to be generally weakly mineralised.

5.2.3 Wells, Springs, Ponds, Sinks and Issues

Within the area of the site high dissected relief over much of the basement promotes shallow groundwater flow along short flow paths. Springs and seepages occur wherever water-bearing conduits intersect the surface but their exact location may be hidden by standing or flowing surface water or by peat or other drift deposits.

5.2.4 Flood Risk

The SEPA Flood Risk Map indicates that the Croe Water is at risk of flooding. Within the vicinity of the debris flow no risk of flooding is recorded. The Croe Water located approximately 1km to the southeast of the site, flows from the corrie (Bealach a'Mhaim) under the A83 and down to the valley floor.

The SEPA Flooding map for the area is located in Appendix H.

5.3 Agricultural Soils

The soil type within the area is recorded as Strichen which are drifts derived from arenaceous schists and strongly metamorphosed argillaceous schists of the Dalradian Series.

At lower levels within the valley peaty gleys and podzols typical of hummocky valley and slope moraines are recorded. Vegetation at lower levels is recorded to comprise Atlantic and Boreal heather moor, heather rush, fescue grassland and rush pastures.

Within the area of the debris flow, the soils are recorded to comprise peaty gleys, peaty podzols and peaty rankers typical of hill sides with steep to very steep slopes. The vegetation within this area is recorded as heath rush, fescue grassland and heather moor.

Above the debris flow the soils are recorded to comprise subalpine soils, some rankers and peat typical of mountains with gentle to very steep slopes. The vegetation at the upper levels of the slope is recorded to comprise upland bent-fescue grassland, stiff sedge and mountain heath communities.

Soil capability within the area of the site is recorded as land capable of use only as rough grazing. The lower levels of the slope are likely to have a high proportion of palatable herbage in the sward and better grasses. At higher levels moderate quality herbage is recorded such as white and lying bent grasslands, rush pastures and herb-rich moorlands.

The Soil and Land Capability Maps for the area are located in Appendix I.

5.4 Site History

The following historical summary was undertaken by reviewing the available historical Ordnance Survey maps. Extracts of the historical maps are located within Appendix J.

1874

Site: The site was recorded as steep, rocky rough grazing land on the 1874 map. The Tarbet to Inveraray road was recorded to trend northwest to southeast above the level of the unnamed tributary of the Croe Water at the valley floor.

Site Surrounds: The site surrounds were recorded to consist of steep rocky rough grazing land. The buildings of High Glen Croe were recorded to the south west of the site and the buildings of Laigh Glencroe were recorded to the south of the site.

1900

Site: No significant changes were recorded to the site between 1874 and 1900.

Site Surrounds: No significant changes were recorded to the site surrounds between 1874 and 1900.

1977

Site: The A83 (T) was recorded to have been constructed between 1900 and 1977. The road previously marked as the Tarbet to Inveraray road was denoted as 'Old Military Road' on the 1977 map. The new A83 (T) trended in a similar direction to the 'Old Military Road' but was recorded as located further up the valley side. The positions of the rock outcrops previously recorded were depicted differently on the 1977 map – the rock outcrops were recorded in the same general position but fewer larger rock outcrops were recorded. In addition several more unnamed watercourses were recorded to drain the hillside on the 1977 map compared to those recorded on the 1900 map. It is unclear whether this is due to higher accuracy mapping or due to the construction of the A83 (T) and resulting change to the drainage regime.

Site Surrounds: The opposite (west) side of the valley was denoted as coniferous forest on the 1977 map. A disused quarry was recorded on the A83 (T) to the south east of the site and may have been used during the construction of the road for sub-base materials.

5.5 Mining and Mineral Extraction

The Rest and Be Thankful is noted on the Coal Authority website as an area where a Mining Report is not required.

A review of the current and historical ordnance survey maps indicates that the site does not lie within an area of past or present mining, although isolated surface quarrying was recorded prior to 1977, approximately 1km south-east of the site.

5.6 Protected Species

The area of the recent debris flow is located around 650m east of Beinn an Lochain SSSI. This site is designated and is notified for the nationally important upland habitats it contains. Any works likely to impact on these notified interests will require consent of SNH before proceeding.

SNH does not hold detailed species records for the area but information on the SNH website lists the Scottish Framework Species for Beinn Luibhean. The species listed as under conservation (and therefore requiring consideration prior to site works) were the Water Vole, Red Squirrel, Lesser Butterfly Orchid and Wild Cat.

