HIGHLAND REGIONAL COUNCIL

A890 STROMEFERRY BYPASS

ALTERNATIVE ROUTES: INCEPTION REPORT

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SYNOPSIS

During the meeting on 25 March 1991 at the offices of Highland Regional Council (HRC), James Williamson and Partners (JWP), a division of the Mott MacDonald Group, were asked by HRC to carry out an extension to the study carried out by JWP in 1990 (Report No. 4080/2879/002, Feb 1991) into the stability of rockslopes along the A890 between Cuddies Point and Ardnarff.
This extension was to examine solutions to the current problems posed to the road user by the potential instabilities on the rock slopes and overlying hillsides as alternatives to the programme of remedial measures proposed within the JWP report. The possible solutions include alternative road routes and the installation of protective structures, eg. avalanche shelters, over the existing road. Potential options have been assessed in this inception report with a view to recommending practical alternative routes for progress to preliminary design and development stage and hence for economic evaluation. Design, development and economic evaluation will be carried out as part of a preliminary study immediately following this report.

Various options were considered, these included:

- 2 possible bridge routes across the Strome Narrows
- 2 possible road routes to the south of the present alignment
- re-establishing a ferry route across the Strome Narrows
- extending avalanche shelter protection to both road and railway
- realigning the road onto a causeway or viaduct on the seaward side of the railway
- tunnel options, one crossing the Strome Narrows and one bypassing the present alignment

Following comparison of the various options it was recommended that 7 options progress to preliminary design and development stage for route appraisal and economic evaluation against the present scenario. (The present scenario would include the cost of slope stabilisation and maintenance as recommended in the JWP slope stability report of February 1991).

The options recommended for further study are:

- Bridge crossing from Portchullin to Port á Mheirlich, including approach roads from Achmore to Portchullin and upgrading of the present road from Lochcarron to Port á Mheirlich.

- Bridge crossing from North Strome to South Strome including approach roads from the A890 to South Strome and from North Strome to Loch Carron.

- Road route following Glen Udalain then either via Lochan Breac Mora or via Allt Loch Innis nan Seangan, joining the existing A890 at Attadale.

- Road route following the existing route but at high level. Junctions with the existing A890 being at South Strome and Attadale.

- Tunnel crossing from Portchullin to Port à Mheirlich including approach roads.

- Tunnel bypassing area of major remedial works between Allt an Fhraigaich and Cuddies Point Burn.

- Avalanche shelter protection to road over area of major risk from Allt an Fhraigaich to Cuddies Point.

The cost of those options which replace the existing road would include the cost of slope stabilisation and maintenance costs for those slopes created by construction of the present A890 between Ardnarff and Cuddies Point whose potential instability could affect the nearby Kyle of Lochalsh to Inverness railway should any failure occur.

1.0 INTRODUCTION

1.1 Remit

A meeting was held between Highland Regional Council (HRC) and Mott MacDonald (MM) on 25 March 1991 to discuss the findings of the report "Stromeferry Bypass, A890 Slope Stability (Cuddies Point to Ardnarff), Remedial Works: Final Report" which was prepared by James Williamson & Partners (JWP) (a division of the Mott MacDonald Group) in February 1991 (Report No. 4080/2879/002). As a result of discussions during the meeting HRC asked MM to prepare a report on the feasibility of solutions to the problems identified other than the remedial measures proposed in the report. Such solutions were to include alternative road routes avoiding problem areas highlighted during this report as well as options to secure the current route. Costs were to be prepared for each of the options on a comparable basis to the costs prepared for the remedial work proposed in the above report. The approach proposed entailed the production of this Inception Report which seeks to provide an overview of the options and identify which of the options are likely to be feasible and economic and determine the programme for further studies. Based on this, HRC may then select the options they require to be progressed to preliminary report stage.

1.2 Background

The JWP 1991 report concluded that stabilisation of the slopes adjacent to the existing single lane road would cost approximately £8M, would be disruptive to implement and would take some years to complete. The suggested package of work would not preclude the possibility of large landslips such as the ones which occurred during excavation for road construction.

However, although the risk of such a failure would remain without artificial disturbance, such failures would normally be considered to occur within a timeframe of thousands of years. Consequently, and acknowledging the likely cost and environmental difficulties in implementing preventative measures for such failures, this topic has not been pursued.

The study area is illustrated in Figure 1

1.3 Scope of Studies

The present remit requires the examination of alternatives which would permit the road route to be isolated from the slope stability problems. A revised routing could also permit upgrading from the present single lane standard. The options considered are:

- The construction of a bridge at Strome Narrows (single and dual lane bridge deck to be considered), with suitable approach roads
- The construction of a tunnel at Strome Narrows, with suitable approach roads.
- The construction of a new road to the south of the present alignment bypassing the unstable slopes
- Re-establishment of a vehicular ferry at Strome Narrows, and the upgrading of the approach roads to a suitable standard
- Construction of "Avalanche Shelter" type structures at the required sections of the present road alignment to accommodate two carriageways.
- Realignment of the road onto the seaward side of the railway line
- Construction of a tunnel to bypass the major remedial works which have been described in JWP report (4080/2879/002)

The study is also required to advise on the stability and stabilisation requirements of rockslopes which were formed at the time of road construction in the context of long term security of the railway, on the basis that an alternative road route is provided. (See Appendix B).

As a parallel exercise, HRC have requested a review of appropriate slope surveillance and maintenance procedures to enhance security until such time as full stabilisation on route diversion works are completed. This is the subject of a separate report by MM; preliminary considerations are included here in Appendix A.

2.0 SLOPE INSTABILITY ON A890 ARDNARFF TO CUDDIES POINT

A study carried out in 1990 by JWP to appraise the stability of the slopes between Ardnarff and Cuddies Point concluded that severe stability problems are present on the rock slopes immediately adjacent to the road and hillside above. The study established that the principal hazards are located on a 1km stretch encompassing the existing avalanche shelter. In addition, the report identified that the slopes have experienced very large landslips, historically, but considered that the scale, occurrence, and timing of deep seated major events such as this lie beyond the scope of this study.

The study was concerned with the remedial measures to the routine stability problems and the failure of relatively near surface features, which are likely to be amenable to economic remedial measures.

An extensive package of remedial measures was proposed for the surface-related potential hazards to the road including rock reinforcement, rock fences, surface meshing, tree removal and general clearance, and ground and surface water control. The proposed works were programmed as six contract packages over a period of seven years, with the implementation of the work within the vicinity of the avalanche shelter identified as being a priority. To avoid total road closure it was proposed to divert traffic onto the railway line, similar to the diversion set up for Ch906m emergency works, in 1990. An overall cost estimate of £8M was calculated, including management, design and supervision costs. The cost of these proposals will be included in the "Do minimum" option for comparison with alternative proposals.

3.0 ALTERNATIVE ROUTES

In considering possible means of avoiding the long term slope stability problems within the Ardnarff to Cuddies Point stretch of the A890, the assessment of the options for progress to preliminary report stage has been based partly upon their ability to provide a minimum 6.0m wide carriageway with 2.0m verges on either side to Highway Link standard: Other factors included in the assessment were safety, social, environmental and economic considerations.

The advantages and disadvantages of each option considered at this stage are given below.

3.1 Bridge Crossing

3.1.1 Introduction

The location of a bridge at Strome Narrows will largely be determined by the need for the approach roads to traverse around the steep sided Creag Mhaol hill on the south shore. Two potential routes have been selected, one from a point near Portchullin on the south to Port à Mheirlich on the north of the Narrows, and another from South Strome to Strome Castle. These are shown on Fig 2.

At each of these locations the average depth to sea bed level is estimated to be 10-15 metres and the underlying strata as assessed from the local geological map are believed to be metamorphic rocks. A preliminary investigation of the rock outcrops along both shorelines reaffirmed this view. The waters both to the east and west of the Narrows are considerably deeper. This phenomenon is consistent with the rise in rockhead which occurs at the mouth of glacially formed fjords. Therefore it is anticipated that the superficial deposits will be relatively thin at the Narrows. Site investigations are required to confirm this. These conditions at the Narrows should provide foundations for a bridge at shallow depth and, provided the bridge deck level required for navigation requirements are reasonable, the bridge may be an economic option.

The bridge alignment, and the navigation width and minimum clearance have yet to be established, however both of the following options are flexible enough to meet a range of requirements.

3.1.2 Bridge route 1. (From east of Portchullin to Port à Mheirlich)

The south approach to this route traverses a raised beach which stands approximately 25m above shore level and is approximately 20m away from the high water mark. This may provide a suitable platform to cross the existing railway which runs near to the shore line and it may also be useful in meeting the vertical alignment of the bridge. It is envisaged that, should the deck level be low, the most economic crossing may be to extend the approach embankment a distance into the narrows, the shallow water depths around this area would seem to make this possible. (Photographs 4, 5 and 6, [4][5][6]). If the deck level is 20 to 30m above sea level the bridge spans would be extended to the shore line.

The alignment of the bridge may be skewed to meet a suitable landing point on the north side. To the west of Port à Mheirlich there is a steep rock face behind the shore line, which rises to a height of 61m above high water level, and which would rule out this stretch as a suitable location. [7]

At Port à Mheirlich the shore line remains reasonably level and would facilitate a link with the existing road. On such a line the length of the bridge will be approximately 600m.

On the south shore a length of new road will be required to link the bridge crossing with the A890 at Achmore, a distance of approximately 2km. At the north shore the existing single track road would require to be upgraded to Highway Link standard between Port à Mheirlich and Lochcarron. This would entail road widening, straightening of corners and realignment at various locations, notably on 2km of road approaching the junction with the A896. Land acquisition and accommodation works would be required to allow upgrading. [18][19][20][21][22]
[23][24]

3.1.3 Bridge route 2. (From South Strome to Strome Castle)

South Strome is located on the east side of Creag Mhaol. Should the approach road follow a route over South Strome it may be difficult to comply with Highway Link standard. To alleviate this it may be necessary to move further east which will take the bridge outwith the extent of the narrows. [7][8][9]

The shortest distance from a point at or near to South Strome across the loch would have the bridge spanning 550m onto the peninsula at Strome Castle at a point adjacent to the existing slipway.

As with bridge route 1 the presence of rock outcrops along both shores would indicate that suitable landing areas will be found.

On the south shore the A890 runs near to South Strome and thus only a short length of new road will be required. At the north shore the existing single track road would require to be upgraded to Highway Link standard between Strome Castle and Lochcarron as explained in 3.13.

3.2 Road Re-alignment

3.2.1 Introduction

Several alternative road routes have been considered in the study. The routes were chosen and developed from examining large scale Ordnance Survey maps and the use of stereoscopic viewing of aerial photographs. These activities eliminated certain routes on a topographical basis. The site visit and walking of the principal routes identified in more detail potential topographical and geotechnical benefits and difficulties. The Road routes considered are shown on Fig 3.

3.2.2 Road alignment 1

Route 1 alignment starts 500m east of Stromeferry on the A890 and traverses uphill through the Strome Forest to Loch an Arbair. The road then skirts the top of the hills adjacent to Loch Carron. The descent to Attadale gradually drops to the southern end of the River Attadale floodplain where the road turns back towards Loch Carron and joins the A890 at the Attadale bridge. The alignment would maintain the direct link between the communities of Stromeferry and Attadale with one of the attractions of the route being the spectacular view over Loch Carron and Cuillin mountains of Skye.

This alignment would encounter problems in maintaining gradient limits, as well as the many deep river gorges to be bridged along the top of the hills. Three major bridges would be required at high level and a further bridge on the descent to Attadale. Maintenance to the various bridges would be extremely difficult and expensive to undertake at such an altitude (approximately 300m). The geomorphology of the alignment is predominantly rocky outcrops with intermittent areas of deep peat mainly at water courses. Initial assessment indicates that substantial rock cuts, embankments and bridge crossings would be required to facilitate this route. To avoid the risk of creating rock slope problems similar to those currently being experienced, rock slopes will require to be designed, incorporating benching and rock catch ditches as required.

3.2.3 Road alignment 2A

Route 2A alignment leaves the existing A890 approximately 4km south of Stromeferry and follows the existing forestry track along Glen Udalain for 3km [10]. The proposed route then follows the River Udalain for 2.5km and then bridges the river [11]. The route then traverses through the forest plantation passing Loch nam Breac Mora and down through the forest at the head of the River Attadale floodplain [14]. The area is densely afforested in deep peaty soils which are drained by many small watercourses. This route will require the clearing of large areas of forest with consequent compensation to the Forestry Commission.

There should be few topographical problems with the alignment: the overall safety and comfort of this route would be a substantial improvement on the existing A890 with gentler gradients although with maximum altitudes of 350m, winter maintenance costs would increase. The local community of Stromeferry would have a longer but less tortuous journey to Attadale or Loch Carron than with the existing A890.

3.2.4 Road alignment 2B

Route 2B alignment follows Route 2A until the latter route crosses to the north bank of the River Udalain. Route 2B at this junction follows the line of the deer fence down the north bank of Allt Loch Innis nan Seangan [12] before contouring round the hill south of Loch nam Breac Mora and crossing the pass west of Mam Attadail [13]. Route 2B rejoins Route 2A one kilometre beyond Lochan Fuar and both routes continue down to the Attadale bridge [14]. Route 2B is the lowest of the three routes with the maximum altitude being approximately 240m at the River Udalain junction with Route 2A. The geomorphology is variable, predominantly peat measures with rocky outcrops. Maintenance costs per unit length of Route 2B should be less than those of Routes 1 and 2A as it is at the lowest altitude, however, the route is also the longest of the three, being approximately 14.5km long.

3.2.5 Consideration of other routes (Fig 9)

A route following Achmore valley and passing north of Carn na Creige was examined, but the adoption of Highway Link design was not feasible because of the topography, particularly in the Allt Cadhan Eas area.

A further route through Dornie and following the west side of Loch Long via Sallachy and Glen Ling to Attadale was also considered. This route, at 18km, is much longer than Route 1 and Route 2, and while feasible would be detrimental to local communities near Plockton and render the upgraded A890 between Auchtertyre and Stromeferry redundant but for minor local traffic.

3.3 Ferry Crossing (Fig 4)

3.3.1 Introduction

Initial discussions with interested parties regarding the reintroduction of a ferry crossing at Strome Narrows have established that this option is very unpopular, since it is viewed as a downgrading of the route. Aside from this, there are a number of problems with this option.

The present slipway facilities are inadequate for present needs and would require complete replacement. Both slipways, while in reasonable structural condition are too steep and too narrow to cope with the volume of traffic using the A890 (maximum daily flow of 1300 vehicles). Approaches to the ferry locations at both north and south Strome are difficult, if not impossible for heavy goods vehicles and buses, and have no facilities for queuing vehicles. [1][2]

Mooring facilities at both slipways require complete replacement.

The replacement of all facilities and upgrading of approach roads for the ferry option would be recommended. Two options for re-establishing the ferry have been identified. The first option moves the termini west to the locations identified for bridge route 1 in section 3.1. The second option maintains the ferry termini in North and South Strome but requires considerable road re-alignment and terminal up-grading. Both ferry options require upgrading of the existing North Strome to Lochcarron road to Highway Link standards. (See Fig 4).

3.3.2 Ferry route 1

The ferry termini will be moved west to locations near Port a Mheirlich on the north bank of the Loch and at Portchullin on the south bank (Fig 4). Slipways of ten metres width and 1 in 8 gradients will be required to service the ferries although mooring requirements will be negligible as no mooring is required during operation and overnight mooring would be on a buoy.

Approach to the south ferry terminal would be via a 2 kilometre section of new road leaving the existing road near Achmore and skirting the base of Creag Mhaol along a raised beach. For the north terminal, the upgrading of the road to Highway Link standard would require to be extended a further kilometre to Port á Mheirlich.

3.3.3 Ferry route 2

The ferry termini are retained in approximately the original location although approach alignments dictate repositioning locally to ease manouverability for larger vehicles. Possible sites would be west of Strome railway station for the South terminal and west of Strome House for the North terminal. Both sites would require short lengths of new approach road incorporating queuing facilities. Slipway standards would be similar to those for ferry route 1.

3.4 Avalanche Shelter/Causeway (See Fig 5)

Two options for retaining the road on its present route were considered. The first involves building a two way link on the seaward side of the railway track by rockfill causeway or viaduct. The second option extends the avalanche protection along the existing route and uses a twin deck shelter, one single lane running above the other. Site reconnaissance was carried out on the 24th to 26th April to access the practicality of these options.

3.4.1 Causeway option

The site reconnaissance, the patchy bathymetric survey information available on Admiralty Chart 2209 and its source information, the 1850 survey suggest that while a causeway providing a 6m wide carriageway would be feasible over much of the Ardnarff to Cuddies Point shore, an 800m stretch immediately west of Cuddies Point could present difficulties because of the depth of water. Two areas, comprising 150m of shoreline immediately west of the avalanche shelter, and 200m of shoreline between the avalanche shelter and Cuddies Point, had depths close inshore of 13 and 22 metres respectively [17]. The Admiralty Charts indicate the intervening areas of shoreline to have an average depth of 5m. For both deep water areas, a causeway option would not be possible without extensive filling or major piled or anchored cantilever structures. Progress to the Preliminary Report stage would be dependent on a detailed bathymetric survey proving the viability of the causeway.

3.4.2 Avalanche shelter option

Consideration was given to extending avalanche protection using a structure either similar to that west of Cuddies Point or a simpler, cheaper solution using a corrugated steel sheet structure backfilled with crushed rock. It has been assumed here that the shelter would also provide protection to the railway. If the shelter was not extended over the railway, a substantial requirement for slope stabilization would remain. Without site investigation to confirm the stability of the embankment on the seaward side of the railway, it is not possible to assess at present whether ground conditions would allow such construction. A length of 1.2km has been identified as requiring protection, mostly within the Site of Special Scientific Interest. Early discussions with the Nature Conservancy Council indicate that the main features of interest are the rock formations exposed on the slopes immediately adjacent to the existing shelter and while they would not lodge an objection if the safety of road and rail users were threatened, they would prefer that an alternative solution to one involving obscuring the rock be found. They would have no objection if access to the area via the existing road was no longer available [17].

The avalanche shelter option would require that this length of road would continue to be single track unless a rigid concrete construction similar to the present shelter was proposed in which case traffic from one direction could travel on top of the shelter. It is the latter option that HRC would prefer if the avalanche shelter is to be pursued.

The avalanche shelter would consist of a two storey reinforced concrete structure founded on rockhead, a minimum of 3m from the nearside railway line as required by British Rail. This would allow a lane width of 3.8m, assuming a 0.6m pier thickness. A fill protection layer and a rock catch fence would be required to provide protection to the structure and the nearby railway.

One disadvantage would be that the rockslopes are up to 30m high, and assuming 6m clearance to deck level, for a single height shelter and 12m for the double height option there would remain 24m and 18m respectively of rockface above the shelter. This would partly be taken up with soft covering over the top of the shelter, however some rock slope remedial works are still likely to be required in order to prevent failed rock reaching the railway track. Similarly within the avalanche shelter, if rock faces were left exposed as requested by NCC, rock slope stabilisation would be required to protect road users. An inherent problem with the shelter is the effect of breakdowns and accidents within the restricted carriageway width and the subsequent access difficulties for breakdown and emergency vehicles. The existing shelter would require to be demolished and replaced.

3.5 Tunnel Options (See Fig 6)

3.5.1 Introduction

Two alternative road tunnel routes have been considered for incorporation in the Preliminary Report. Route 1, a potential crossing of the Strome Narrows, and Route 2, bypassing the 1.5km of existing road which requires the major rock remedial works. In both cases an 8m wide, 6m high section has been considered, providing a 6.1m wide, two lane carriageway with provision for pedestrian traffic. British contractors have limited recent experience in similar hard rock tunnelling. Costs for rock tunnels in the UK are correspondingly high as is illustrated by a contract cost of £18.5m for the 930m long Pen-y-clip A55 road tunnel in North Wales.

We have assumed therefore, in considering these options, that Norwegian or other Scandinavian tunnelling contractors are invited to tender for the options and that Norwegian style low cost tunnelling methods are adopted. In contrast to the many European countries such as Switzerland and Austria who construct expensive motorway standard tunnels continuously lined with in-situ concrete and with full lighting and ventilation, more economical methods have been adopted in Norway. The vast majority of tunnels are predominantly unlined, with only 5% of all tunnel length being concrete lined through zones of difficult ground. This has been achieved through strictly controlled smooth blasting techniques and follow up support techniques, principally consisting of roof rock bolting methods to prevent rock falls. An additional support technique widely adopted includes the use of fibre reinforced shotcrete in the roof area.

Water ingress into unlined tunnels has proved to be a problem particularly if the water freezes. The Norwegians have successfully solved this problem by lining such tunnels with an inexpensive corrugated aluminium sheeting, which directs water into culverts on either side of the tunnel, draining to either end. Where there remains a potential for severe freezing, additional insulating materials such as rock wool are incorporated into the 'lining'.

In excess of 500 tunnels have been constructed in Norway and of these only 7% are ventilated, relying on natural ventilation 'draughts', and 40% are lit with the majority of these luminated to $1cd/m^2$ or less. It is considered by the Norwegians that if a tunnel cannot be longitudinally ventilated, it is unlikely to be built. This approach minimises both capital and operational costs. The latter could be expected to be greater for sub-sea tunnels, which cannot be self draining, and therefore incur pumping costs.

No detailed information has yet been obtained regarding Norwegian tunnel maintenance costs. The current approach appears to be to install sufficient rock support and reinforcement to minimise long term stability maintenance, whilst stopping short of extended concrete linings.

- The ability of the Norwegians to construct low cost tunnels efficiently and quickly largely stems around their adoption of a contract system which shares the risk of tunnelling between the client and the Contractor. This system, termed NOTCOS (Norwegian Tunnelling Contract System), provides a tool for converting work into time equivalents by which contingencies arising from changes in ground conditions can be incorporated, therefore eliminating any future discussions over the regulation of construction time where needed, or over costs incurred.

Costs for tunnels recently completed and currently under construction are shown in Appendix E. Using a conversion of £1 = NKr 10.5, costs of the order of £2.5M to £9M per km are indicated. Based on these figures, preliminary budget cost for a tunnel at Strome Narrows would be £8M, and for Cuddies Point, £6M. A special study of the makeup of the out-turn cost of Norwegian tunnels is needed to enable their applicability in Scotland to be established.

3.5.2 Tunnel Route 1 (Portchullin to Port à Mheirlich).

The approach roads to this route follow a similar line to those of Bridge Route 1 (see 3.1.2). Although the narrows are only 600m wide at this point, rock cover of at least twice the tunnel diameter below the deepest point on the crossing (16m below LAT), would dictate a total tunnel length of approximately 2300m, assuming maximum road gradients of 8%. As with Bridge Route 1 the south approach to the route traverses a raised beach at a height of 25m above shore level. Should site investigation indicate considerable depth to rockhead, the south portal would be located on the south face of Creag Mhaol. Construction of a link road from the A890 to the tunnel portal would be required.

On the north shore it is envisaged that the tunnel portal would be located east of Port à Mheirlich and upgrading of the existing single track road between North Strome and Lochcarron to Highway Link standard would be required.

3.5.3 Tunnel Route 2

This option would bypass the most critical unstable section of slope between chainages 0m and 1500m, as identified on Figure 7. These form the majority of the major works recommended in the February 1991 JWP report.

The west portal would be located near the road crossing of the Allt an Fhraigaich stream (Ch 1500m), the east portal being located approximately 400m east of chainage 0m, near the point where the A890 crosses the Cuddies Point Burn.

The total length of tunnel would be approximately 1900m and would be sited some 200m back from the rock slopes over the majority of its length.

3.6 Tidal Power Generation

A tidal power scheme across the entrance to Loch Carron has previously been investigated by the National Engineering Laboratory in 1978. Various locations for a barrage were examined, the most favourable being across the Strome Narrows, producing 35 GWh for a unit cost of 3.2p/kWh. However in 1978, the unit costs for North of Scotland Hydro-Electric Board (NSHB) electricity was only 1.15p/kWh. It was therefore not economic to promote this scheme, which had a capital cost of approximately £10 million.

The primary purpose of this original scheme was to provide electricity. A new road crossing across Loch Carron could possibly make the scheme more economical. The scheme would consist of a rockfill barrage constructed across the narrows with the road running along the crest. Bulb turbines would be housed within concrete caissons. Similar caissons would contain large sluices to allow water to enter Loch Carron on the flood tide. A shipping lock would also be required to allow the access of vessels into the loch.

A very rough estimate was carried out based on 1984 figures for the Mersey Barrage and assuming that five turbines would be installed. The planned turbines for the Mersey Barrage are considerably larger than those likely to be installed at Strome Narrows. Plant costs have therefore been reduced to reflect the size of turbines anticipated. A capital cost of £50 million was estimated for the construction of the power station and barrage but excluding the approach roads. In 1978 it was estimated that approximately 35.4 GWh could be produced annually. At present Scottish Hydro-Electric (HE) only pay 1.5p/kWh to private generators of electricity. Therefore assuming that an alternative method of loch crossing cost £15 million it would take over 60 years to recover the additional costs associated with a tidal barrage scheme, unless a better electricity rate could be agreed. A similar scheme proposed for Loch Broom in 1986 was estimated at £90 million.

4.0 COMPARISON OF OPTIONS

4.1 Preliminary selection

In Section 3 some of the advantages and disadvantages of the possible road realignment options have been highlighted. For some of the options, the disadvantages are considered to be fundamental and it is recommended that these options be discounted at this early stage. These include road routes from Dornie via Loch Long and from Achmore valley passing north of Carn na Creige, discounted for social and topographical reasons respectively. It is also suggested that HRC could discount at this early stage both ferry routes and the causeway option in the light of the difficulties discussed below.

As explained in Section 3.3 the existing ferry facilities at North and South Strome are inadequate for modern traffic needs. Ferry traffic could not therefore be re-established without replacement of all facilities and upgrading of approach roads. This would require a considerable financial investment, albeit with a lower initial capital cost than other options, for a service that most parties would see as a downgrading for road transportation rather than a move forward. While there are a number of attractions in reviving the ferry link, notably the fact that two Loch class vessels of 38 car capacity will become available from the Kyle-Kyleakin crossing in 1995 should the proposed Skye bridge proceed according to plan, there are many more long term disadvantages. These include reduced availability due to poor weather, ferry operators reluctance to operate a 24 hour service, delays to emergency services and general delays to all road users. The result is likely to be a reduction in traffic using the A890 and A896. The tourist traffic, all important to the local economy, may also suffer as a result.

The causeway option cannot be progressed to Preliminary Report stage without a detailed bathymetric survey to locate the deep water areas accurately and allow the potential pier positions for the viaduct crossing to be identified. This would require considerable investment at this early stage in the development process on an option that may not prove to be practical. For this reason, we recommend that study of this option is deferred, to be reactivated only if the other options do not prove viable.

Seven options then remain for comparison prior to recommendation for progress to Preliminary Report stage. These being bridge routes 1 and 2, road re-alignments 1 and 2 (A and B variations), Tunnel routes 1 and 2 and the Avalanche shelter.

4.2 Selection of Routes for Progress to Preliminary Report Stage

4.2.1 Bridge Options

Both bridge routes could provide two way traffic with a much shortened journey time. Of the two routes considered, Route 2, from North to South Strome would, at 550m, be the shortest crossing, but only by 50m. However due to the steep gradients on the southern approach to Route 2, deck levels are likely to be higher than for bridge Route 1. Approach roads to Route 1, while longer, would be significantly easier to construct to Highway Link standards. This would have cost implications. It is considered to be worthwhile to progress both options in order to compare the relative effects of the variations in approach road length, bridge deck height and Highway Standards of the two routes. If, however only one route is to be pursued to Preliminary Report stage it is recommended that this be Route 1 from Portchullin to Port a Mheirlich.

4.2.2 Road Options

Of the road re-alignment routes, Route 1, while shortest at approximately 11km, would be sited at much higher altitudes and be much more difficult to construct, requiring four crossings of river gorges. In some areas of Route 1, hillside gradients are such that to contour along them would require extensive rock cut, thereby risking maintenance requirements similar to those found on the present alignment. Routes 2A and 2B on the other hand, while longer at 12.5km and 14.5km respectively, appear from the initial walkover to have few major problems to overcome and have the advantage of 5km of existing forestry commission track which could be up graded to Highway Link standard. Routes 2A and 2B would provide routes at lower altitudes than Route 1, and primarily on south facing slopes, so winter maintenance unit costs should be lower. Routes 2A and 2B only differ in that Route 2A crosses an extensive forestry commission plantation and Route 2B skirts round. Routes 2A and 2B would tend to isolate the villages of South Strome and Achmore. The likely drop in local tourist traffic may only affect South Strome, as Achmore is populated mainly by Forestry Commission staff. Route 2 is recommended if the selection for progress to preliminary report stage is to be restricted.

Both routes join the original road at Attadale , and this would require that traffic will still negotiate nearby An Maman which is single track road with very steep gradients, notoriously impassable for large vehicles in winter. This factor would weigh heavily against both road options. It is suggested that HRC may consider it worthwhile to extend the original brief for the road realignment option to allow Route 2B to be extended, bypassing Attadale, and joining the original route near Strathcarron. [15][16]

4.2.3 Tunnel Options

Of all the options considered, the most environmentally sympathetic are the two tunnel routes, one crossing the Strome narrows and the other bypassing the principal rock slopes of concern. Route 1 will provide a two lane crossing of the Strome narrows while preserving unlimited navigation to shipping. Water depths are relatively shallow (deepest 16m), and, assuming superficial deposits are thin, this should permit an economic solution. Route 2 will again provide a two lane route, although the road between Stromeferry and the West Portal will remain mostly single track with passing places until future upgrading is carried out. Route 2 will also provide a bypass facility without affecting the SSSI. Cost estimates for both tunnel options will be difficult without site investigation to provide the same level of confidence as will be available on the other options recommended.

4.2.4 Avalanche Shelter

In considering the avalanche shelter, without preliminary site investigation it is not possible at this stage to confirm the stability of the embankment on the seaward side of the railway and hence confirm the practicality of protection for both rail and road traffic. In the event of a two storey avalanche shelter being constructed, rock slope remedial works are still likely to be required in order to protect the railway track.

Any objections from the Nature Conservancy Council in respect of the SSSI can be obviated by maintaining access to the rock faces within the shelter, although this has cost implications in terms of rock slope maintenance.

Similarly, breakdown and accident problems may be alleviated by spacing supports such that a 3.8m wide lane width may be increased to 5m outwith structural column locations. Visual intrusion will be a major source of objection should this option reach planning stage.

5.0 RECOMMENDATIONS

5.1 <u>Options for Preliminary Study</u>

During the preliminary report study it is recommended that the following options are designed and developed to a level of detail sufficient to allow cost/benefit comparisons to be made on a like for like basis (using the NESA programme for economic evaluation of highway schemes if HRC confirm that this level of detail is required at this stage).

- Bridge route 1: Bridge crossing from Portchullin to Port à Mheirlich, including approach roads from Achmore to Portchullin and Highway Link upgrading from Lochcarron to Port à Mheirlich.

- Bridge route 2: Bridge crossing from North Strome to South Strome including approach roads from the A890 to South Strome and Highway Link upgrading from Loch Carron to North Strome.

- Road route 1: Road route following the line of the existing A890 but at higher level. Junctions with the A890 would be at South Strome and Attadale.

- Road routes 2A and 2B: Road route following Glen Udalain then either via Lochan Breac Mora or via Allt Loch Innis nan Seangan, reaching the existing A890 at Attadale. An extension to this route bypassing Am Maman may be worthy of consideration at this stage.

- Tunnel Route 1: Tunnel crossing from Portchullin to Port à Mheirlich including approach roads from the A890 to Portcullin and Highway Link upgrading from Lochcarron to Port à Mheirlich.

- Tunnel Route 2: Tunnel bypassing area of major remedial works between Allt an Fhraigaich and Cuddies Point Burn.

- Avalanche Shelter: Avalanche shelter between Allt an Fhraigaich and Cuddies Point offering direct rock fall protection to road traffic and indirect protection to rail traffic.

- "Do Minimum" option: Monitoring the existing route but incorporating the maintenance and slope stabilisation works recommended in JWP report no. 4080/2879/002 (Feb 1991).

It is anticipated that the economic evaluation of these schemes will include the following tasks:

1. Preliminary design and development sufficient to confirm the practicality of each option and provide sufficient detail to allow costing.

2. Construction costs. The accuracy of these costs is very much dependent on whether topographical or geotechnical studies are included within the scope of the preliminary report.

3. Potential disruption during construction. Assessment of delays to road traffic during construction of all options including the "Do minimum" option (re. road/rail interface Autumn 1990).

4. Long term operation and maintenance costs.

5. Assessment of socio-economic aspects, with particular reference to improved local links and the growth of tourist economies through improved communications to large areas of the North West Highlands.

6. Environmental considerations including:

- Ecology: An assessment of the habitats along the various routes is required (marine, estuary, moorland and forest) and potential impact of the route on birds, animals and plants.

- Visual Impact of Bridge: A critical impact will be the view of the bridge as it crosses the estuary, and an assessment of its prominence in the landscape will be needed. Depending on the setting, it may be that a high quality architectural solution will mitigate against this impact.

- Visual Impact of Roads: Within a remote wilderness area, the potential impact of a manmade feature such as a road is likely to be considerable, and this will be a key factor in the landscape assessment (eg how far from distant hills is the road visible?). Other factors to consider are how well it fits the topography; will cut and fill operations leave ugly manmade scars within a natural landscape?

- Impact on Settlements: The impact of the various options on the local village settlements needs to be considered, including the disruption that construction work will cause.

- Mitigation Measures: Consideration of potential mitigation measures must be considered, such as screen planting (either offsite or adjacent to the road). This can help to 'knit' the road into the landscape or serve to screen parts of it from critical viewpoints.

Evaluation of the options will follow the procedures as set down in the Scottish Traffic and Environmental Appraisal Manual, unless requested to omit particular areas, and will be presented in an appraisal framework as recommended within this manual.

5.2 Cost Estimates

The tasks recommended to form the preliminary report appraisal study are listed below with accompanying task descriptions and budget cost estimate. The tasks are identified separately to illustrate how the overall budget reflects the number of options and the level of detail pursued.

(a) Bridge Option 1 (Portchullin to Port á Mheirlich). £ 14,500

- site visit
- developing alternatives
- preliminary design
- drawing production
- cost estimate
- bridge approach roads

(b) Bridge Option 2 (South Strome to Strome Castle). £ 7,300

- site visit (included in (a))
- developing alternatives (partly included in (a))
- preliminary design (partly included in (a))
- drawing production
- cost estimate
- bridge approach roads

(c) Road Option 1 (via Loch an Arbair) £ 10,507

- site visit
- vertical alignment
- horizontal alignment
- land acquisition/PUSWAS
- structures/drainage
- drawing production
- cost estimates

(d) Road Option 2 (via Glen Udalain and Loch nam Breac Mora) £ 6,700

- site visit (included in c)
- vertical alignment
- horizontal alignment
- land acquisition/PUSWAS
- structures/drainage
- drawing production
- cost estimates

(e) Tunnel Option 1 (Portchullin to Port à Mheirlich) £ 5,000

- site visit (included in c)
- vertical alignment
- horizontal alignment
- geological studies
- preliminary design
- drawing production
- cost estimates
- upgrading of single track road from North Strome to Lochcarron included in (a)

(f) Tunnel Option 2 (Allt an Fhraigaich to Cuddies Point Burn) £ 3,000

- site visit included in (c)
- vertical alignment
- horizontal alignment
- geological studies
- preliminary design
- drawing production
- cost estimates

(g) Avalanche Shelter (Allt an Fhraigaich to Cuddies Point) £ 6,750

- site visit included in (c)
- developing alternatives
- preliminary design
- drawing production
- cost estimate
- approach roads

(h) Environmental Impact Appraisal £ 5,000

- liaison with sporting and conservation bodies
- site survey of ecological and visual aspects
- preparation of drawings showing visual intrusion, mitigation measures and perspective sketches.
- assignation of factors to environmental features affecting NESA options
- reporting

(i) Slope Maintenance Aspects £ 7,100

- site visit
- remedial requirements for abandoned slopes (capital and maintenance)
- cost estimates
- assignation of risk factors to features affecting NESA options
- reporting

(j) NESA Study Data Assembly £ 3,500

- traffic survey including turning movement counts, accident rates, journey time survey, highway inventory
- option capital and maintenance costs
- incorporation of environmental/socio economic factors ie noise, visual intrusion, ecology, severance, agricultural land take, employment opportunities.

(k) NESA Study £ 6,500

- preparation of input data
- running options
- reporting

(l) Project Management, Project Planning and production of Preliminary Report £ 9,544

- project management
- project planning
- report production
- expenses

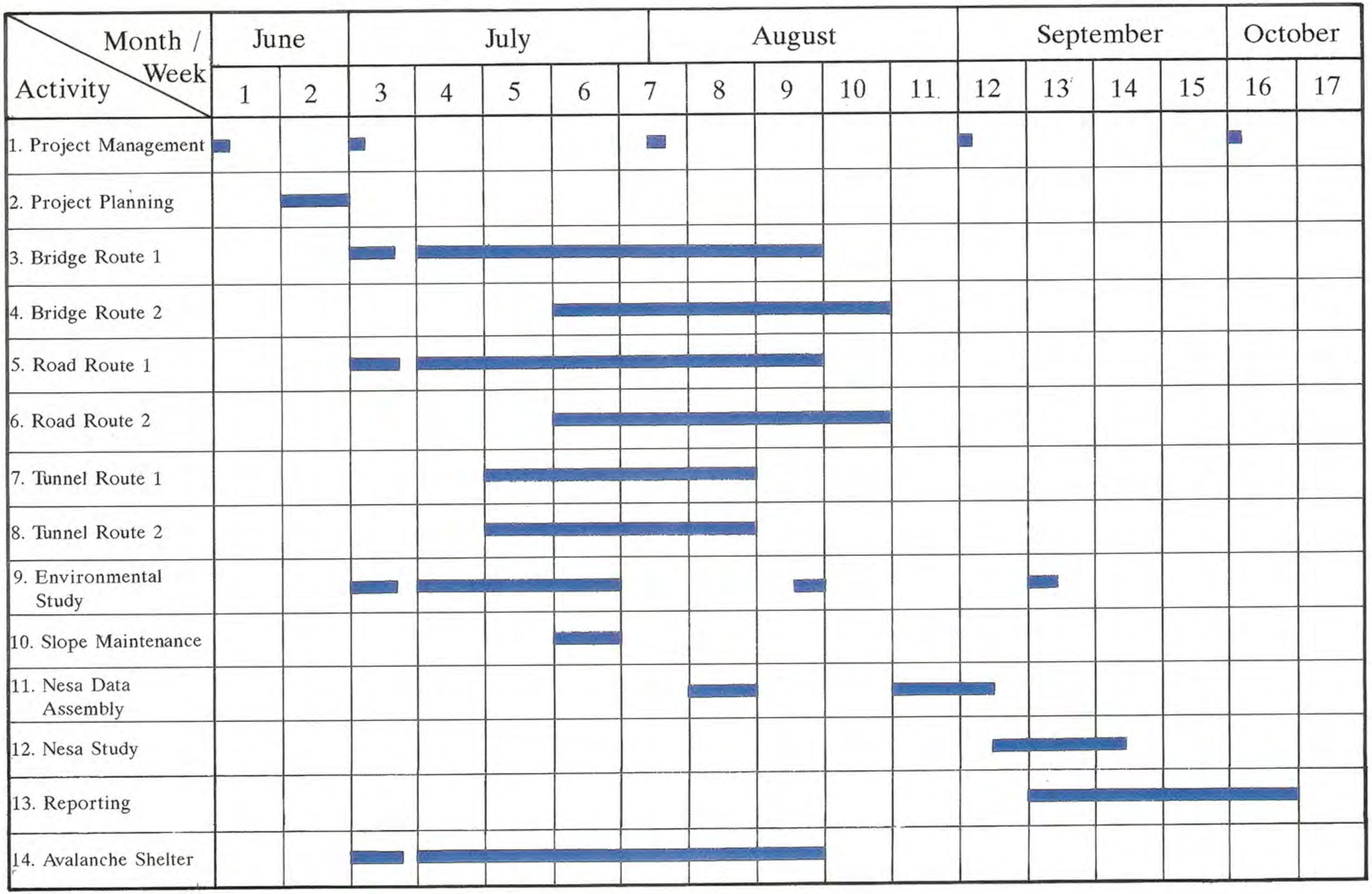
Total Budget Cost including all options £ 85,315

NOTE 1. These costs are calculated at June 1991 rates.
2. These costs do not include VAT.

The total budget cost of the Preliminary Report will vary according to the number of options chosen and the specialist studies selected. Should all options be pursued, and including a 10% contingency, we would recommend that a budget of £95,000 be allocated for this work.

5.3 Programme

A tentative programme for the Route Appraisal Study has been prepared and is included in this section. While a target of mid October for the completed report is proposed this may vary according to the number of options pursued, the specialist studies carried out and the timing of the instruction to proceed.


Month / Week
Activity
June
July
August
September
October
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
1. Project Management
2. Project Planning
3. Bridge Route 1
4. Bridge Route 2
5. Road Route 1
6. Road Route 2
7. Tunnel Route 1
8. Tunnel Route 2
9. Environmental Study
10. Slope Maintenance
11. Nesa Data Assembly
12. Nesa Study
13. Reporting
14. Avalanche Shelter

APPENDIX A

MAINTENANCE REQUIREMENTS FOR EXISTING SLOPES

APPENDIX A

MAINTENANCE REQUIREMENTS FOR EXISTING SLOPES

A separate report is proposed, detailing slope surveillance and maintenance actions for the anticipated period of several years before the implementation of full slope stabilization or the provision of an alternative road route. The principal recommendations are expected to entail systematic recording of surveillance observations and actions, and a rolling programme to upgrade the mesh system, allied to very localised rock removal under close supervision. MM will also develop a proposal for slope instability risk assessment to assist HRC in decision making at this site.