The Red Squirrel relies on broadleaf woodland and is under threat due to the Grey Squirrel. The Lesser Butterfly Orchid requires a habitat of wet heathland, grassland and open scrub and is under threat due to drainage of fields, woodland disturbance, ploughing of grassland and heathland and use of fertilizers and herbicides. The habitat of the Water Vole comprises lowland areas with small/static burns and steep sloping banks. The Scottish Wild Cat habitat is within the margins of mountainsides and moorlands with rough grazing.

It is recommended that the habitat of the species under conservation should be considered during the design of the ground investigation and proposed remedial work.

The LLTNP have not highlighted any special requirements to be adhered to during the ground investigation. The LLTNP have requested to be kept informed during design of the ground investigation and prior to commencement of site works.

5.7 Contaminated Land

Any contamination on the land is likely to be associated with the current and historical land use. However there is no indication of contaminated land from the available information.

5.8 Archaeological Sites

The website of the Royal Commission of Ancient and Historical Monuments of Scotland (RCAHMS) indicated that there were no sites of historical interest in the location of the site. However, there were several historical monuments on the register within the surrounding area.

The Croe Water, Mid Glen Croe, High Glen Croe, Gleann Mor Shieling Huts, Tyndrum Military Road and the Rest and Be Thankful Memorial Stone were noted to

be of historical interest within the surrounding area. The locations of these sites are shown within Appendix K.

5.9 Photographs

Photographs from the opposite side of the valley after the debris flow, show the change in morphology of the area. These changes have been described previously in Section 3.2 and are shown within Appendix L.

6 Previous Ground Investigation Information

6.1 Literature Review

Reference was made to the numerous reports written on previous instability, hillside slope assessments and culvert condition surveys. These are listed in Section 10.

6.2 Previous Ground Investigations

Date of Site Works	Report Date	Contractor	Engineer	Job Title	Area
October 2002	December 2002 (4)	Terra Tek Ltd	BEAR Scotland	Ground Conditions Report	Cascade: approximately 400m west of the recent debris flow.
November 1982	April 1983 (5)	Unknown	Strathclyde Regional Council	A83 Rest and Be Thankful Slope Failure	Down slope of road: approximately 150m north-west of recent debris flow.

Reference to the report on the ground investigation carried out on site by Terra Tek in October, 2002, is given as Reference 4 in Section 10.

The only information available from the Strathclyde Regional Council ground investigation is a plan diagram drawn on a local grid with corresponding geological cross sections. No borehole logs or testing results are available for inspection. The exact locations of the boreholes are unknown from the information available.

The information from the above ground investigations is summarised in the following sections. It should be noted that the ground conditions within the area of the current debris flow may be significantly different than those reported within nearby areas.

6.2.1 Superficial Deposits

Within the Strathclyde Regional Council ground investigation the superficial deposits below the A83 were recorded to consist of “loose to medium dense grey brown slightly organic slightly micaceous very silty very gravelly SAND (some interbedded medium dense sandy very silty sub-angular GRAVEL)”. The superficial deposits were recorded to be of the order of 10m to 15m thick.

According to the BEAR Report, the ground conditions comprise 0.65m to 0.70m of made ground associated with the carriageway construction or a thin layer of topsoil overlying Upper Glacial Deposits, described as very loose to loose orange brown silty sand and brown silty sandy gravel. The thickness of these Upper Glacial Deposits was recorded as ranging from 0.40m to 2.60m. Lower Glacial Deposits were recorded as medium dense orange brown to yellow brown very silty gravelly sand with occasional lenses of silt. The Lower Glacial Deposits were recorded at depths of between 0.60m and 3.20m below ground level with layer thicknesses ranging between 1.00m and 10.10m.

6.2.2 Bedrock Geology

The Strathclyde Regional Council ground investigation recorded the depth to bedrock as being approximately 10m to 15m below the A83.

The BEAR Report indicated possible rockhead at depths between 12.15m and 13.30m below ground level. No rotary coring was conducted and therefore rockhead could not be proven.

6.2.3 Groundwater

In the Strathclyde Regional Council borehole summary diagrams, no information regarding the groundwater was provided.

The BEAR Report indicated that groundwater was found within the Lower Glacial Deposits at depths of between 3.40m and 4.35m below ground level (90.80m AOD and 89.85m AOD respectively).