For the immediate future (ie whilst studies and reporting continue, a period of months), it is recommended that HRC should continue daily surveillance and consider the practicality and timing of upgrading works. From a subjective visual assessment of the stability condition of the slope, the following priority areas have been identified:

Chainage (m)	Feature
423	Dilated 2-3m^3 rockmass
434	Dilated 2m^3 rockmass
580	Sliding Slabs (small failure 1990)
792	Severely undercut soil at crest
840	Dilated 2m^3 rockmass
945 (area)	Dilated rockmasses
1510	Severely undercut soil at crest

Apart from enhancing short term security, the suggested upgrading works would provide a useful measure in the context of enhancing security to the railway in the event of the road route being abandoned.

APPENDIX B

SECURITY OF ABANDONED SLOPES

APPENDIX B

SECURITY OF "ABANDONED" ROCK SLOPES

1. General

If the present Stromeferry Bypass was abandoned in favour of an alternative route, the rock slopes would continue to pose a potential hazard to the railway line. The aim of this section is to identify slopes formed during the construction of the road, and to establish whether hazards to the road, identified in previous JWP reports, will present hazards to the railway taking into consideration that the abandoned road will itself provide a rock trap. (Report reference 1 in appendices). Possible measures to enhance the security of the railway in these areas are discussed.

2. Location of Slopes

The locations of the formed rock and soil slopes has been established from record drawings of the road construction held by HRC, aerial photographs and a roadside visual appraisal. The location of these slopes are shown approximately on Fig 7 and are described more precisely in Table 1. The majority of the formed slopes, particularly the rock faces, lie in JWP slope areas 1, 2, 3 and 6, between Ch 0 and 1520m and 3300 to 3850m, with localised soil and rock cuts within areas 4 and 5, Ch 1520 to 3300m. The roadside appraisal revealed that a number of rock slopes consist of natural upper faces and lower faces cut back at the time of road construction; these are detailed in Table 1.

3. Hazard Assessment

The hazard assessment to the railway from the formed cuts was based on a former assessment carried out for the road for all the slopes between Cuddies Point and Ardnarff. Individual hazards identified were subjectively reassessed to establish whether there was a risk of material reaching the railway in the event of failure. The results of this study are tabulated in Table 2. In general, it is considered that due to the presence of the relatively wide rock catchment area afforded by the abandoned road, not less than five metres across, all road MODERATE hazards will be contained on the road. However, the majority of MAJOR and EXTREME road hazards on formed cuts principally contained in slope areas 2 and 3 will still present hazards to the railway due to the risk of overspill of debris from the road and flyrock. Formed slopes in area 1 which also contain serious hazards are remote from the railway and therefore are of no risk to the railway.

Consideration of potential large scale landslide instability was excluded from the scope of previous studies and similarly has not been addressed within this report.

4. Remedial Works

As identified during the appraisal the principal hazards to the railway are due to overspill and flyrock from the failure of MAJOR and EXTREME road hazards. It is considered that the construction of a barrier structure on the seaward side of the road will retain overspill from the road and prevent flyrock reaching the railway. A retaining structure might typically consist of a 1.5m to 2m high gabion wall to retain overspill, backed by a 3m high tensioned mesh fence to contain flyrock; as illustrated in Fig 8 the final design of any retaining structure would be dependent upon design studies which should take account of current published views on rock trap widths and debris scatter for various heights and inclinations of slope. Due to the extensive occurrence of MAJOR and EXTREME hazards within areas 2 and 3, consideration should be given to construction of a barrier structure along the entire lengths of these areas. Localised barrier structures will be required in areas 4, 5 and 6. The barriers proposed should leave sufficient space for vehicular access for periodic surveillance and maintenance operations.

From the present brief review it has been noted that the barrier solution alone might suffice, possibly backed up by reinforcement of the slope meshing system in some areas. However, the need for more substantial stabilisation measures should be more fully addressed at a subsequent stage.

TABLE 1 LOCATION OF MANMADE SLOPES

	Description
0 - 2509	Rock cut
269 - 190	Rock cut (loch side)
250 - 309	Soil cut
290 - 440	Rock cut
440 - 500	Localised lower rock cut, upper natural rock slope with some soil
500 - 612	Rock cut
612 - 675	Avalanche shelter
675 - 700	Rock cut
700 - 735	Natural rock slope
735 - 750	Soil cut with natural upper rock slopes
750 - 810	Rock cut
810 - 840	Soil cut
840 - 860	Lower rock cut, upper natural rock slope
860 - 940	Rock cut
940 - 950	Possible natural rock slope
950 - 1110	Natural rock slopes, possible localised toe rock cut
1110 - 1160	Natural rock slopes
1160 - 1200	Rock cut
1200 - 1248	Soil cut
1248 - 1284	Rock cut
1284 - 1480	Natural rock slopes with toe cuts
1480 - 1520	Rock cut
1520 - 1622	Soil cut
1622 - 1677	Natural rock slope
1677 - 1744	Soil cut
1744 - 2060	Natural rock slopes with local soil cuts
2060 - 2380	Natural soil slopes with local soil cuts
2380 - 2420	Natural rock slope
2420 - 2476	Natural soil slope
2476 - 2488	Soil cut
2488 - 2506	Natural rock
2506 - 2600	Soil cut, quarry at Ch2500 (remote)
2600 - 2811	Natural slopes
2811 - 3000	Soil cut

TABLE 1 SUGGESTED TARGET LOCATIONS FOR WORK TO IMPROVE SHORT TERM SECURITY

Chainage (m)	Feature	Remedial Work
Ch 420m	Dilated 1.5m^3 rock mass (Plate 1)	Scale and mesh
Ch 430m	Dilated 2m^3 rock mass (Plate 2)	Scale and mesh
Ch 580m	Sliding slabs (Plate 3)	Scale, possible dowel, mesh
Ch 800m	Undercut soil at crest	Remove, batter back, mesh
Ch 840m	Dilated rock mass	Scale, dowel ?, mesh
Ch 940 - 950m	Dilated rock mass	Scale, dowel ?, mesh

Chainage (m) (approximate)	Description
3000 - 3120	Rock cut
3120 - 3220	Soil cut
3220 --3300	Rock cut, set back from road
3300 - 3354	Soil cut
3354 - 3375	Natural slope
3375 - 3390	Soil cut
3390 - 3405	Natural slope
3405 - 3543	Soil cut
3543 - 3597	Natural rock/soil slope
3597 - 3671	Rock cut
3671 - 3695	Natural rock slope, possible cut
3695 - 3850	Rock cut

TABLE 2 LOCATION OF PRINCIPAL POTENTIAL HAZARDS TO RAILWAY FROM FORMED ROCK SLOPES

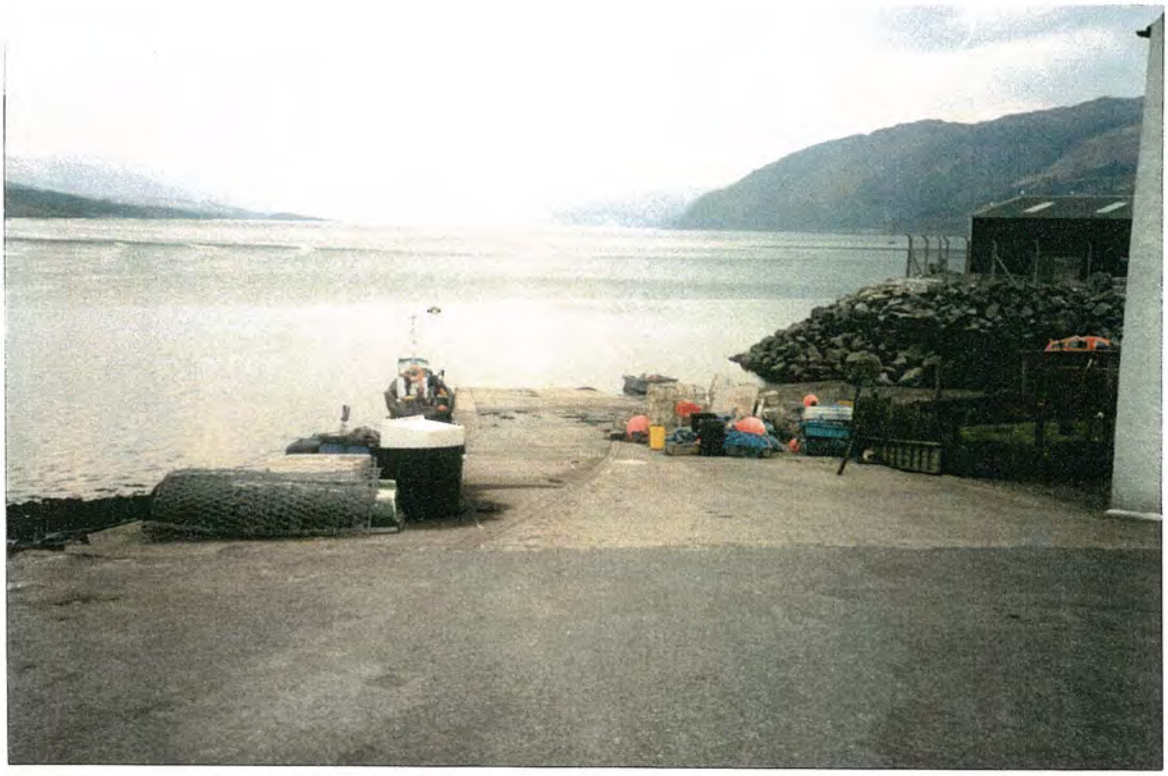
Chainage (m)	Catchment area width (m)	Nature of hazard
330 - 336	7	Sliding mass 6m a.r.l.
336 - 347	7	Overhanging mass 6m a.r.l.
349 - 363	7	Dilated and overhanging blocks at crest
380 - 385	8	Large overhanging mass at crest
385 - 390	8	Dilated stack
395	8	Dilated overhanging block in open wedge
400 - 420	7	Overhanging masses
432	7	Overhanging mass at crest
433 - 436	7	Dilated rib from 5m a.r.l.
436 - 440	7	Undercut blocks
440 - 454	7	Undercut blocks
528 - 533	6	Large sliding mass
533 - 546	6	Large sliding mass
567	6	Dilated stack from 6m a.r.l.
572 - 580	6	Sliding masses near crest
590	6	Dilated stack from 6m a.r.l.
596 - 600	6	Wedges and dilated blocks
675 - 692	6	Undercut crest
770 - 810	7	Wedge and dilated columns
840 - 897	7	Dilated rock masses
941 - 950	5	Dilated rock masses
1258 - 1265	6 - 7	Dilated stack 5m a.r.l.
1271	6 - 7	Dilated mass
3676	8	Sliding mass
3682	8	Sliding mass

Note:
1. a.r.l. - above road level.
2. All catchment area widths are approximate measurements from rock face to railway fence, generally 2m from closest rail.

APPENDIX C

PHOTOGRAPHS

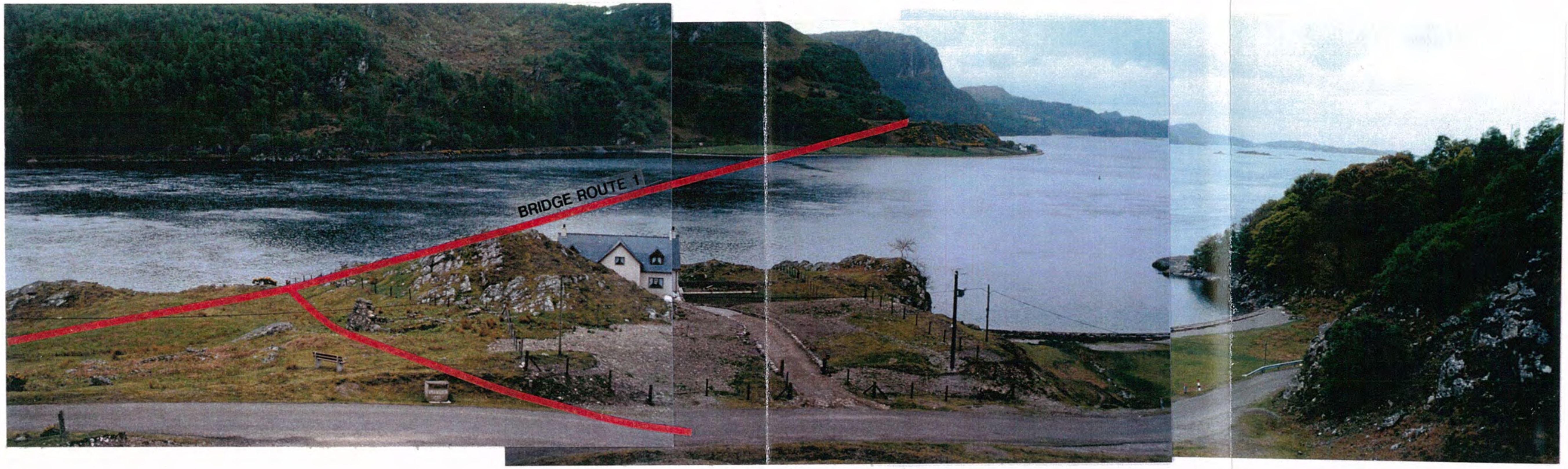
1. North Strome Slipway



2. South Strome Slipway

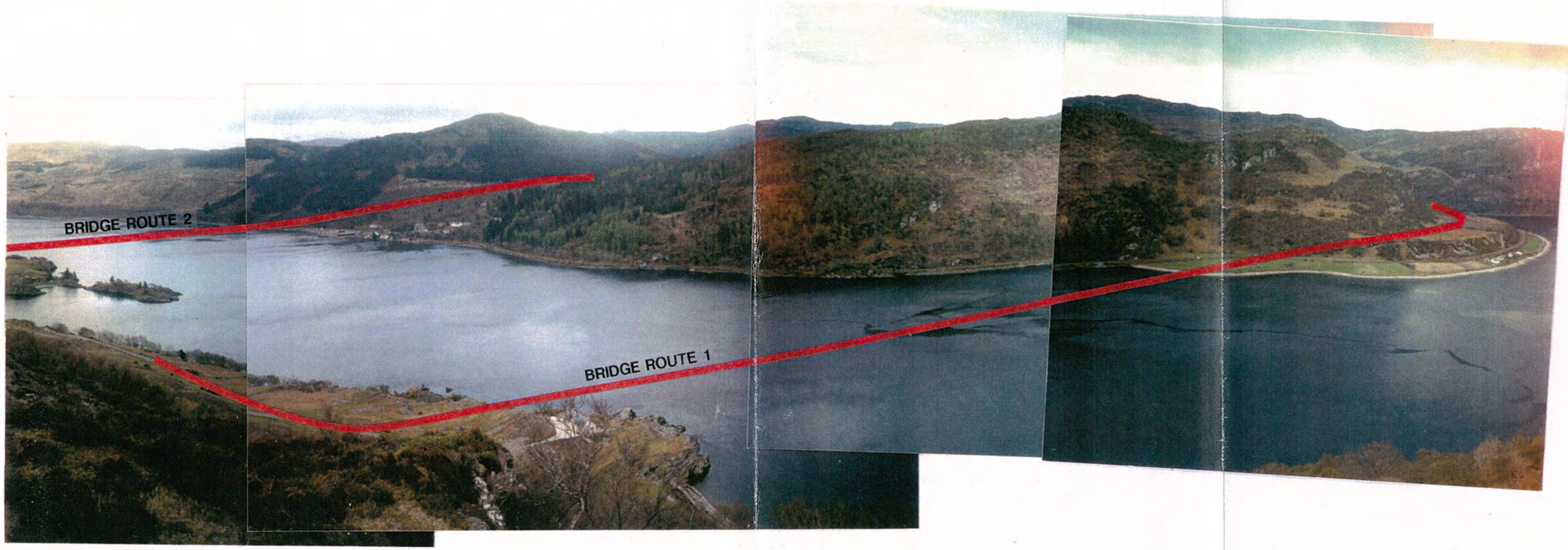
3. Strome narrows from the East

4. Bridge Route 1 from the North Shore

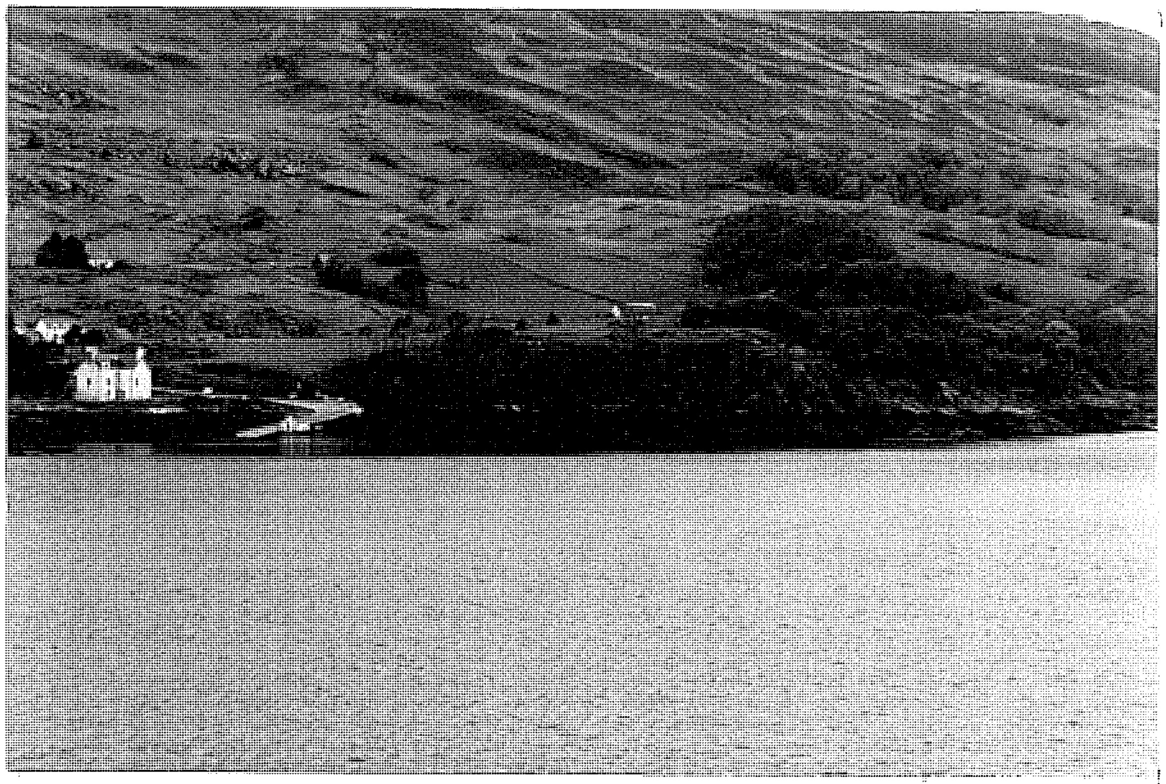


5. View from the North Shore on the line of Bridge Route 1

6. Photograph taken from top of raised beach on South Shore looking across to Port a Mheirlich - Bridge Route 1

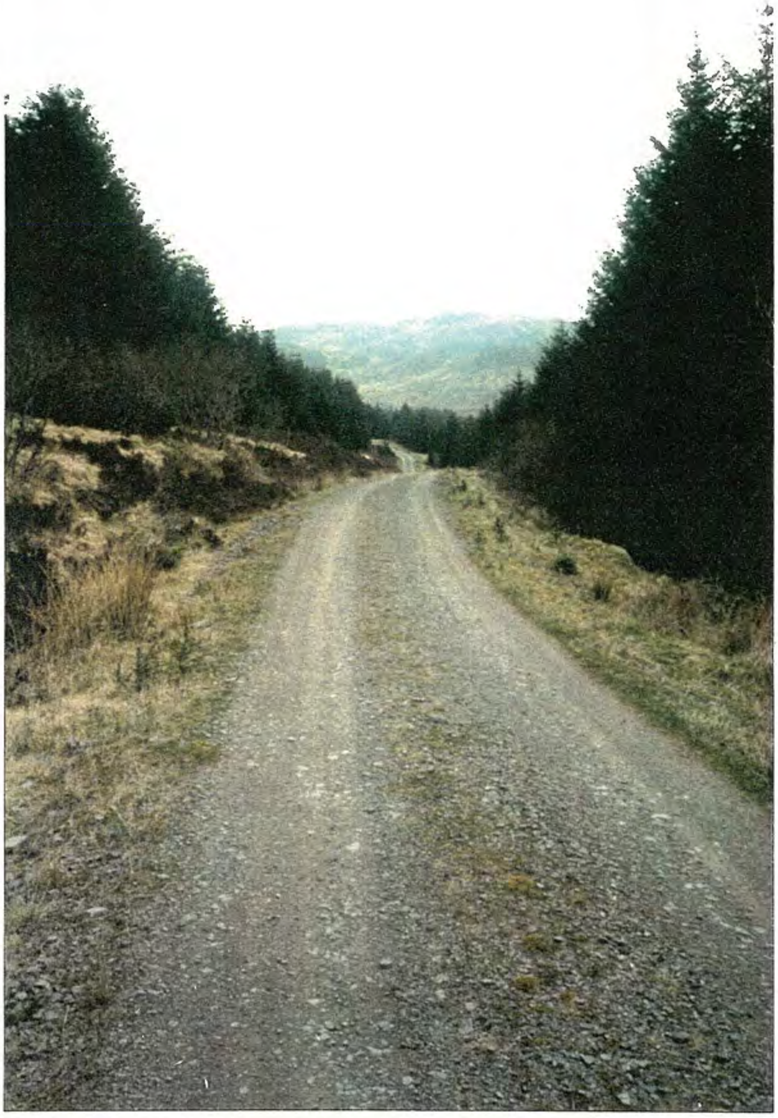


7. View from the North Shore looking over Bridge Routes 1 and 2



8. Strome Cas. North embankment Bridge Route 2

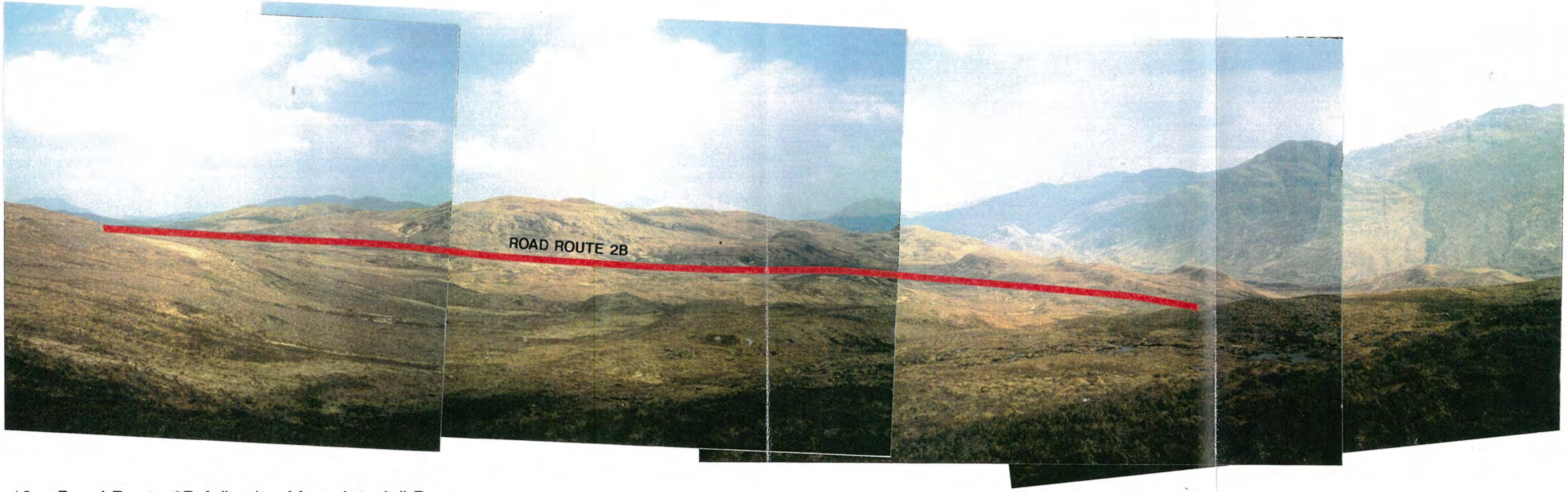
9. Stromeferry. South embankment Bridge Route 2



10. Forestry commission track following Road Route 2

11. Glen Udalain, Road Route 2

12. Road Route 2B following Allt Loch Innis nan Seangan



13. Road Route 2B following Mam Attadail Pass

14. Road Route 2 following Glen Attadale

15. Looking North from Am Maman

16. Am Maman

17. Existing road from Cuddies Point

18. Bridge near Dalacladdich

19. Retaining wall at North Strome

20. Retaining wall at mid Strome

21. Restrictions at Tullach Ard

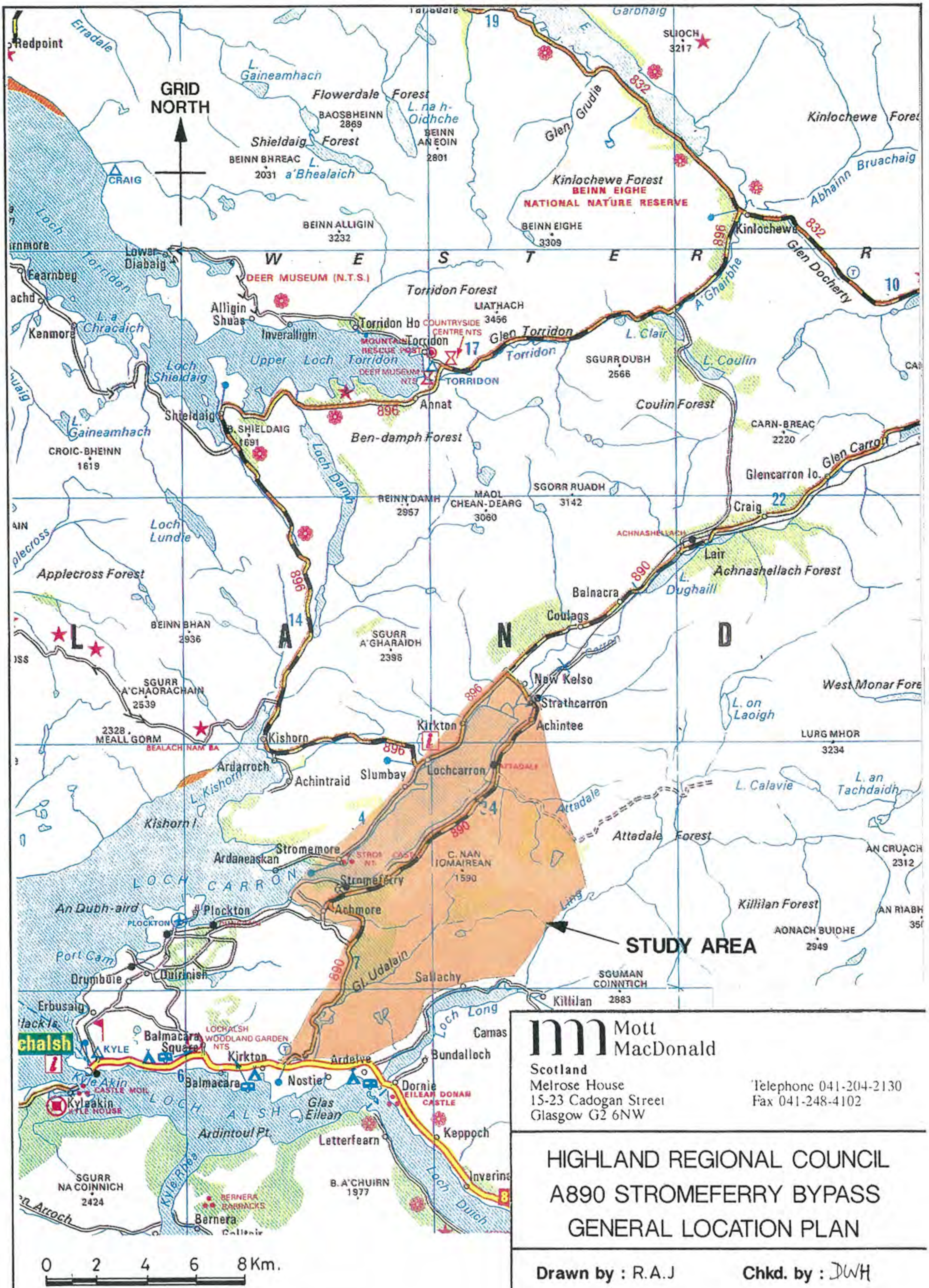
22. Approach to Lochcarron

23. Retaining wall near "Woodside"

24. Bridge near "Millbank Cottage"

APPENDIX D

FIGURES



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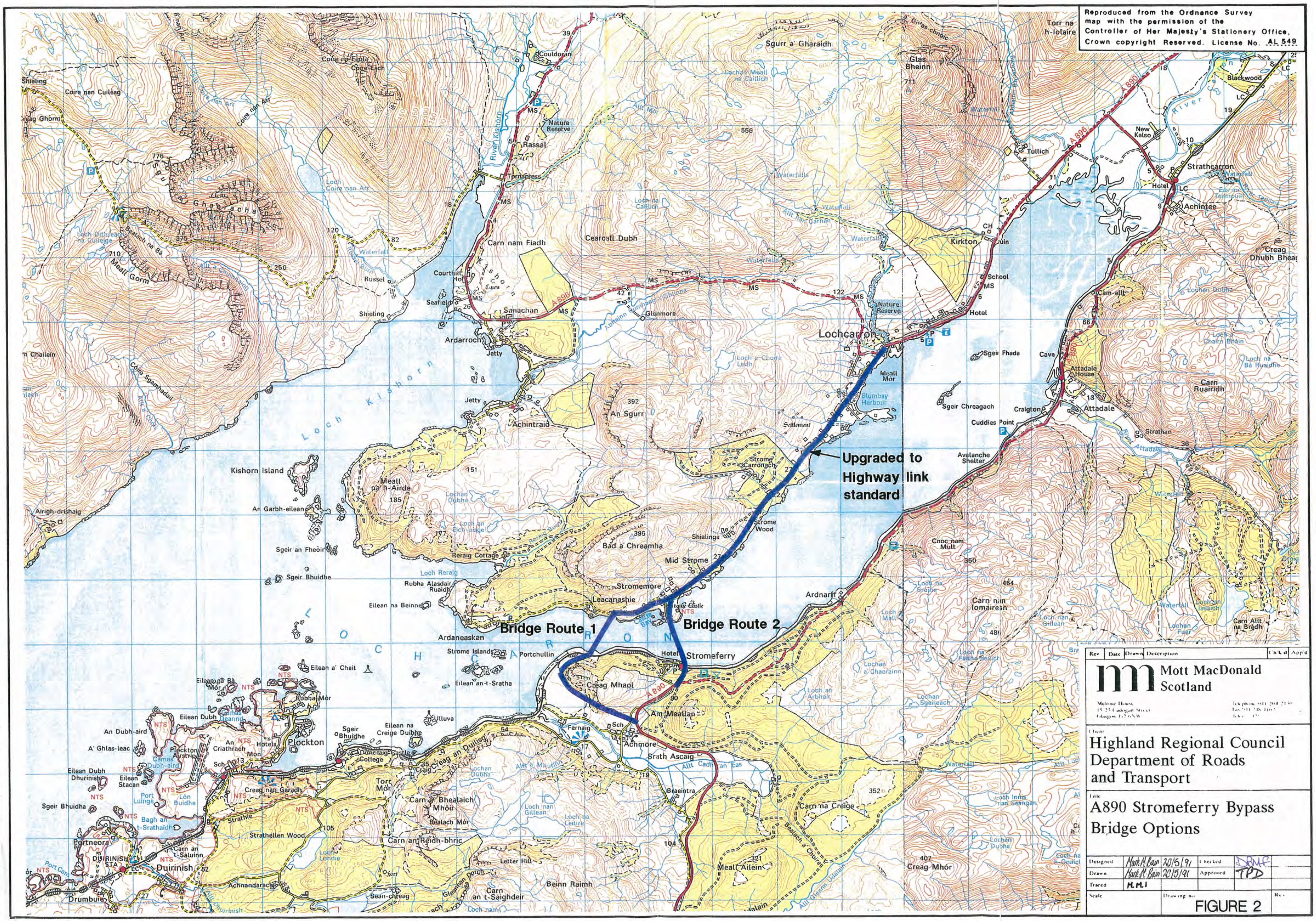
Fax 041-248-4102

HIGHLAND REGIONAL COUNCIL
A890 STROMEFERRY BYPASS
GENERAL LOCATION PLAN

Drawn by : R.A.J	**Chkd. by :** DWH
Appd. by : T.P.D.	**Date :** 21·1·91

FIGURE 1



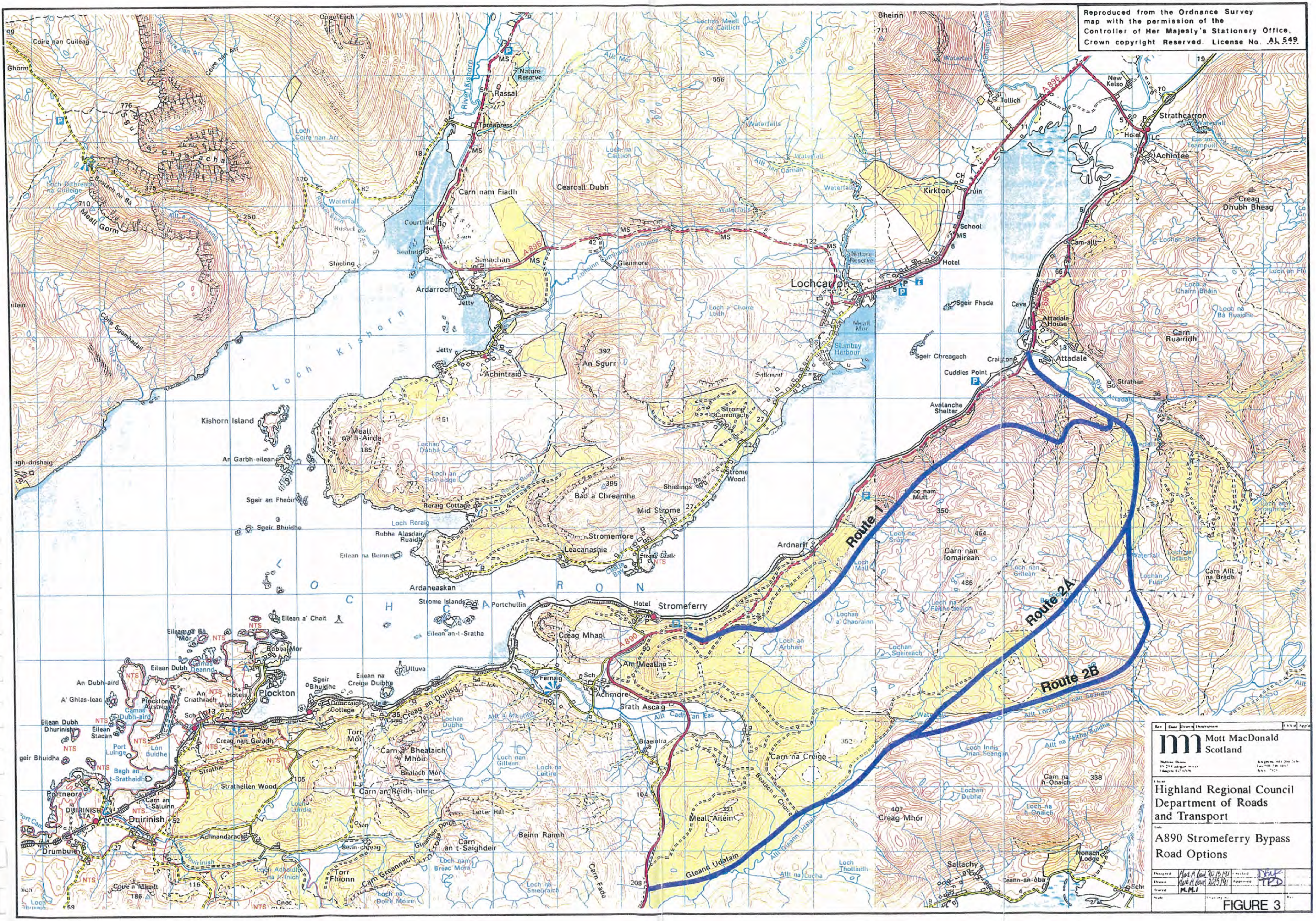
Mott MacDonald Scotland

Highland Regional Council
Department of Roads and Transport

A890 Stromeferry Bypass
Bridge Options

Designed: Mark H Bain 20/5/91
Drawn: Mark H Bain 20/5/91
Traced: H.M.I
Checked: DAMcP
Approved: TPD

FIGURE 2



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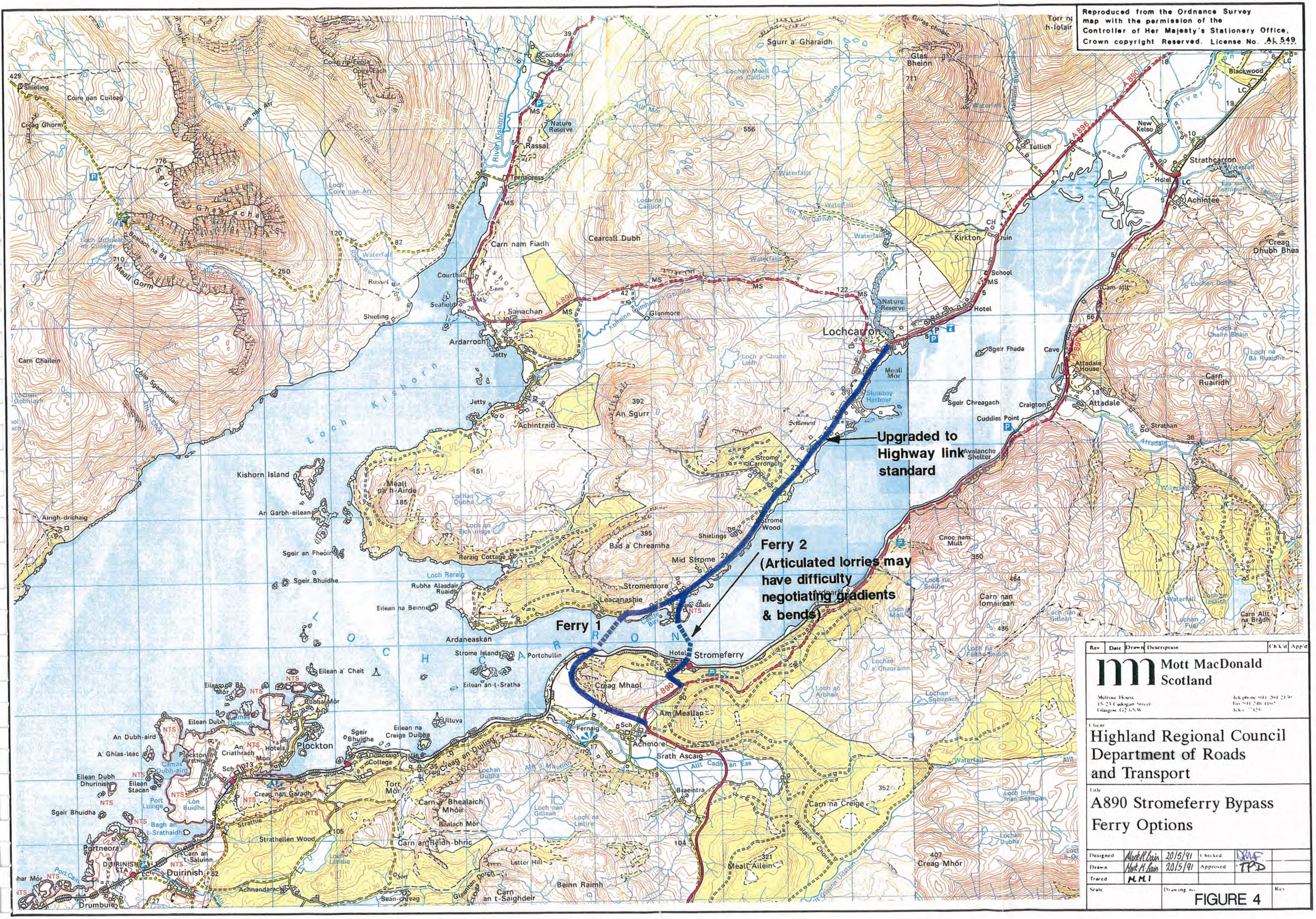
Route 1
Route 2A
Route 2B
Lochcarron
Stromeferry
Loch Carron
Loch Kishorn
Plockton
Duirinish
Attadale
Strathcarron
Mott MacDonald Scotland
Highland Regional Council
Department of Roads
and Transport
A890 Stromeferry Bypass
Road Options
FIGURE 3