7 Geotechnical Risk

A review of the geotechnical risk associated with the project has been undertaken using a risk evaluation matrix to create a Geotechnical Risk Register. This matrix is based on the publications HD 22/02 (Managing Geotechnical Risk), and HD 41/03 (Maintenance of Highway Assets).

The risk evaluation matrix and Geotechnical Risk Register for this study area are contained within Appendix M. In summary the main potential geotechnical risks at the site are considered to be:

- Contamination of surface water and groundwater by ground investigation
- Potential for flooding
- Risk and disruption to road users
- Safety of workforce
- Steep and unstable slope

Before control, the degree of risk was calculated to be up to a value of '16', which is equivalent to an 'intolerable' risk and 'work must not start on the project until risk has been reduced'. The strategy to respond to the geotechnical risks identified in the project as advocated by the HD 22/02 document is outlined below:

- Avoid risk, or
- If unavoidable, transfer the risk, or
- If non-transferable, mitigate the risk, or
- If unable to mitigate, accept and manage the risk.

The risks identified have been accepted and managed by undertaking measures to control them, such as by undertaking this Desk Study exercise and designing the Ground Investigation. It is anticipated that following detailed design of this scheme using the latest standards and 'best practise' the degree of risks are likely to be reduced to a value of 4 or below which is equivalent to an acceptable risk.

The preliminary Geotechnical Risk Register will be reviewed at each stage of the design process (i.e., after the ground investigation and after detailed design) to ensure that all risks have been considered and that all possible precautions have been made against the risk.

8 Proposed Ground Investigation

A Ground Investigation is required to provide relevant information to allow safe and economic design of the proposed works and to reduce the geotechnical risks at the site to an acceptably low level. The objectives of the ground investigation will include:

- To identify the type, distribution and thickness of drift deposits, together with their engineering properties in relation to the proposed works;
- To identify the level and nature of any solid geology, where present, within the proposed zone of influence of the proposed works;
- Assess the chemical nature of the soil and groundwater to determine if either could have an adverse effect on new concrete;

It is anticipated that the Ground Investigation will comprise cable percussion boreholes conducted on the A83 and on the 'Old Military Road'. This would provide information on the type, distribution, thickness and engineering properties of the soil.

In addition, rotary open drilling will be progressed through the superficial deposits to rockhead on the A83 and on the 'Old Military Road', with rock core recovery below rockhead. This will confirm the depth to rockhead and provide information on the engineering properties of the rock.

Geotechnical and chemical laboratory testing will be undertaken on samples of soil, water and rock obtained during the ground investigation. Data from which will be used to establish geotechnical parameters for use in the design of the replacement culvert, embankment remediation works and concrete ancillary structures.

Standpipe piezometers will be installed in order to ascertain groundwater levels and piezometric pore water pressures.

9 Summary and Conclusions

The October, 2007, debris flow at the Rest and Be Thankful caused failure material to flow across the road and over the supporting embankment, resulting in a temporary road closure, blockage of the culvert beneath the road, erosion of the road embankment and undermining of the road. This section of the A83 is susceptible to landslides and instability of the hillside has been reported on several occasions. The previous geotechnical reports and limited available ground investigation information have been reviewed and summarised.

Soils within the area are recorded to consist of colluvium and glacial till with underlying schist bedrock possibly encountered at approximately 12m below ground level.

Several unnamed watercourses drain the area. Although the area is not recorded to be at risk of flooding it has previously been reported in a Culvert Assessment Report[(2)] that Culvert 18 'did not accommodate the 1 in 50 year flood event' and in the "Culverts 17 and 18 Option Study Report"[(6)] there is 'potential for debris blocking the ditch at a location just upstream of the inlet'. Design options were provided for a new culvert by BEAR in 2005[(6)]. The culvert was blocked by debris from the failure and emergency works were undertaken to divert the hillside water flow to the adjacent downhill culvert. It is proposed, therefore, that a replacement culvert is constructed and this should provide a larger capacity flow, with its inlet protected against blockage and the outlet designed to protect the downhill slope from erosion. During construction of the new culvert, the undermined road embankment is to be reinstated and the temporary rock fill removed and replaced with a permanent solution.

Prior to this work taking place, it is proposed to carry out a detailed ground investigation to provide data for the design of the culvert. It is anticipated that the ground investigation will comprise cable percussion boreholes and rotary boreholes on the A83 and on the 'Old Military Road' below to establish the depths and engineering properties of the soil and the bedrock. Due to the protected species in the area it is recommended that SNH and LLTNP are kept informed of proposed works.