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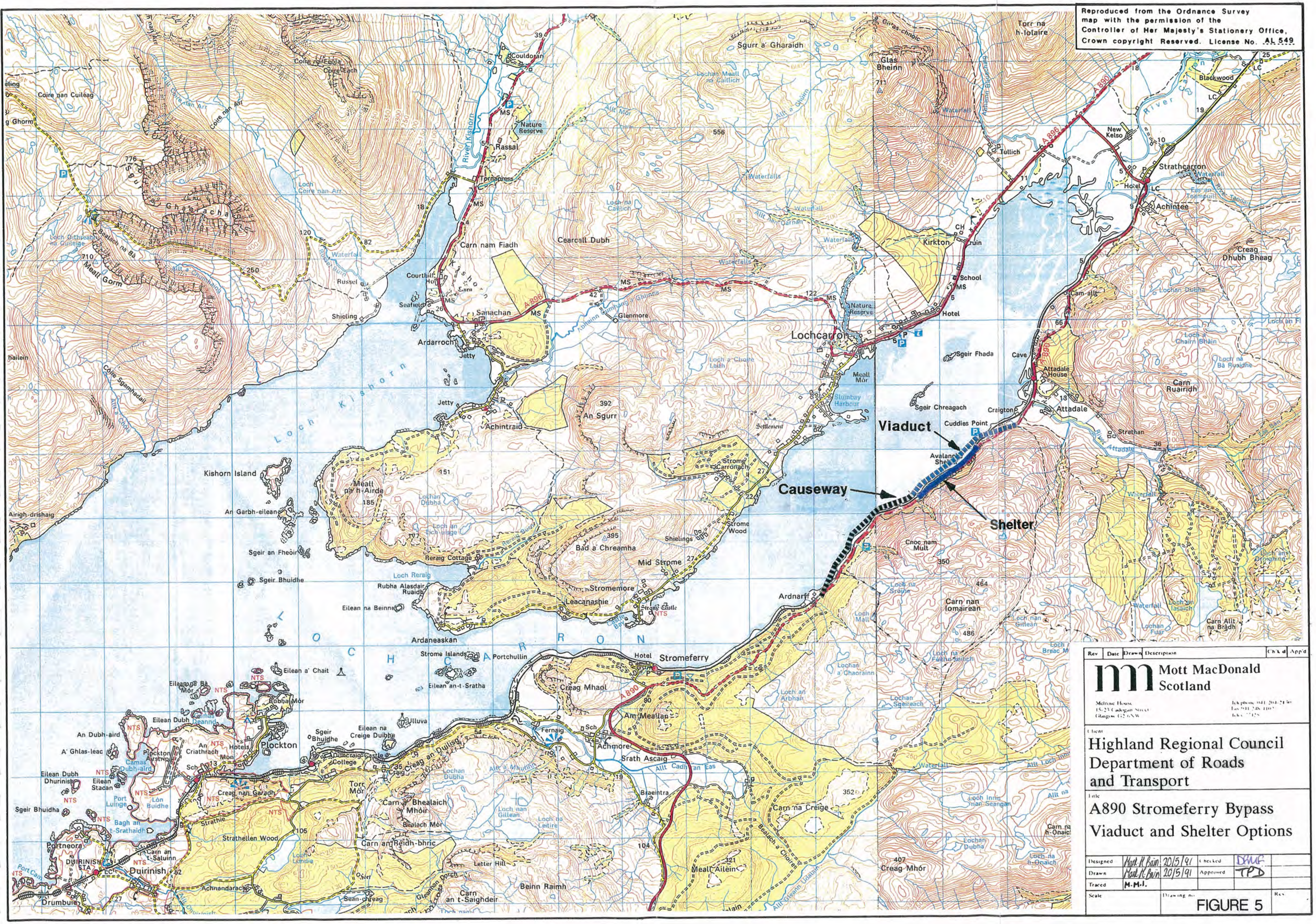
Upgraded to Highway link standard
Ferry 2 (Articulated lorries may have difficulty negotiating gradients & bends)
Ferry 1
Lochcarron
Stromeferry
Plockton
Loch Kishorn
Loch Carron
A890
Mott MacDonald Scotland
Highland Regional Council Department of Roads and Transport
A890 Stromeferry Bypass Ferry Options
FIGURE 4



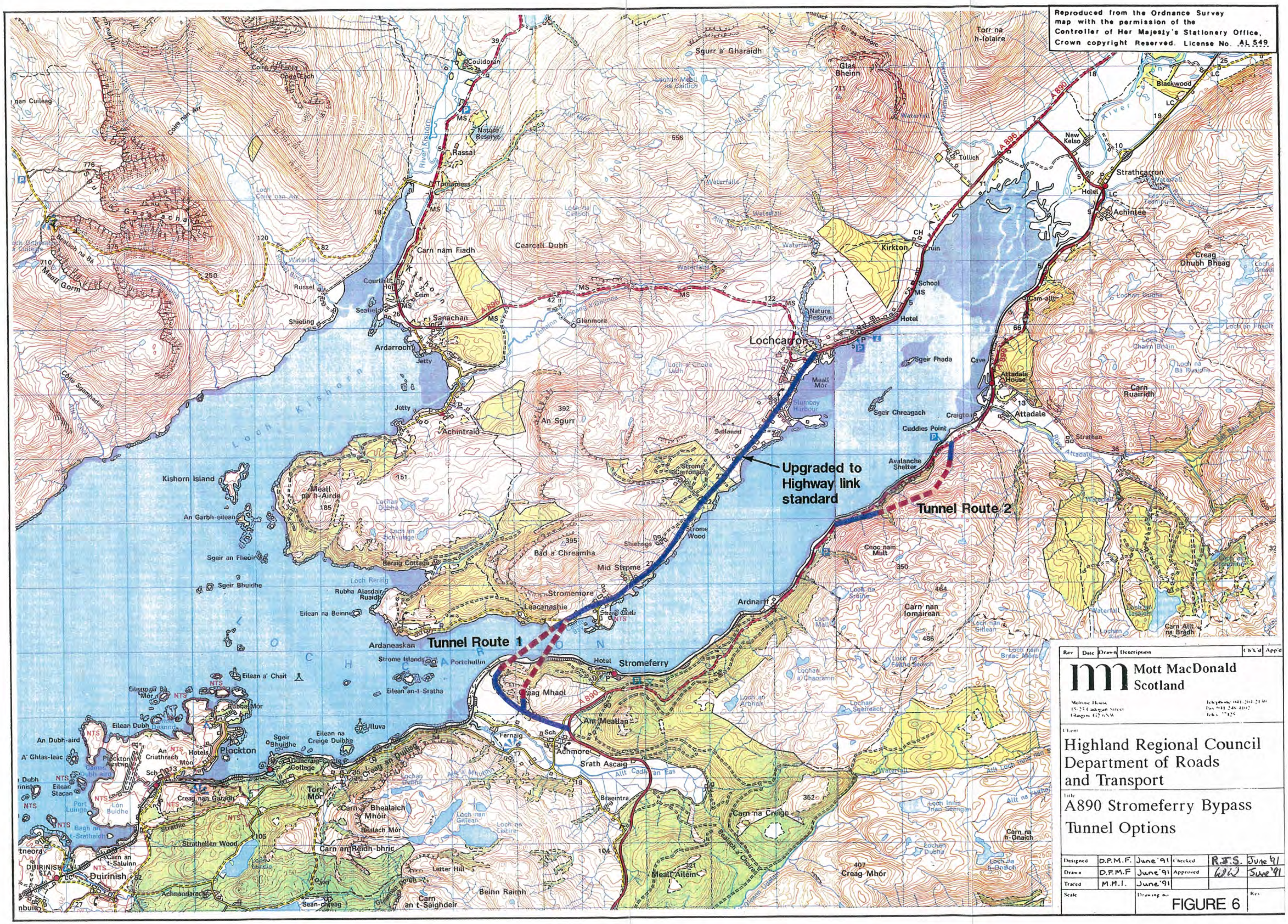
Mott MacDonald Scotland

Client
Highland Regional Council
Department of Roads and Transport

Title
A890 Stromeferry Bypass
Viaduct and Shelter Options

Designed	Mark H Bain	20/5/91	Checked	DMcF
Drawn	Mark H Bain	20/5/91	Approved	TPD
Traced	M.M.I.			

Scale | Drawing no. | FIGURE 5 | Rev



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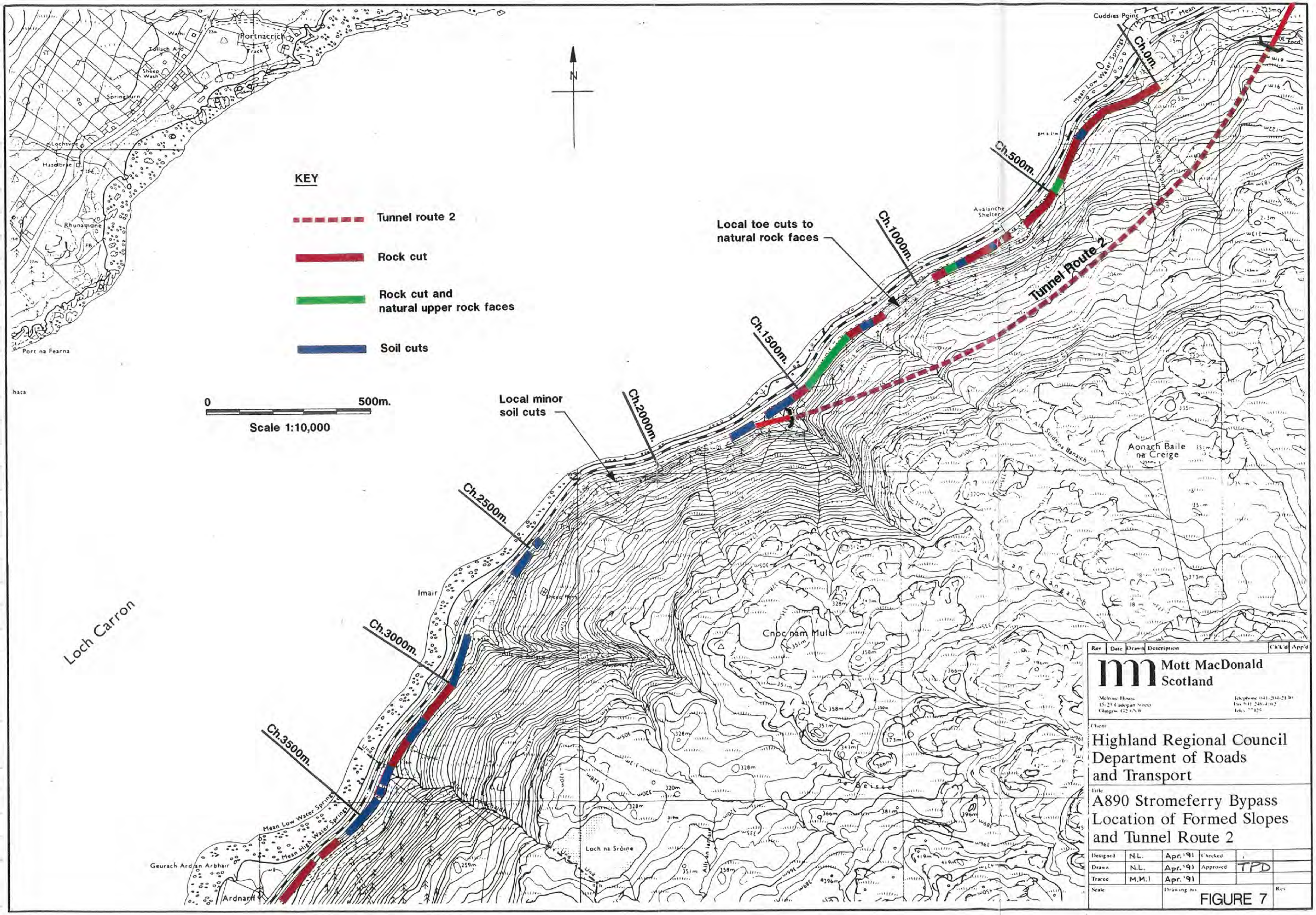
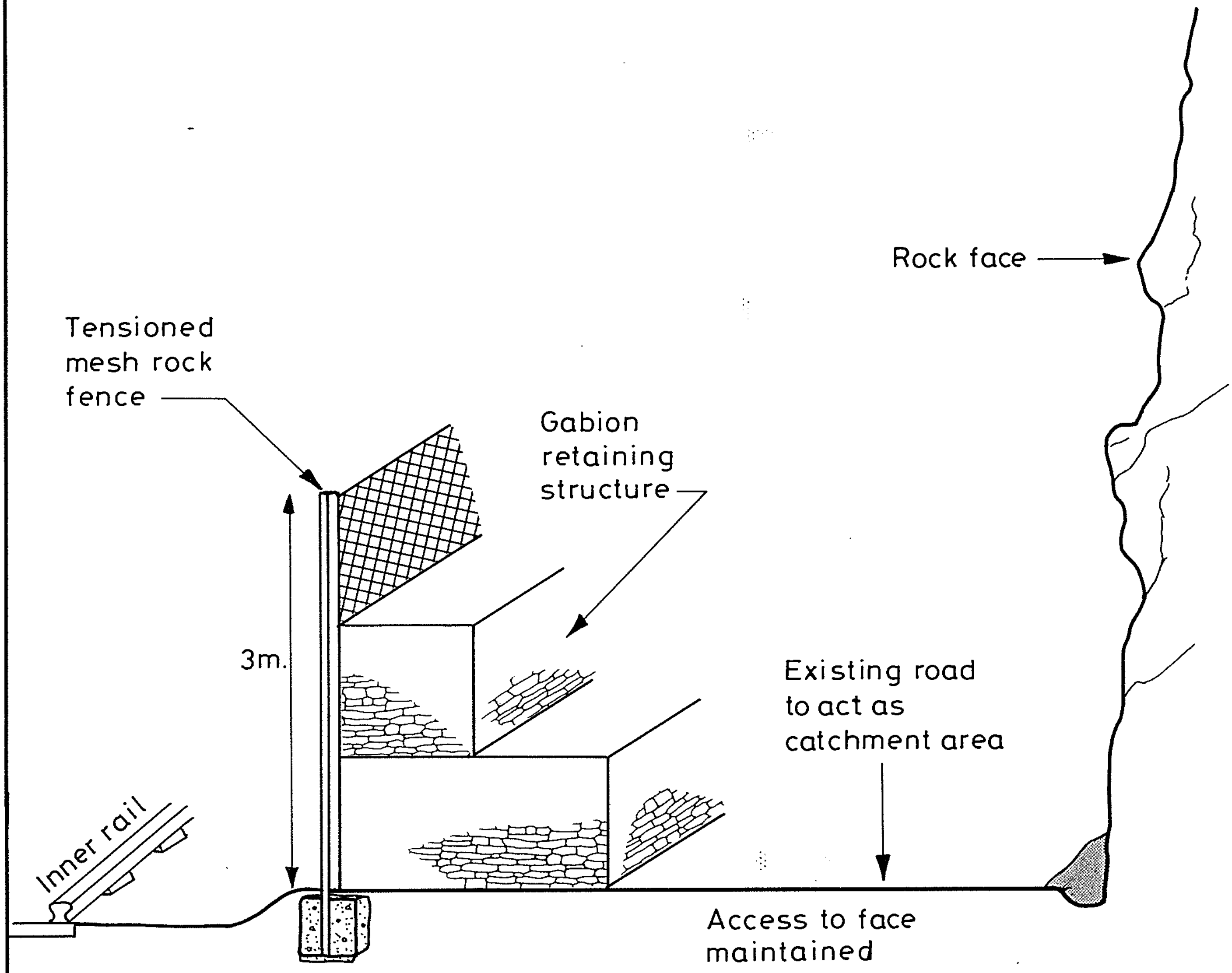
Upgraded to Highway link standard
Tunnel Route 1
Tunnel Route 2
Lochcarron
Stromeferry
Plockton
Strathcarron
Attadale
Ardaneaskan
Achmore
Duirinish
Kishorn Island
Loch Kishorn
A890
A896
Mott MacDonald Scotland
Highland Regional Council
Department of Roads
and Transport
A890 Stromeferry Bypass
Tunnel Options
Designed D.P.M.F. June '91
Drawn D.P.M.F June '91
Traced M.M.I. June '91
Checked R.J.S. June '91
Approved June '91
FIGURE 6


KEY
Tunnel route 2
Rock cut
Rock cut and natural upper rock faces
Soil cuts
0
500m.
Scale 1:10,000
N
Local toe cuts to natural rock faces
Local minor soil cuts
Ch.0m.
Ch.500m.
Ch.1000m.
Ch.1500m.
Ch.2000m.
Ch.2500m.
Ch.3000m.
Ch.3500m.
Tunnel Route 2
Loch Carron
Cuddies Point
Avalanche Shelter
Portnacrich
Springburn
Rhunamone
Port na Fearna
Imair
Aonach Baile na Creige
Cnoc nam Mult
Loch na Sròine
Geurach Ard an Arbhair
Ardnarff
Mean Low Water Springs
Mean High Water Springs
Mott MacDonald Scotland
Highland Regional Council
Department of Roads
and Transport
A890 Stromeferry Bypass
Location of Formed Slopes
and Tunnel Route 2
Designed N.L. Apr.'91
Drawn N.L. Apr.'91
Traced M.M.I Apr.'91
Approved TPD
FIGURE 7



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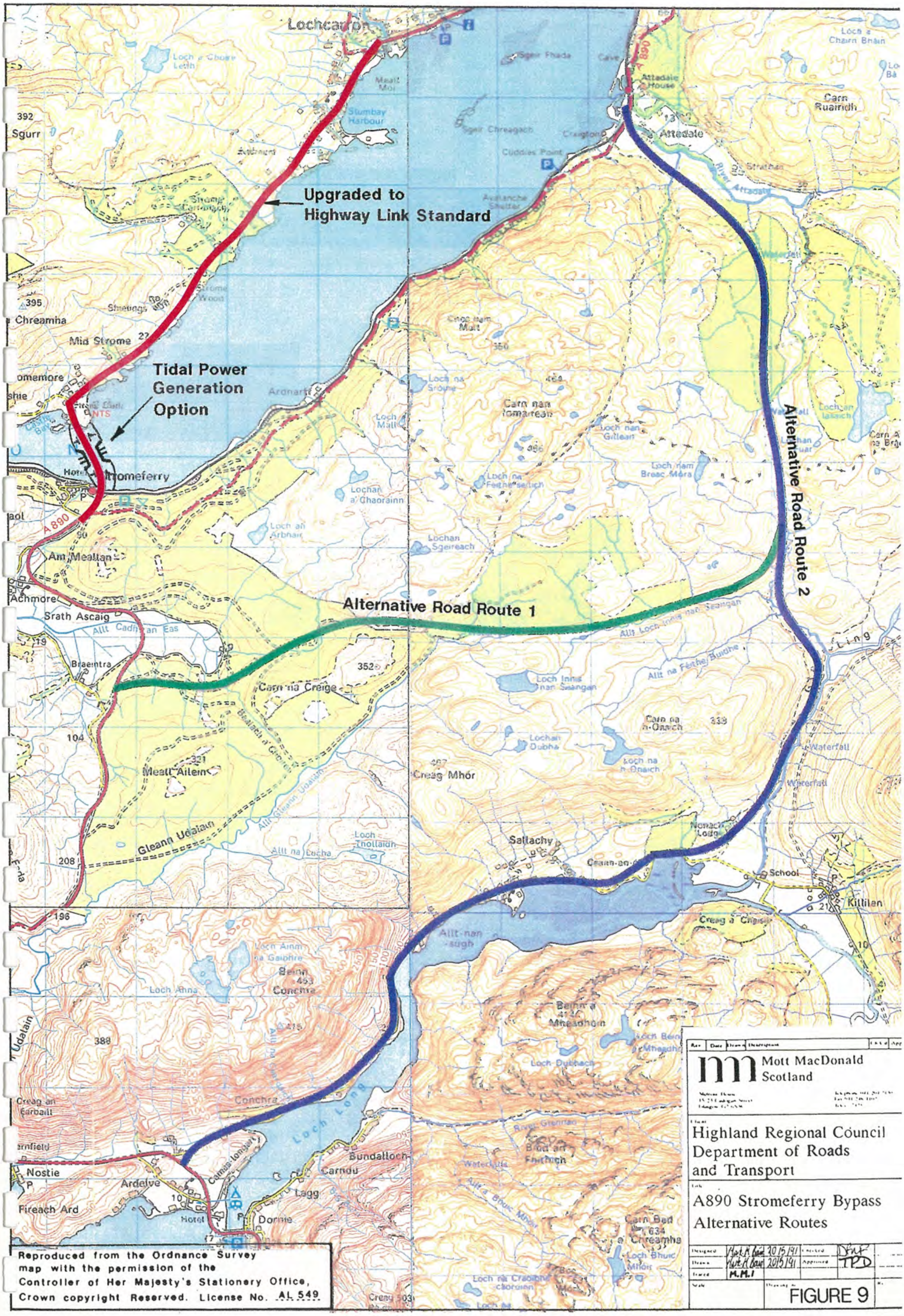
A890 Stromeferry Bypass

Typical Rockfall Protection Barrier

Drawn by : N.L **Chkd. by :** TPD

Appd. by : DPMF **Date :** MAY '91

FIGURE 8



Mott MacDonald
Scotland

Highland Regional Council
Department of Roads
and Transport

A890 Stromeferry Bypass
Alternative Routes

FIGURE 9

APPENDIX E

NORWEGIAN TUNNEL COSTS

APPENDIX E

Tolled road projects in Norway which include tunnels and are either in operation, under construction or planned.

Name of Project	Number and length of tunnels	Project Value	Tolled financing	Construction period	Toll period	Cost/km £M
		(in 1990 - NKrmillion)				
Undersea tunnel to Hvaler Island	1 x 3.7km	141	124	1988-89	1989-2002	3.8
Undersea tunnel to Flekkeroy Island	1 x 3.22km	89	66	1988-89	1989-2003	2.76
Undersea tunnel to Rennesoy Island	5.7km 4.3km (twin bores)	820	820	1990-93	1989-2008	4.1
Land tunnel between Vallavik and Granvin	1 x 7.5km	186	74	1981-85	1977-1992	2.48
Land tunnel on new road between Vik and Voss	1 x 100m	25	15	1982-84	1982-1990	25
Undersea tunnel on main road to Molde	1 x 2.7km	253	248	1989-91	1988-2007	9.2
Alesund undersea tunnel and bridge links	4.2km 3.5km (twin bore)	764	764	1985-88	1987-2008	4.9
Undersea tunnel for link to Kristiansund	1 x 5.2km	1077	711	1988-93	1989-2005	21
Tunnel under the Nappstraumen fjord	1 x 1.8km	128	60	1988-90	1990-2005	7
Undersea tunnel to Ringvassoy Island	1 x 2km	86	37	1986-88	1988-2004	4.3
Proposed schemed yet to be approved						
Tunnel from Naustdal to Eikefjord	1 x 6km	147	116	1991-93	Not fixed	2.45
Land tunnel between Fjorland - Sogndal	2.7km 6.7km (twin bore)	315	315	1991-95	Not fixed	1.67
Undersea tunnel between Hitra - Froya	5.8km 4.8km (twin bore)	725	228	1990-93	Not fixed £1 = NKr10.5	3.42

APPENDIX F

PRELIMINARY OPTION COST ESTIMATES

APPENDIX F

Preliminary Cost Estimates have been calculated for each option considered during the Inception study based on similar recent project tender costs and a review of site conditions and the solutions anticipated. These costs are tentative and may vary following the forthcoming study.

Option	Description	Cost Estimate	
Bridge Option 1	Portchullin to Port à Mheirlich (including £3.9M allowance for approaches and road upgrading)	{50m-100m mainspan {200m mainspan	£16M-£23M £23M-£30M
Bridge Option 2	South Strome to Strome Castle (including £3.9M allowance for approaches and road upgrading)	{400m mainspan	£23M-£38M
Road Option 1	via Loch an Arbair	£11.50M	
Road Option 2A	via Glen Udalain and Loch nam Breac Mora	£ 7.25M	
Road Option 2B	via Allt Loch Imis non Seangan	£ 8.00M	
Tunnel Option 1	Portchullin to Port à Mheirlich (including £3.9M allowance for approaches and road upgrading)	£12.00M	
Tunnel Option 2	Allt an Fhraigaich to Cuddies Point	£6.00M	
Avalanche Shelter	Allt an Fhraigaich to Cuddies Point	£13.00M	
Causeway/Viaduct	Ardnarff to Cuddies Point	£18.00M	
Ferry Option 1	Portchullin to Port à Mheirlich	£ 5.40M	
Ferry Option 2	South Strome to Strome Castle	£ 5.00M	
Tidal Barrage	South Strome to Strome Castle	£50.00M	
Alternative Road option	via Dornie and Glen Ling	£11.00M	

HIGHLAND REGIONAL COUNCIL
REGIONAL ROADS UNIT

A890 STROMEFERRY BYPASS ROAD IMPROVEMENT

FEASIBILITY OF WIDENING THE EXISTING ROAD ALIGNMENT

by

P McMillan
Ground Engineering (Road)
TRL Scotland

A890 STROMEFERRY BYPASS ROAD IMPROVEMENT
FEASIBILITY OF WIDENING THE EXISTING ROAD ALIGNMENT

CONTENTS

A890 STROMEFERRY BYPASS ROAD IMPROVEMENT
FEASIBILITY OF WIDENING THE EXISTING ROAD ALIGNMENT

1. INTRODUCTION

The A890 Stromeferry Bypass has a history of rock fall associated with the man made and natural rock slopes that flank the road on it's southern side. Several studies have been carried out in recent years (James Williamson and Partners, 1989a, 1989b, and 1991a) to evaluate the nature, extent and severity of the instability present in the slopes and a range of remedial solutions have been recommended. At present only one of the remedial schemes has been fully implemented (remedial work at ch 900 in 1991). Other sections of unstable rock slope have been netted in order to contain the rock fall but this netting has only been partially successful.

The cost of a complete remedial solution to the rock instability on the Stromeferry Bypass is such that HRC have decided that it may be more cost effective to completely upgrade the road. This can be achieved in a number of ways, most of which are discussed in the report by James Williamson and Partners (JWP 1991).

In September 1993 HRC Regional Roads Unit commissioned TRL Scotland (TRLS) to evaluate the feasibility of widening the existing road by cutting into the hillside, determine stable cutting slope geometries and advise on the most appropriate methods of excavation. This report presents the results and recommendations arising from this work.

2. GEOLOGY AND BACKGROUND

The geology of the site has been dealt with elsewhere (JWP 1989a, 1989b and 1991a) and only a brief discussion is included here to summerise the general setting.

The Stromeferry Bypass is cut into the side of a steep glacial valley. The rocks forming this hillside belong to the Lewisian and Moine, are gneissose and schistose in character and lie within the Caledonian thrust belt of North West Scotland. In this location the complex gneisses and schists of the Lewisian and basal Moine have been further deformed by being thrust over younger rocks to the west. The Moine thrust is believed to outcrop in the loch to the north of the Bypass. In addition to the thrusting, the rocks have been subjected to more recent, shallow, brittle deformation and a number of fault sets can be recognised in the area. With the exception of joints parallel to the schistosity and gneissosity the discontinuity orientations are remarkably uniform within the limits of the area investigated. These orientation patterns are described in detail in Sections 5 & 6.

When the Stromeferry Bypass was built in 1969/70 fragmentation blasting techniques, including the use of lifter charges, were used to excavate the rocks. The use of such crude blasting methods caused extensive and penetrative damage to the rock mass. In addition to this, the rock structure was not taken into account when the cuttings were formed. As a result the rock excavations on the Bypass have experienced instability since construction.

3. REVIEW OF EXISTING INFORMATION

Previous studies on the Stromeferry Bypass have been targeted toward evaluating the stability of the existing slopes and making appropriate remedial recommendations. Unfortunately, detailed discontinuity surveys have not formed part of these studies, presumably because reprofiling of the rock slopes was not considered as a remedial option. The data required to design new, stable slopes was therefore, not available from any of these studies.

Following the decision by HRC to consider upgrading, several studies have been carried out, four by JWP and one by Electro Watt of Switzerland. The first of the JWP studies was a general feasibility study looking at several options, including the possibility of widening the existing road by further excavation (JWP 1991b). The later JWP studies concentrated on a route inland from the existing road line involving constructing 14 Km of new road (JWP 1992a, 1992b and 1992c) and a tunnel (JWP 1993). The study by Electro Watt examined the possibility of constructing a tunnel and thereby bypassing the least stable 1.5Km of the existing road line (Electrowatt 1992). Once again these studies did not consider forming new stable rock slopes along the existing line and are therefore only partly relevant to the present study.

Air photographs are available for this site as follows:-

a. Vertical, black and white stereo pairs - 1/10,000 scale (SDD 1947).
b. Vertical, colour stereo pairs - 1/2500 scale (Fisher Spence Associates 1989).
c. Vertical, colour stereo pairs - 1/3000 scale (BKS 1992).
d. Oblique, colour stereo pairs - 1/2500 scale (Fisher Spence Associates 1989).
e. Oblique, colour stereo pairs - 1/1000 scale (Fisher Spence Associates 1989).

All were of use in the current study.

4. FIELD WORK

To enable rock slopes to be designed for the route widening option it was essential to carry out a discontinuity mapping exercise. This was undertaken in the four day period between 27 Sept and 30 Sept 1993. Discontinuity data were collected from seven sites over the least stable 1.5Km length of the bypass (Fig 1). The locations were selected in order to provide data representative of the general discontinuity orientation pattern in each area. Unfortunately it was not possible to obtain data from any of the netted sections of rock face as the steel in the netting interfered with the magnetic compass being used. Data from these sections were obtained by visual estimation. It is therefore likely that the data collected may not be fully representative of such areas. Further detailed studies of the rock mass behind the netting is strongly recommended if this route option is pursued.

Specialist rope access techniques were used to allow data collection from the natural and man made rock slopes (McMillan and Wallace 1992).

The data collection was primarily targeted at measuring discontinuity orientation with a Clar type compass. The following characteristics were recorded for each discontinuity:-

a. Type
b. Dip
c. Azimuth (dip direction)
d. Trace Length

A list of the discontinuity data is given in Appendix 1.

At each location the data were collected judiciously rather than objectively. Using the judicious method skilled personnel can establish the pattern of important discontinuities with relatively few orientation measurements (Matheson 1983a). The objective method requires the collection of large quantities of data to establish patterns of orientation and importance at each location.

In addition to the above, observations of the rock type, general structure and slope stability were also made during data collection

5. DATA ANALYSIS

Discontinuity orientation data recovered from rock slopes adjacent to the Stromeferry Bypass were evaluated using two computer aided techniques, DIPS - a program from Toronto University, Canada and ROCKS - a TRLS program. These programs are based on stereographic techniques of analysis and allow the discontinuity data to be manipulated and evaluated. DIPS is primarily of use in evaluating structural trends within the rock mass and ROCKS is used to establish the potential stability of selected slope geometries.

The first exercise in evaluating the discontinuity data was to establish the number, location and limits of structural domains present within the study area (structural domains are areas in which the rock structure is consistent and so can be considered as units for the purposes of rock slope design). The data in each domain was then analysed to determine the optimum slope angle at which potential instability is eliminated or reduced to an acceptable/manageable level. In this case, because of the steep nature of the natural hillsides, selection of rock slope design dip had to be balanced with the required excavation volumes as well as with the potential for instability.

The results of data analyses using both computer methods are presented in Section 6 below and in Appendix 2.

Stereo air photos and the geological map of the site were also studied and used to establish regional structural trends and geomorphological features.

6. RESULTS AND ROCK SLOPE DESIGN

The discontinuity data collected from this site indicates the presence of at least three structural domains (Fig 1) . Domain 1 is located to the East of the avalanche shelter (ch 0 to 315) and is within the Lewisian Gneiss. Domain 2 is the area of hillside above and immediately west of the avalanche shelter (ch 315 to 410). Domain 3 is all of the rock slopes west of Domain 2 to the western limit of the study area (ch 410 to 1200). Each of the domains is considered separately in the following sections and the preliminary rock slope designs are then summarised in Table 1.

6.1 Domain 1, Chainage 0 to 315.

Area east of the avalanche shelter.

6.1.1 General Structure

The rocks in this domain are Lewisian gneisses and show characteristic segregation into light and dark coloured bands. The banding is parallel to the main rock fabric and there is little evidence of discordant veining or melt segregation. There appears to be a thrust fault parallel to the main gneissosity. The thrust outcrops above road level near the western end of the new Macaferry netting and it's trace rises slowly across the unnetted area. About half way across this area the thrust appears to "climb" or is faulted to a higher level.

6.1.2 Discontinuity Data

Analysis of the discontinuity data shows the presence of three well defined discontinuity sets (Fig 2). Two of these are joint sets (Set 1 and 2) and the third are discontinuities parallel to the foliation/gneissosity (Set 3). The azimuth of the proposed road through this domain varies from 301 to 325 degrees (relative to magnetic North). The most critical discontinuities which respect to stability of the proposed rock cuttings are the Set 1 joints. These joints are regular, planar, persistent, steeply dipping and closely parallel to the proposed road azimuth along much of this section. They are exerting a major controlling influence on the stability of the existing cuttings and natural slopes in this domain.

6.1.3 Outline Design of Proposed Cutting

The proposed rock cuttings should dip at 70 degrees and be formed in two lifts with a 4m berm between the lifts. The berm location should be dictated by available burden on the proposed slope profile. Where there is more than 8m burden on the slope presplit blasting should be used and so the lower lift should extend to this limit. The top lift should be excavated using smooth blasting. A hole spacing of ten times the hole diameter (to a max of 1000mm) should be adopted for the presplit lift and a hole spacing of 600 to 800mm should be used for the smooth blasting. The charging guidance given in Matheson 1983b, should be followed for the presplit faces.

Where the road azimuth is in the range 301 - 315 degrees (mag. North) the cut faces are approximately parallel to Set 1 joints which will enhance the formation of a clean presplit/smooth blast plane. Where the road azimuth swings from 315 to 325 degrees (mag. North) the final face may have a saw tooth appearance as the major joints of Set 1 are likely to exert a stronger control on the final geometry than the induced presplit/smooth blast planes. This saw tooth effect should not present a serious stability problem but local treatment against toppling may be necessary.

A large rock trap, 4m wide and 1.5m deep should be formed at the base of the main slope. A small catch fence/crash barrier should be erected on the road verge. These rock trap dimensions are smaller than predicted by the design charts of Ritchie (Ritchie 1963) but it has been shown that presplit slopes require smaller rock traps than those predicted by Ritchie (Mak and Blomfield, 1986).

The proposed cutting design for this section is illustrated in Fig 3.

6.1.4 Stability Considerations

It is likely that by forming the cuttings parallel to a dominant joint set, a face requiring no general remedial treatment and very little maintenance will result. Provided that no large instability is induced, small superficial stability problems can be allowed to progress to failure as the rock trap and fence will contain them. Observation of the easternmost netted face and part of the netted face adjacent to the east end of the avalanche shelter suggests that occasional persistent low angle discontinuities can be expected to daylight on the proposed cutting faces. Where these occur there will be a potential for planar failure and local remedial treatment will be necessary. The nature and scale of the treatment will be dictated by the geometry and can be determined on excavation (dowels will probably suffice). Less than 5% of the existing faces are presently affected by such planar instability and there is no reason to assume that the incidence is likely to be increased by cutting further into the hillside.

Where faults and/or thrusts are encountered on the cut faces it is likely that the rock whithin and adjacent to these features will be susceptible to weathering and erosion. To prevent progressive instability developing protective measures should be taken eg. covering with dentition or gunite. A significant fault can be expected to daylight on the proposed slopes at about chainage 200.

6.2 Domain 2, Chainage 315 to 410.

Area from the east end of the avalanche shelter to the first netted rock slope west of the shelter.

6.2.1 General Structure

Both Lewisian gneiss and Moine schists are present in this domain. The two rock types appear to have been juxtaposed by faulting although the exact spacial relationships are far from clear. Field observations indicate that the numerous gullies in the hillside are formed along the lines of these faults. Such intensive faulting is likely to increase joint frequency and reduce mass strength.

6.2.2 Discontinuity Data

The very difficult terrain and time constraints did not allow a full evaluation of the structure of this domain and relatively few discontinuity measurements were taken. The data recovered indicates a pattern that appears to be a hybrid of the other two domains which is complicated by joints parallel to the numerous faults.

6.2.3 Proposed Cutting Design

The formation of any excavation in this area is likely to be met with considerable problems. These will arise from the geotechnical properties of gully talus slopes, overburden slopes and the faulted rock mass. It would therefore be prudent to leave the avalanche shelter in place and not attempt to form new cuttings in this area. If this is done then narrowing the road to single track on the western approach to the shelter will reduce the rock excavation requirement to one of local trimming.

If it is decided to widen the road along this section (either as part of this scheme or in the future) then it is advised that this is done by adding another lane to the existing shelter. A very detailed study of both surface and subsurface rock structure and overburden/talus slopes should be undertaken to allow the design of the western approach excavations to the shelter. It may be that some form of reinforced rock/soil or structural portals will be required for this approach.

6.2.4 Stability Considerations

The limited amount of discontinuity data recorded from this area and field observations indicate that rock excavations are likely to be prone to large scale wedge failure. A large wedge failure scar was observed in a natural rock face high on the hillside behind the shelter. The joints forming the wedge were both minor fault planes.

The talus filling the gully immediately uphill of the shelter appears to be the remnants of the slope failure that occurred during construction of the road. Great care must be taken with any form of excavation or construction in this talus.

The numerous faults and gullies in this area will have rendered much of the rock mass susceptible to weathering and erosion. If slopes are excavated it is likely that large areas of protective treatment will be required.

6.3 Domain 3, Chainage 410 to 1200.

Area from the first netted slope west of the avalanche shelter to the western limit of the study area.

6.3.1 General Structure

The rocks in this area are part of the Moine series and are generally schists with local gneiss bands. The schistosity has been folded into recumbant, tight, isoclinal folds. The axial plane of these folds is sub-parallel to the regional trend of the Moine thrust.

There are numerous faults present in this domain. Most of these faults are now apparent as gullies in the rock slopes.

6.3.2 Discontinuity Data

There are three principle discontinuity sets in this domain, Sets 1 & 2 are joints and Set 3 is parallel to the foliation (Fig 4). The joint sets have broadly the same orientation as the joint sets in Domain 1 but are not as well defined and show significant scatter. The scatter in Set 1 joints is such that it necessary to divide the Set into two subsets, 1a and 1b, for the purposes of stability evaluation. The two subsets have the same azimuth but subset 1a is dipping more steeply than subset 1b. The discontinuities parallel to the foliation show considerable local variation in orientation. This pattern is caused by the very tight recumbent, isoclinal folding that is present in the Moine schist in this area.

Set 1 joints are the dominant discontinuities in this domain and control the stability on most of the existing slopes. Where the road alignment varies from being sub parallel with Set 1 joints, the dominant control on slope stability becomes the intersection between Set 1 and Set 2 joints resulting in a potential for wedge failure.

In addition to the three principal sets there are minor discontinuity Sets, 2a and 4, which do not appear to be present throughout the entire domain. This may be the result of sampling bias or a function of the frequency of these minor joint sets.

6.3.3 Proposed Cutting Design

The proposed rock cuttings should be formed with a dip of 65 degrees. They should be formed in two lifts with a 4m berm between the lifts. As in Domain 1 the height of the berm should be dictated by the available burden on the proposed slope profile (Section 6.1.3). The top lift should be excavated using smooth blasting and the bottom lift using presplit blasting. The hole spacing for presplit blasting should be ten times hole diameter (up to 1000mm) and for smooth blasting should be 600mm. Close smooth blast hole spacing is required as the slope face will generally cut accross the dominant joints.

Where very persistent joints are within 15 degrees of the proposed presplit/smooth blast planes the final face is likely to partly follow the joints leading to an irregular face profile. This may lead to localised stability problems particularly in areas prone to toppling.

A large rock trap, 4m wide and 1.5m deep should be formed at the toe of the slope. A small catch fence/crash barrier should be erected on the verge.

A typical section through the proposed cutting design is illustrated in Fig 5.

6.3.4 Stability Considerations

A range of stability problems can be expected on these proposed cutting slopes. This is due to the adopted slope angle of 65 degrees and the wide range of discontinuity orientations within each set. A 65 degree slope does not eliminate all failure potential from these proposed slopes. To achieve this a slope angle of around 50 degrees would be necessary. The topographic constraints in this case rule out this low slope angle and provision for remedial work on the finished slopes will be necessary.

The wide range of discontinuity orientations makes it almost impossible to determine where stability problems will arise and what form they are likely to take. A better orientation as the joint sets in Domain 1 but are not as well defined and show significant scatter. The scatter in Set 1 joints is such that it necessary to divide the Set into two subsets, 1a and 1b, for the purposes of stability evaluation. The two subsets have the same azimuth but subset 1a is dipping more steeply than subset 1b. The discontinuities parallel to the foliation show considerable local variation in orientation. This pattern is caused by the very tight recumbent, isoclinal folding that is present in the Moine schist in this area.

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The wide range of discontinuity orientations makes it almost impossible to determine where stability problems will arise and what form they are likely to take. A better estimate of this may be possible following more detailed investigation of the area. In general terms the slope will be prone to plane, wedge and toppling failure although not all in the same area. Instability is generally unlikely to involve large rock volumes as the potential release joints are seldom very persistent.

If the presplit and smooth blasting are successful in forming planar slopes the potential for toppling will be reduced but long term degredation and weathering may increase this potential. Plane failure potential is most likely on slopes with azimuths in the range 280 - 320. Wedge failure potential is most likely on slopes with azimuths in the range 315 - 360. It is essential that all slopes are evaluated immediately after mucking out and the necessary remedial action is undertaken as soon as possible after this.

In addition to the stability problems discussed above, the proposed slopes will require protective treatment where faults daylight on the face. This is likely to occur in the vicinity of each of the gullies in this domain.

A remedial work contingency will be required in any contract to form these excavations. The contingency should allow for a range of remedial options including anchors, bolts, dowels, gunite and dentition. This will allow the most appropriate measures to be used in each situation. Provided there is no risk of large instability developing, small scale superficial instability can be allowed to fail as this will be contained by the rock trap and fence.

Table 1. Summary of Preliminary Rock Slope Design.

Domain	Road	Cutting Dips		Excavation Method		Berms		Trap		Instability Potential		
	Azimuths	Bottom Lift	Top Lift	Bottom Lift	Top Lift	Top	mid.	Width	Depth	Plane	Wedge	Topple
1	306 - 330	70	70	presplit	smooth	4m	4m	4m	1.5m	low	low	low
2	No Rock Excavation Recommended											
3	305 - 345	65	65	presplit	smooth	4m	4m	4m	1.5m	high	moderate	low

7. OTHER DESIGN CONSIDERATIONS

In addition to the optimum design of rock slopes, other design considerations have a direct bearing on the feasibility of this route option. These are described below:-

7.1 Construction access track/Top of slope berm

In order to form the rock cuttings access to the steep hillside slopes will have to be provided for drilling plant. This will require an access track approximately 4m wide to be excavated into overburden and rock.

The hillside slopes above the Stromeferry bypass are very steep (30 - 45 degrees). There is evidence of historical and recent instability in both the superficial deposits and the surface of the rock on these steep slopes. It is likely that the slopes are close to limiting equilibrium with respect to sliding failure.

If an unsupported, undesigned excavation is opened into these deposits the risk of a large slip occurring is high. One way of reducing the risk is to design the access track as part of the permanent works and incorporate it as a top of slope berm.

To limit the risk of failure occurring some form of top down reinforcement or support construction is advised for the cutting slopes. If this is adopted it should be possible to form stable slopes at the same angles as the lower rock slopes. The most appropriate form of reinforcement/support can only be chosen and designed following a detailed ground investigation. This investigation should focus on deriving detailed information on the nature and geometry of rockhead and the depth and type of superficial deposits. The presence and location of groundwater seepages and flows will also be critical for design purposes.