In addition, the hillside slope monitoring should continue to be conducted. The specific recommendations for continuing slope monitoring are reported under a separate cover within the 2007 Annual Slope Monitoring Report [(3)].

10 References

1) A83 Rest and Be Thankful Debris Flow Emergency Works, 28 October – 20 November 2007 Prepared by Scotland TranServ February 2008

2) A83 Rest and Be Thankful Culvert Assessment Report Prepared for BEAR Scotland by Babtie Group April 2003

3) A83 Rest and Be Thankful Annual Slope Monitoring Report 2007 Prepared by Scotland TranServ December 2007

4) Report on Ground Investigation on the A83 Rest and Be Thankful Prepared by Terra Tek Limited December 2002

5) A83 Rest and Be Thankful Slope Failure Report Prepared by Strathclyde Regional Council Roads Geotechnical Unit April 1983

6) A83 Rest and Be Thankful Culverts 17 and 18 Option Study Prepared for Bear Scotland by Jacobs Babtie September 2005

7) A83 Rest and Be Thankful Annual Slope Assessment Report 2006 Prepared for BEAR Scotland by Jacobs Babtie March 2006

8) A83 Rest and Be Thankful Initial Geotechnical Assessment Report Prepared by Babtie Group January 2002

9) A83 Rest and Be Thankful Ground Conditions Report Prepared for BEAR Scotland by Babtie Group May 2003

10) A83 Rest and Be Thankful Soil Slope Assessment Report Prepared for BEAR Scotland by Babtie Group December 2003

11) A83 Rest and Be Thankful Annual Soil Slope and Boulder Assessment Report 2005 Prepared for BEAR Scotland by Jacobs Babtie March 2005

Appendix A - Site Location Plans

Appendix B – Culvert 18 - Historical Photographs

Appendix C – Debris Flow Photographs

Appendix D – Photographs Taken After Debris Flow Event and Embankment Reinstatement

Appendix E – Hillside Areas of Concern

Appendix F – Sketch Plan and Section After Debris Flow Event

Appendix G – Geologic Map

Appendix H – SEPA Flooding Map

Appendix I – Soil and Land Capability Maps

Appendix J – Historical Ordnance Survey Sheets

Appendix K – Royal Commission of Ancient and Historical Monuments of Scotland

Appendix L – Photographs of the Debris Flow from the Opposite Side of the Valley

Appendix M – Geotechnical Risk Matrix

PROBABILITY (P)		
Very Likely	1 in 10	**5**
Likely	1 in 100	**4**
Probable	1 in 1000	**3**
Unlikely	1 in 10000	**2**
Negligible	1 in 100000	**1**

X

IMPACT (I)			
TIME or COST			
Very High	**5**	>10 Wks on completion	>£1M
High	**4**	>4 Wks on completion	100K to £1M
Medium	**3**	>4 Wks but <1Wk on completion	10K to 100K
Low	**2**	1 to 4 Wks but none on completion	1K to 10K
Very Low	**1**	<1 Wk to activity but none on completion	<1K

=

Probability		**Impact**				
		5	**4**	**3**	**2**	**1**
	5	**25**	**20**	**15**	**10**	**5**
	4	**20**	**16**	**12**	**8**	**4**
	3	**15**	**12**	**9**	**6**	**3**
	2	**10**	**8**	**6**	**4**	**2**
	1	**5**	**4**	**3**	**2**	**1**

Risk Ratings
1 to 4 ***Trivial,*** but no action required.
5 to 8 ***Tolerable,*** but must consider more costs effective solutions or improvements at no additional cost.
9 to 12 ***Substantial*** and work must not start until risk has been reduced.
13+ ***Intolerable*** and work must not start on the project until risk has been reduced.
If risk can not be reduced, project should not proceed.

Impact Assessment Time estimated as a function of presumed delay and project scope. Cost taken as arbitrary indicative value

Risk Rating (R) = Probability (P) x Impact (I)

DEALING WITH GEOTECHNICAL RISK

- Avoid the risk, or
- If unavoidable, transfer the risk, or
- If non-transferable, mitigate the risk, or
- If unable to mitigate, accept and manage the risk