It is likely that rock head will be shallow and very irregular. In such circumstances a method that gives construction flexibility is likely to be most appropriate. Soil nailing is one such method. Typical nail length and spacing for given slope heights can be obtained from Bruce and Jewel (1987). These estimates should be used for preliminary purposes only.

If the access track is adopted as a top of slope berm, an avalanche fence should be erected on this berm once excavation of the rock slopes is complete. The fence should be located approximately 1m back from the rock face edge. The height of the fence should be determined following an investigation of the block size of the unstable material on the upper slopes. Some form of tensioned wire, netting and steel post construction is likely to be most appropriate for this fence.

7.2 Stability of the Existing Slopes and Hazard to the Rail Line.

All of the studies undertaken on the Stromeferry Bypass have one conclusion in common, that the existing slopes are unstable and represent a serious hazard to road users. The nature and scale of instability and severity of the hazard vary from one location to another but in the most serious areas the potential instability problems involve thousands of tonnes of rock.

If the inland bypass option is adopted, the unstable cliffs of the existing bypass will be avoided as will the difficulties of excavating further into the hillside. There will however continue to be a threat to the rail line that runs parallel to the existing road. It is understood that HRC own both the man made and natural slopes to the South of the existing road and as such could have responsibility for their maintenance. The maintenance responsibility for the man made slopes is certain; there is however some doubt about responsibility for the natural slopes.

In the event of a complete bypass being constructed it will still be necessary to carry out remedial works on the existing cliffs to ensure the safety of the rail line. The most appropriate actions for most of the length would be to scale the faces, muck up the existing road, create a ditch and erect a substantial avalanche fence. These removal and containment works would prevent failures from encroaching on the rail line in all but the very worst areas. In the worst areas the most appropriate action would be to locally trim (probably by controlled blasting) the existing slopes back to remove the severe instability problems and then allow the rock trap and fence to take care of the remaining failures.

The amount of trimming will be dependant on the outcome regarding responsibility for maintenance of the natural slopes. Less than 10% of the man made slopes and about 5 - 10% of the natural slopes would require trimming.

The cost of these remedial works on the existing slopes will have to be taken into account in any estimates of the cost of the bypass option.

7.3 Construction Logistics

Widening of the A890 by cutting into the hillside will involve excavation of large volumes of rock (>250,000m3) by blasting. To keep the road and railway open during this major rock excavation at such close proximity is impractical and would increase excavation costs enormously. The most likely scenario is a complete closure of the railway for about 6 months during the main rock excavation operations. The road would be closed for longer as the new road construction would have to be completed before the route could be opened again. Once the rail line is open it may be possible to operate a system similar to that used during the ch900 remedial works but over a greater length. At ch 900 road traffic was diverted onto the rail line using a linked rail and road traffic control system. Sleepers were placed along the rail line to render it usable by road traffic.

In view of the technical and logistical difficulties that will be encountered if this option were pursued, a flexible form of contract is likely to be most cost effective in the long term. A standard, ICE 5th Edition contract with a bill of remeasureable quantities would be suitable.

7.4 Environmental Impact

The major rock excavations that will be required as part of this option will have a significant environmental impact on the surrounding area. In particular the cuttings will be clearly visible from the village of Lochcarron on the other side of the loch. The impact of the cuttings can be reduced in a number of ways.

The location of the berm on the rock cutting faces will be dictated to some extent by the hillside topography. It will therefore not be a horizontal feature but will blend with the natural lines of the hillside. The berm can be used to further lessen the severity of the rock slope appearance if it were vegetated. This could be achieved by cutting the berm at a low angle dipping into the hillside. This will provide a trap in which soil can be placed or allowed to collect and allow planting to be undertaken. The choice of vegetation for the berm would be critical. The top of slope berm and soil/rock slope could also be vegetated to break up the top of slope line. A schematic illustration of these measures is shown in Fig 7.

8. FURTHER INVESTIGATIONS

The recommendations and outline designs presented in this report are based on a preliminary feasibility mapping investigation of the slopes above the Stromeferry Bypass. If this option of widening the existing road by cutting into the hillside is to be pursued then further ground investigation work will be required. It is outside the scope of this report to discuss the full requirements of such a ground investigation, however, any such investigation should include the specialist elements outlined below.

8.1. Field Mapping and Discontinuity Surveys

Further, more detailed and rigorous field mapping should be undertaken in the early stages of any investigation. The mapping should define more accurately the limits of the existing domains and identify any subdivisions of these that may be necessary. Additional judicious discontinuity data collection should be undertaken to confirm slope design recommendations made in this report. Discontinuity data should also be collected from scanlines to provide data for fragmentation blast design and material reuse evaluation.

8.2 Down Hole CCTV Surveys

Inclined holes should be drilled from positions above the existing rock faces and on the faces. These holes should then be surveyed with down hole CCTV equipment or other down hole scanning system capable of providing discontinuity orientation spacing and dilation data. These holes should be located to fill any gaps in the surface discontinuity data eg. in areas where the faces are netted. Careful consideration should be given to the orientation of these holes in order to maximise the recovery of discontinuity data.

8.3 Trial Pits/Trenches

Trial pits and trenches should be excavated on the upper slopes to establish the depth to and nature of rockhead at as many locations as practical. These pits will also provide quality information on the nature of the overburden material.

9. SUMMARY

9.1 TRL Scotland were requested to evaluate the feasibility of widening the existing A890 Stromeferry Bypass by cutting further into the hillside and in particular to advise on optimum rock slope geometry and excavation techniques.

9.2 A preliminary structural and discontinuity mapping exercise was undertaken on the rock slopes flanking the A890. The field work concentrated on identifying general structural trends, establishing the limits of structural domains and collecting discontinuity orientation data.

9.3 The rocks in the area are Lewisian and Moine gneisses and schists in which the main structural fabric is controlled by recumbent, tight, isoclinal folding. Analysis of the discontinuity orientation data and field observations revealed three general structural domains as follows:-

Domain 1 - chainage 0 to 315,
Domain 2 - chainage 315 to 410,
Domain 3 - chainage 410 to 1200.

In Domain 1 there are three well defined discontinuity sets. In Domain 2 the structure is complicated by intense faulting and was not able to be clearly established. In Domain 3 there are three discontinuity sets that exhibit a wide orientation variation and there are also local/infrequent minor discontinuity sets.

9.4 Other considerations that impact on the feasibility of this route option are construction access, stability of existing slopes and hazard to the rail line, construction logistics and environmental impact. Construction access and logistics are likely to prove problematical for this option. However all other options have to address the problem of the stability of the existing slopes and hazard to the rail line which has a major cost implication. All options will have an adverse environmental impact on this area.

10. CONCLUSIONS

On the basis of the investigatins carried out to date the widening of the A890 on the existing alignment by cutting furhter into the hillside is feasible. There will however, be considerable technical and contractual difficulties to be addressed if the scheme were to go ahead.

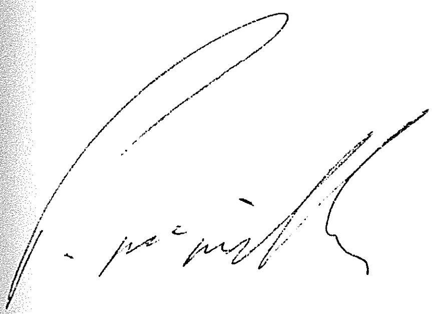
11. RECOMMENDATIONS

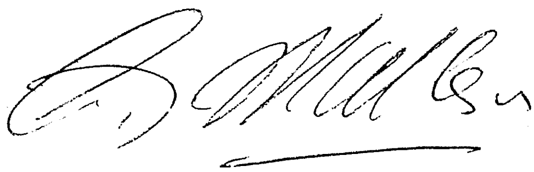
11.1 The rock cuttings in Domain 1 should be formed at a dip of 70 degrees. Only localised stability problems are expected on these slopes. In Domain 2 rock excavation should be avoided or kept to a minimum by retaining the avalanche shelter. If it is decided to excavate in this domain a more detailed study is required to evalute if this is feasable and what the stability risks will be. The rock cuttings in Domain 3 should be formed at a dip of 65 degrees. At this slope angle significant instability can be expect and allowance should be made for remedial works.

11.2 All proposed rock cutting slopes should be excavated in two lifts using a combination of presplit and smooth blasting techniques. The location of the berm between rock cutting lifts should be determined by the burden available on the proposed slope profile. Where there is less than 8m burden smooth blasting should be used and so the berm should be located at this cut off point. The upper lifts should be smooth blasted and the lower lifts presplit.

11.3 If the widening of the A890 by further excavation is to be pursued the ouline design proposals made in this report will have to be confirmed. This will require an exhaustive ground investigation tailored to address the specific difficulties present at this site followed by detailed design. The investigation should include detailed field mapping, discontinuity surveys, down hole CCTV/scanner surveys and trial pit and trench excavations.

11.4 Given the difficulties that are likely to arise on this scheme a standard ICE 5th Edition contract with a bill of remeasureable quantities is likely to prove most cost effective.





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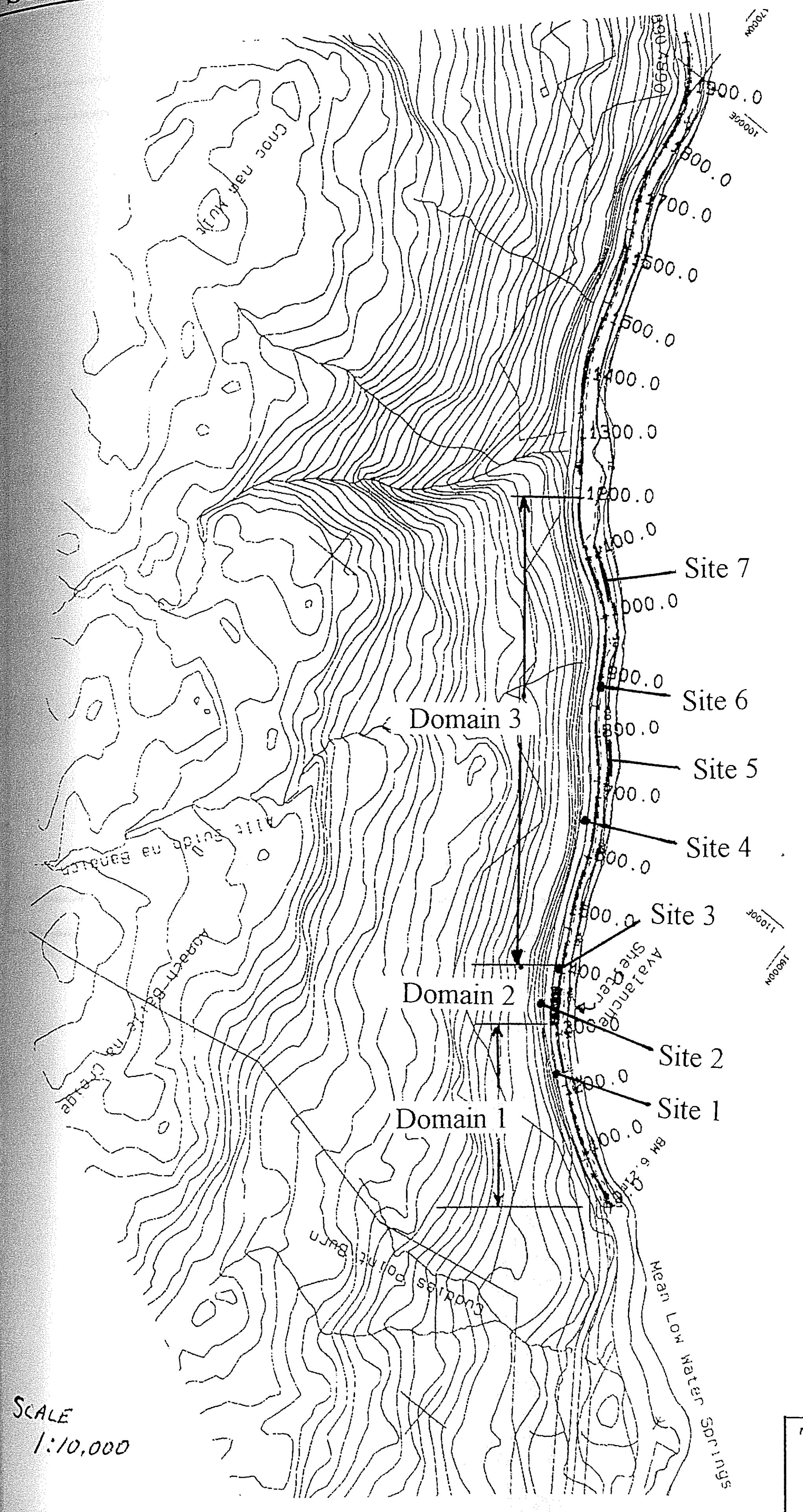
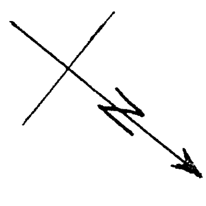
A890 STROMEFERRY BYPASS ROAD IMPROVEMENT
FEASIBILITY OF WIDENING THE EXISTING ROAD ALIGNMENT

FIGURES

Job Title; A890 Road Improvement	Fig. No.	Date
Section; Location of Domains and Mapping Sites	1	Nov. 1993





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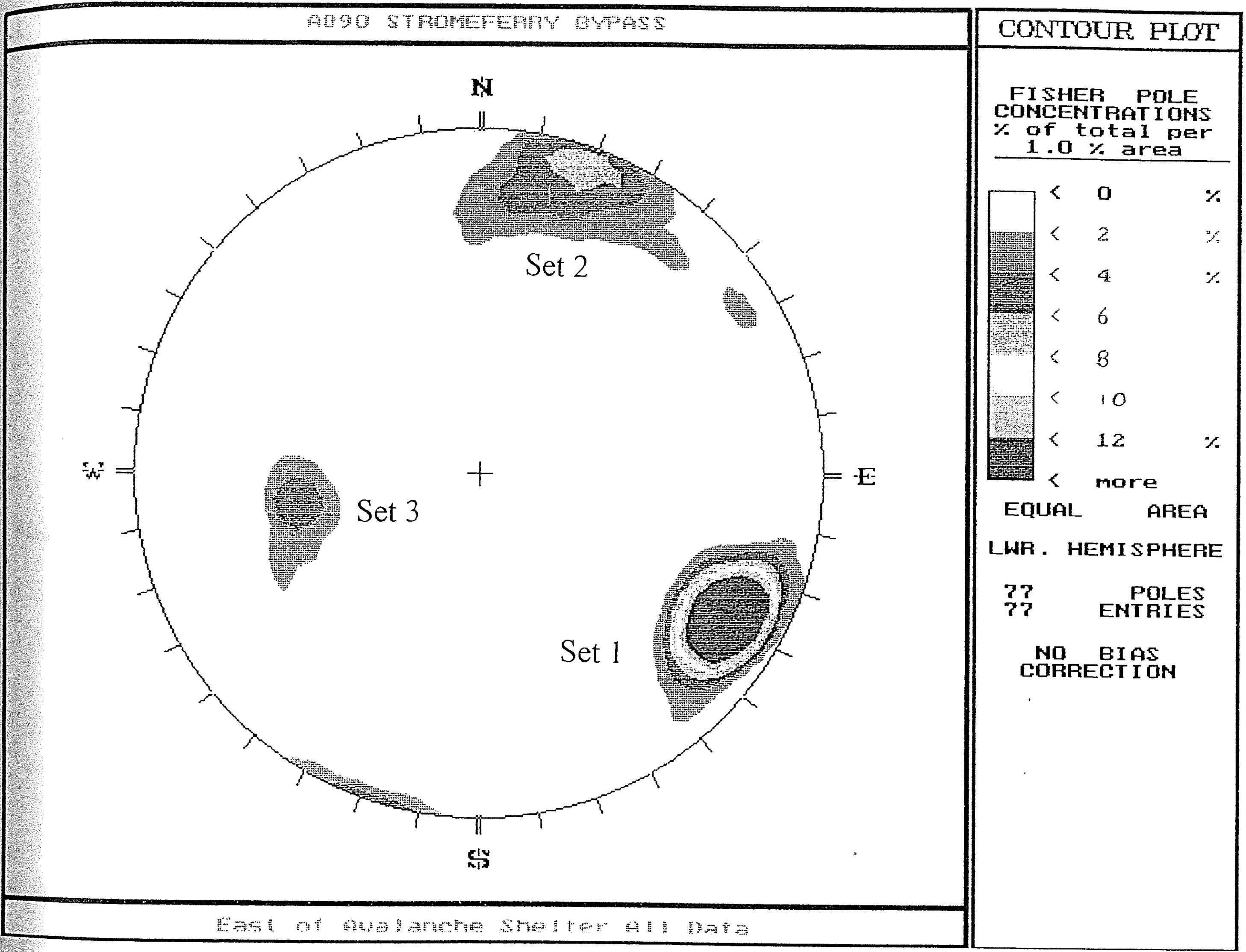
Job Title; A890 Road Improvement	Fig. No.	Date
Section; Domain 1 Discontinuity Data Plot	2	Nov. 1993



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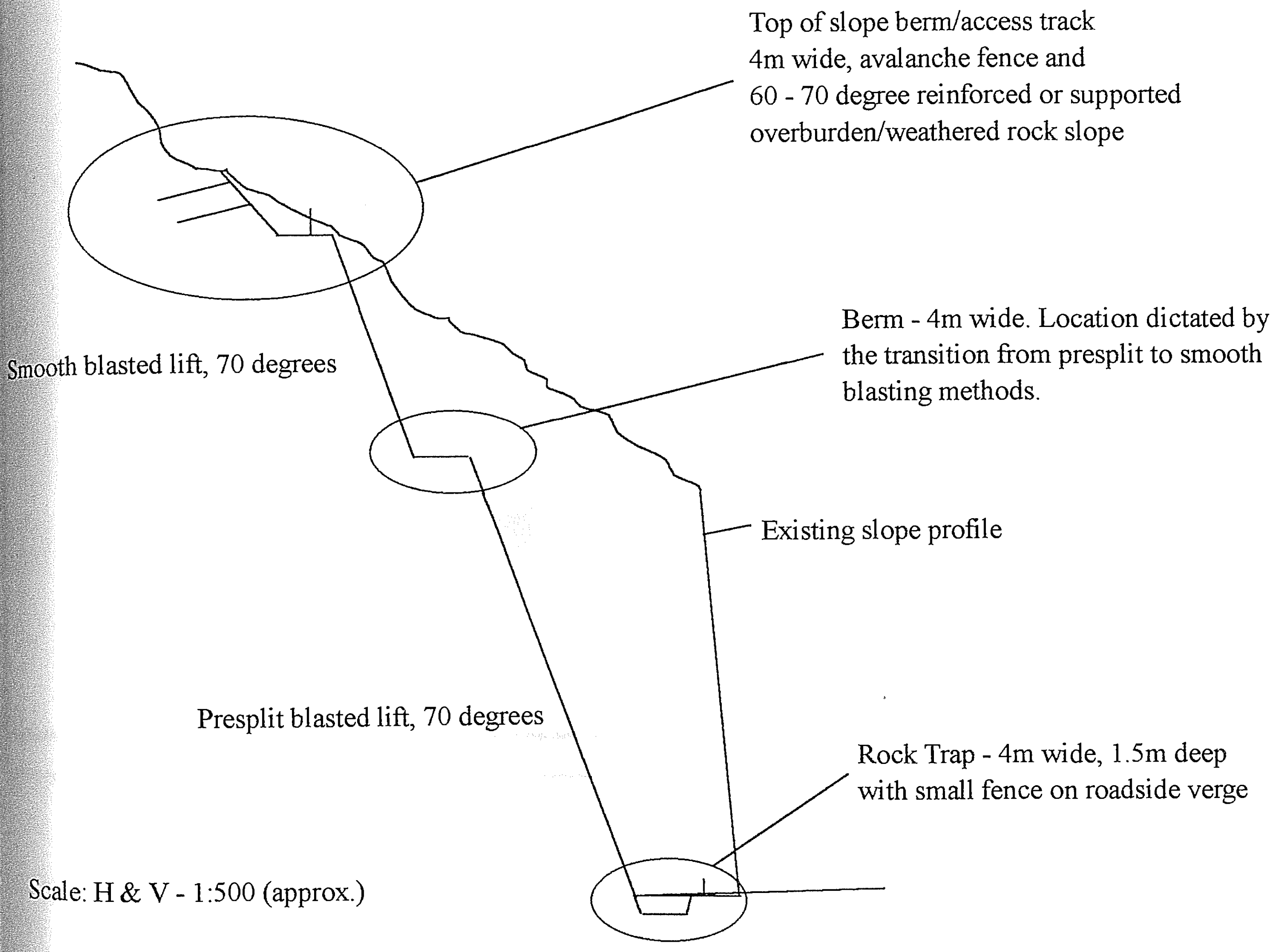
Job Title; A890 Road Improvement	Fig. No.	Date
Section; Typical Section East of Avalanche Shelter	3	Nov. 1993