GEOTECHNICAL RISK ASSESSMENT

Risk No	*Risk/Hazard*	*Cause*	*Before Control (Sol phase)*			*Recommendations*	*After Desk Study*			*Comments*
			P	**I**	**R**		**P**	**I**	**R**	
1	Superficial Deposits	• Unknown thickness of superficial deposits and unknown engineering properties – potential for difficult ground conditions.	4	3	12	Previous ground investigation information suggests superficial deposits will be of the order of 12m thick and of sandy clay.	3	3	9	Ground investigation will confirm depth and properties of superficial deposits
2	Bedrock Geology	• Unknown depth to bedrock and unknown properties/weathering of rock.	4	3	12	Previous ground investigation information suggests that bedrock may at approximately 12m bgl.	2	3	6	Ground investigation will confirm depth and properties of bedrock.
3	Groundwater	• Unknown depth to groundwater - potential for shallow groundwater interrupting ground investigation and remedial works. • Contamination of groundwater due to ground investigation or remedial work construction	4	3	12	Previous ground investigation suggests groundwater may be at approximately 4m bgl.	3	3	9	Groundwater and surface water should be protected from contamination from drilling fluids, diesel etc. during ground investigation. Shallow groundwater should be taken into consideration when designing remedial works – concrete design classification and open trenches kept dry.
4	Hydrology	• Nearby watercourses may be subject to contamination and siltation due to site works and remedial construction works.	4	2	8	There are several nearby unnamed watercourses which flow near the site and into the River Croe at the base of the valley.	3	2	6	Protection measures to prevent contamination and siltation should be put in place during ground investigation and subsequent remedial works.

Risk No	Risk/Hazard	Cause	Before Control (Sol phase)			Recommendations	After Desk Study			Comments
			P	I	R		P	I	R	
5	Flooding	• Any flooding would disrupt the ground investigation and/or remedial works and would disrupt the road. It would also increase the potential for further failure. • Underdesign of culvert capacity could result in problems of flooding and erosion in the future.	4	3	12	The weather should be monitored during site works and until the remedial works are undertaken. Site monitoring should continue in order to confirm that no further failure will take place. SEPA flooding map suggests that the area of the site is not at risk from climate related long-term flooding.	3	3	9	Culvert re-design will increase capacity to cope with flooding events in the future.
6	Mining	• Potential mining could cause subsidence and contamination problems.	3	3	9	Review of historical and current ordnance survey maps indicates that this is not an area of mining. The Coal Authority website also confirms no mining has taken place.	1	3	3	
7	Protected Species and Designated Areas	• Potential for disturbing protected species and habitats	2	3	6	Consultation with SNH, SEPA and National Park Authority to assess habitat and species within the area.	1	3	3	Keep relevant authorities informed in order to protect special species and habitats

Risk No	Risk/Hazard	Cause	Before Control (Sol phase)			Recommendations	After Desk Study			Comments
			P	I	R		P	I	R	
8	Contamination	• Potential for contamination on the site	1	3	3	Historical Ordnance Survey maps indicate little evidence of contamination in the past.	1	3	3	Remain vigilant during site works. Reduce impact of site works by preventing drilling fluids leaking, having spill mats on site etc.
9	Archaeological Sites	• If the site is of archaeological significance, then an archaeological dig may be required to take place.	4	3	12	Desk Study indicates that the site is not within an area of archaeological importance.	2	3	6	
10	Road users	• Disruption and safety of the road users.	4	3	12	Disruption to road users due to traffic management during ground investigation and remedial construction Safety of road users during ground investigation, remedial construction. Potential for further failure – road closures and safety	4	3	12	Disruption to road users is necessary in order to protect drivers – keep emergency services etc informed of road/lane closures. Safety of road users during ground investigation and remedial construction will be protected by traffic management. Potential for further failure will be established during regular slope monitoring visits.
11	Work Force	• Work on a busy road and on a steep slope, with the potential for further failure	4	4	16	Site induction and health and safety awareness of all those working on site should reduce potential for injury.	3	4	12	Correct PPE should be worn. Working conditions should be taken into account when designing the ground investigation and construction of remedial work.

Risk No	Risk/Hazard	Cause	Before Control (Sol phase)			Recommendations	After Desk Study			Comments
			P	I	R		P	I	R	
12	Land Owner	• Potential for landowners to object to works being completed.	4	3	12	Inform and liaise with landowner at each stage of the investigation.	3	3	9	Inform and liaise with landowner prior to site works being conducted.
13	Steep and unstable slope	• Ground investigation conducted in difficult conditions and construction of remedial work will be conducted on a steep slope.	4	3	12	Design of ground investigation and buildability of remedial work should be take into account the steep slope	3	3	9	Ground investigation to be conducted predominantly on Military road and A83 with hand tools used on steep slope.