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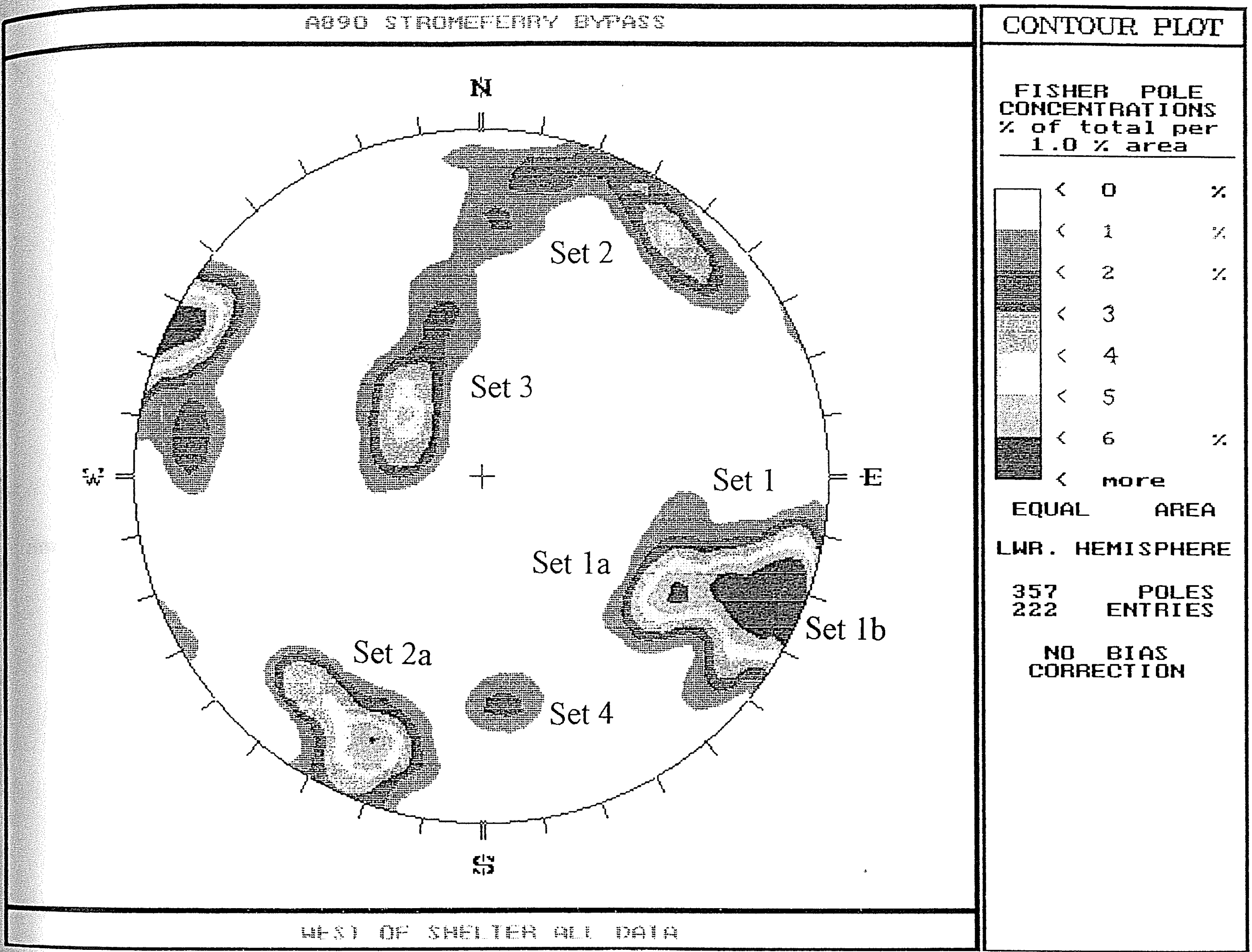
Job Title; A890 Road Improvement	Fig. No.	Date
Section; Domain 3 Discontinuity Data Plot	4	Nov. 1993



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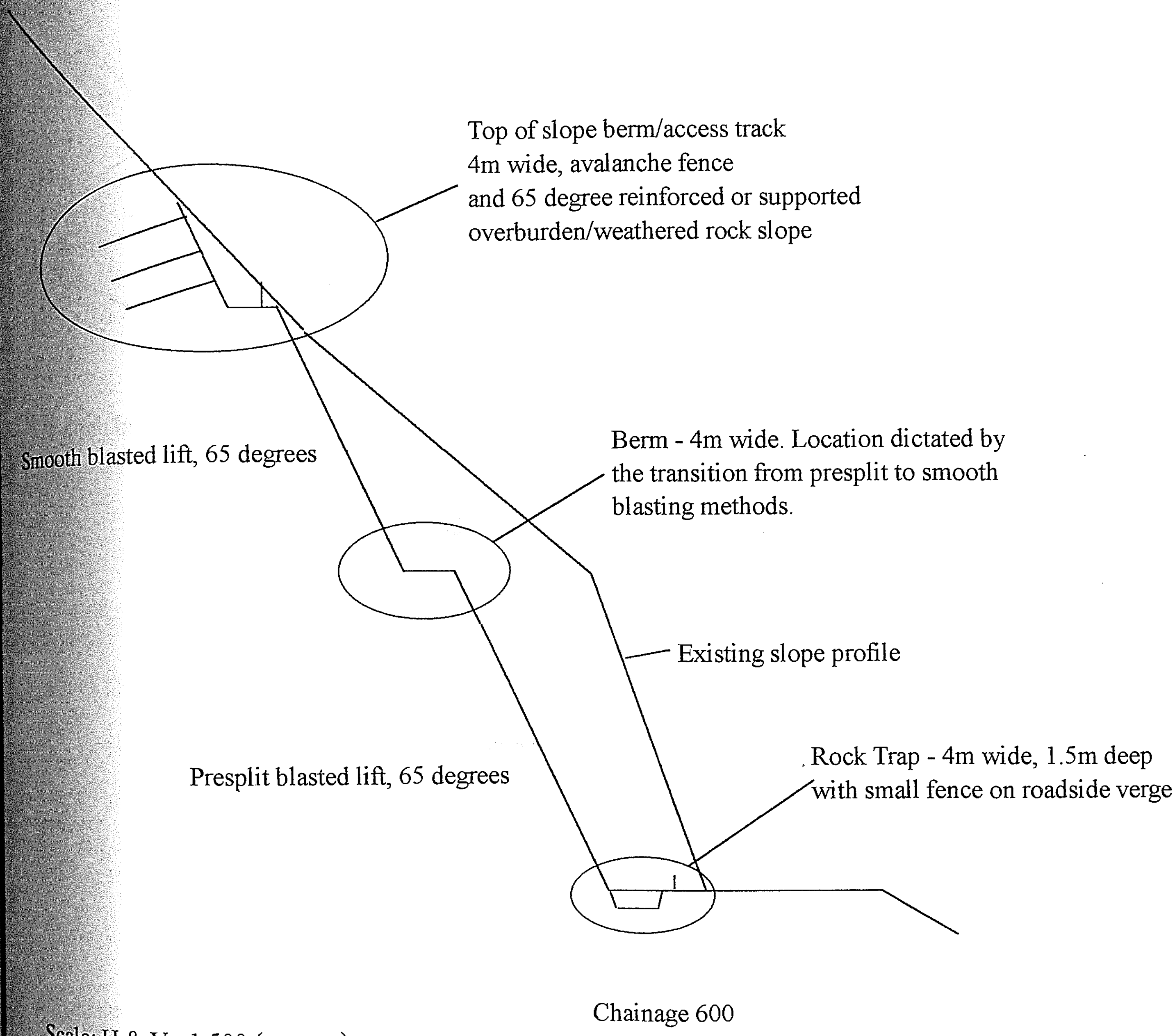
Job Title; A890 Road Improvement	Fig. No.	Date
Section; Typical Section West of Avalanche Shelter	5	Nov. 1993



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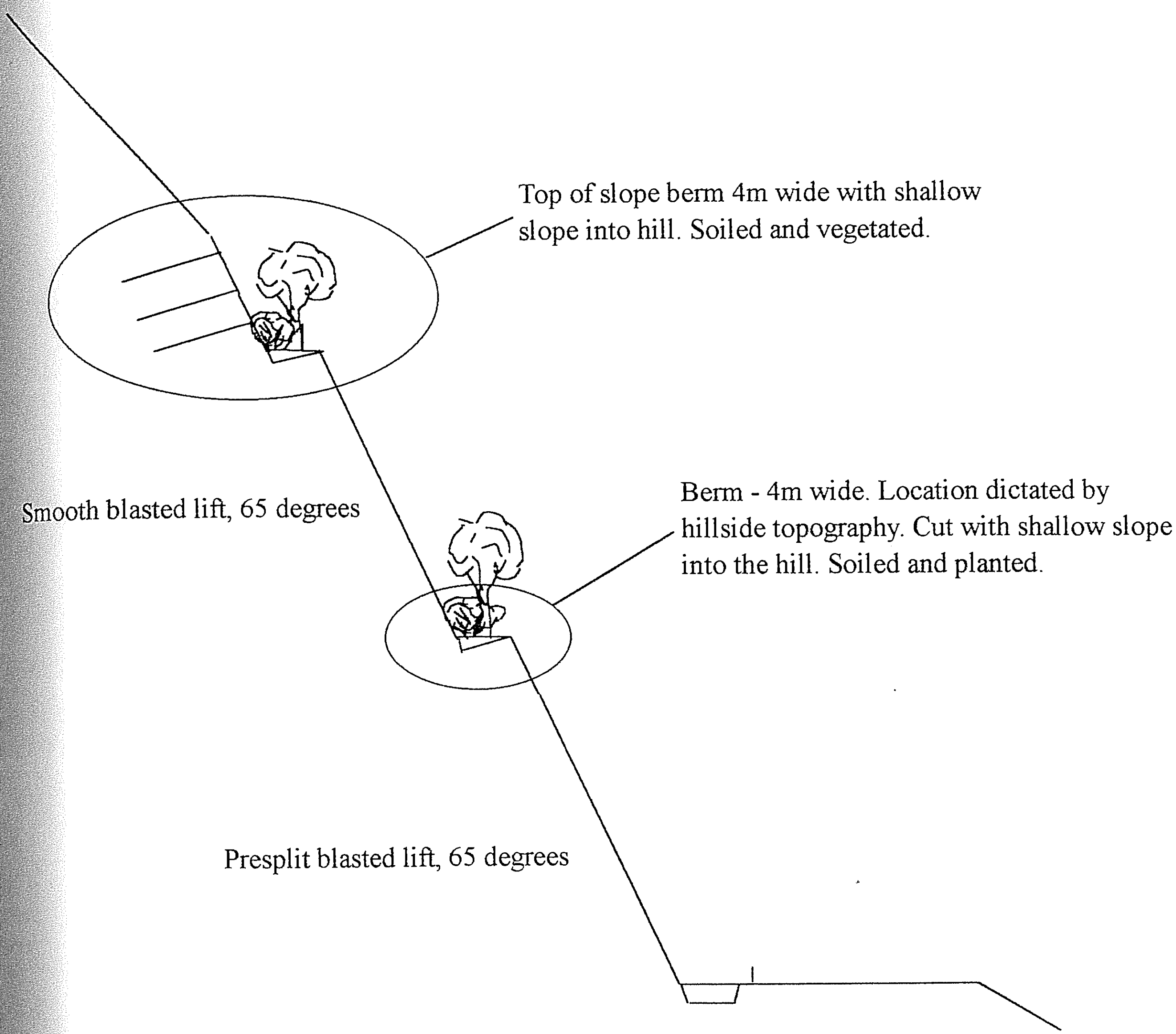
Job Title; A890 Road Improvement	Fig. No.	Date
Section; Section Showing Environmental Measures	6	Nov. 1993



Chainage 600

Scale: H & V - 1:500 (approx.)

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A890 STROMEFERRY BYPASS ROAD IMPROVEMENT
FEASIBILITY OF WIDENING THE EXISTING ROAD ALIGNMENT

APPENDIX 1

DISCONTINUITY DATA

A890 DOMAIN 1 DISCONTINUITY DATA

Type	Dip	Azimuth	Trace Length
JO	70	311	0.5
JO	68	297	1.0
JO	86	211	0.3
JO	71	307	0.2
JO	82	236	1.0
JO	76	302	0.3
JO	76	300	0.4
JO	76	299	0.2
JO	70	301	1.3
JO	75	294	1.0
FO	26	104	0.2
JO	76	283	0.3
JO	70	219	0.3
JO	89	207	0.3
JO	84	202	1.5
JO	84	318	1.0
JO	66	303	0.4
FO	44	085	1.5
JO	67	303	0.5
JO	76	317	0.4
JO	64	301	0.2
JO	84	195	0.2
FO	48	074	0.2
JO	69	204	1.0
JO	89	194	2.1
JO	72	304	4.0
JO	64	296	1.0
JO	75	298	6.5
JO	77	293	3.0
JO	78	304	1.0
JO	69	179	0.5
JO	62	194	0.4
JO	77	303	1.6
FO	30	073	0.2
JO	75	294	1.7
JO	64	300	1.6
JO	75	238	2.0
FO	51	108	2.0
FO	46	087	1.5
JO	64	306	3.5
JO	70	311	2.0

A890 DOMAIN 1 DISCONTINUITY DATA (continued)

Type	Dip	Azimuth	Trace Length
JO	73	306	0.2
JO	75	193	2.5
JO	73	205	1.0
JO	84	190	1.0
JO	46	340	4.0
JO	78	303	3.0
JO	70	186	4.0
JO	78	297	3.5
JO	84	201	1.5
JO	77	300	2.1
FO	16	018	0.3
JO	86	194	6.5
FO	42	081	1.5
JO	86	294	3.0
FO	50	058	1.0
JO	78	184	3.5
FO	43	074	0.2
JO	81	205	4.0
JO	65	291	1.5
JO	85	287	2.0
JO	44	285	2.5
FO	39	049	0.3
JO	75	295	3.0
JO	70	196	1.0
JO	69	300	4.5
JO	77	220	1.5
JO	62	308	4.0
JO	59	297	4.5
FO	58	065	1.5
JO	71	296	3.0
JO	53	175	1.0
JO	74	066	0.3
JO	70	297	1.4
JO	63	181	1.0
JO	79	300	3.0

A890 DOMAIN 2 DISCONTINUITY DATA

Type	Dip	Azimuth	Trace Length
JO	51	084	1.0
JO	72	126	1.0
FO	14	134	1.0
JO	60	085	1.2
JO	66	084	2.2
JO	59	073	1.0
JO	46	076	1.0
JO	56	074	0.3
JO	89	160	2.0
JO	89	156	0.4
JO	68	013	4.5
JO	60	079	3.0
JO	68	019	1.5
JO	73	081	3.5
FO	21	121	0.2
JO	71	085	1.0
JO	68	082	0.3
JO	71	331	1.2
JO	78	198	1.9
JO	64	023	2.0
JO	89	104	1.5
JO	60	035	3.5
JO	74	193	2.3
JO	88	284	2.0
JO	64	024	3.5
JO	66	306	1.4
JO	63	314	1.5
JO	86	065	1.0
JO	77	293	1.0
JO	74	190	0.5
JO	73	304	1.0
JO	82	224	1.5
JO	76	230	1.0
JO	80	313	1.0
JO	76	225	0.4
JO	66	065	1.1
JO	66	298	0.4
FA	65	306	1.6
JO	70	071	14.5
JO	65	064	3.5
JO	65	295	0.3
JO	71	066	0.5
JO	66	178	1.5

A890 DOMAIN 3 DISCONTINUITY DATA

Type	Dip	Azimuth	Trace Length
JO	88	111	1.0
JO	33	010	1.0
JO	65	290	0.5
JO	64	278	1.1
JO	66	296	3.5
FO	18	177	0.2
FO	21	106	0.1
JO	50	312	1.0
JO	56	025	0.3
FO	39	171	0.9
FO	34	169	1.5
JO	37	318	0.2
JO	58	311	0.3
JO	50	175	0.6
JO	56	296	3.0
JO	68	186	1.5
JO	51	273	2.0
JO	90	023	2.0
JO	48	298	1.1
JO	54	195	1.2
JO	62	284	0.1
JO	62	294	0.1
JO	42	320	1.5
JO	76	178	0.5
JO	71	300	1.0
JO	68	286	1.4
JO	83	314	0.3
JO	64	324	0.3
JO	88	033	0.2
FO	47	136	1.5
JO	66	323	1.2
JO	62	298	2.5
FO	30	128	4.0
JO	63	302	0.4
JO	68	238	1.6
JO	28	131	1.0
JO	87	281	1.0
JO	84	218	1.5
JO	49	316	1.0
JO	80	285	3.0

A890 DOMAIN 3 DISCONTINUITY DATA (continued)

Type	Dip	Azimuth	Trace Length
JO	73	016	1.5
FO	33	147	1.6
JO	79	291	1.6
JO	64	021	3.5
JO	86	293	2.0
FO	41	133	0.4
JO	76	288	1.0
JO	84	295	2.0
JO	70	017	1.5
FO	19	107	2.5
JO	77	306	1.0
JO	78	303	0.7
JO	67	013	0.4
JO	56	017	0.2
JO	67	011	0.2
FO	45	164	1.5
JO	66	298	0.4
JO	78	303	1.5
JO	66	028	0.3
JO	59	300	0.2
JO	59	040	1.0
JO	65	288	1.0
JO	81	280	0.5
FO	46	166	1.0
FO	34	164	1.5
FO	52	180	1.0
JO	71	290	2.5
FO	26	146	0.5
JO	86	266	0.2
FO	36	170	1.0
JO	78	285	3.0
JO	76	218	2.0
JO	74	317	0.2
JO	59	180	1.5
JO	78	190	4.0
JO	74	223	8.5
JO	81	194	2.5
JO	86	121	1.0
JO	79	121	2.5
FO	16	124	1.6
JO	75	120	1.5

A890 DOMAIN 3 DISCONTINUITY DATA (continued)

Type	Dip	Azimuth	Trace Length
JO	85	264	0.6
JO	86	290	1.7
JO	66	327	1.7
JO	76	140	1.0
JO	89	208	0.2
JO	83	214	0.6
JO	54	352	3.0
JO	85	022	2.0
JO	86	024	2.5
JO	79	093	1.0
JO	89	119	2.0
FO	22	137	2.0
JO	73	091	1.5
JO	73	227	0.3
JO	72	020	1.0
JO	82	285	1.5
JO	79	006	1.2
FO	34	156	0.6
JO	61	356	1.2
JO	89	117	0.4
JO	46	289	2.5
JO	81	291	1.9
JO	89	030	0.4
JO	85	285	1.4
JO	65	272	1.1
JO	88	296	1.5
JO	64	186	1.8
JO	59	294	2.5
JO	83	103	1.0
JO	75	308	1.4
JO	71	081	1.0
FO	24	140	2.0
JO	78	313	3.5
FO	27	144	4.5
JO	85	249	0.3
JO	53	308	2.0
JO	73	098	6.0
JO	65	026	4.0
JO	84	291	2.5
JO	59	358	0.4

A890 DOMAIN 3 DISCONTINUITY DATA (continued)

Type	Dip	Azimuth	Trace Length
JO	58	008	1.4
JO	79	178	2.0
JO	56	355	3.5
FO	19	120	0.6
JO	82	296	2.5
JO	88	110	2.2
JO	87	113	0.4
JO	83	285	1.6
JO	57	149	0.1
JO	87	065	2.1
JO	87	298	1.2
JO	68	191	0.7
JO	70	293	5.0
JO	88	204	3.1
JO	74	022	3.5
JO	58	138	0.6
JO	76	303	1.1
FO	31	073	1.0
JO	89	118	1.0
JO	80	212	7.0
JO	79	304	1.0
JO	50	161	1.0
JO	88	155	2.0
FO	47	110	0.4
JO	40	226	0.5
JO	65	106	0.7
JO	67	108	0.8
JO	76	146	1.7
JO	84	054	2.0
JO	88	245	1.7
JO	80	231	3.5
FO	35	103	1.0
JO	90	275	1.5
JO	53	304	3.0
JO	86	017	0.4
JO	81	304	1.5
JO	73	037	0.4
JO	51	284	0.6
FO	28	101	0.1
JO	84	122	3.5

A890 DOMAIN 3 DISCONTINUITY DATA (continued)

Type	Dip	Azimuth	Trace Length
JO	51	309	0.6
JO	88	291	1.0
JO	74	127	1.6
JO	74	024	1.0
JO	68	039	11.0
JO	78	029	2.5
JO	51	304	1.5
JO	74	026	2.5
FO	22	115	2.5
JO	68	296	0.4
JO	56	303	1.2
JO	57	310	2.5
JO	69	043	2.0
FO	25	125	1.2
JO	49	299	0.7
JO	77	298	2.0
FO	19	115	1.7
JO	72	022	1.0
JO	43	298	0.3
JO	80	296	1.0
JO	74	024	1.7
FO	19	112	1.2
JO	54	302	2.5
FO	26	123	0.4
JO	84	116	7.5
JO	63	037	1.0
JO	78	110	2.5
JO	84	024	1.1
JO	85	306	1.4
JO	79	028	1.0
FO	24	093	2.0
JO	80	196	1.7
JO	59	291	1.4
JO	49	298	2.0
JO	80	286	1.0
JO	75	296	2.5
FO	64	179	1.6
JO	77	024	1.4
FO	77	024	0.2
JO	66	290	1.0
FO	73	031	0.3

A890 DOMAIN 3 DISCONTINUITY DATA (continued)

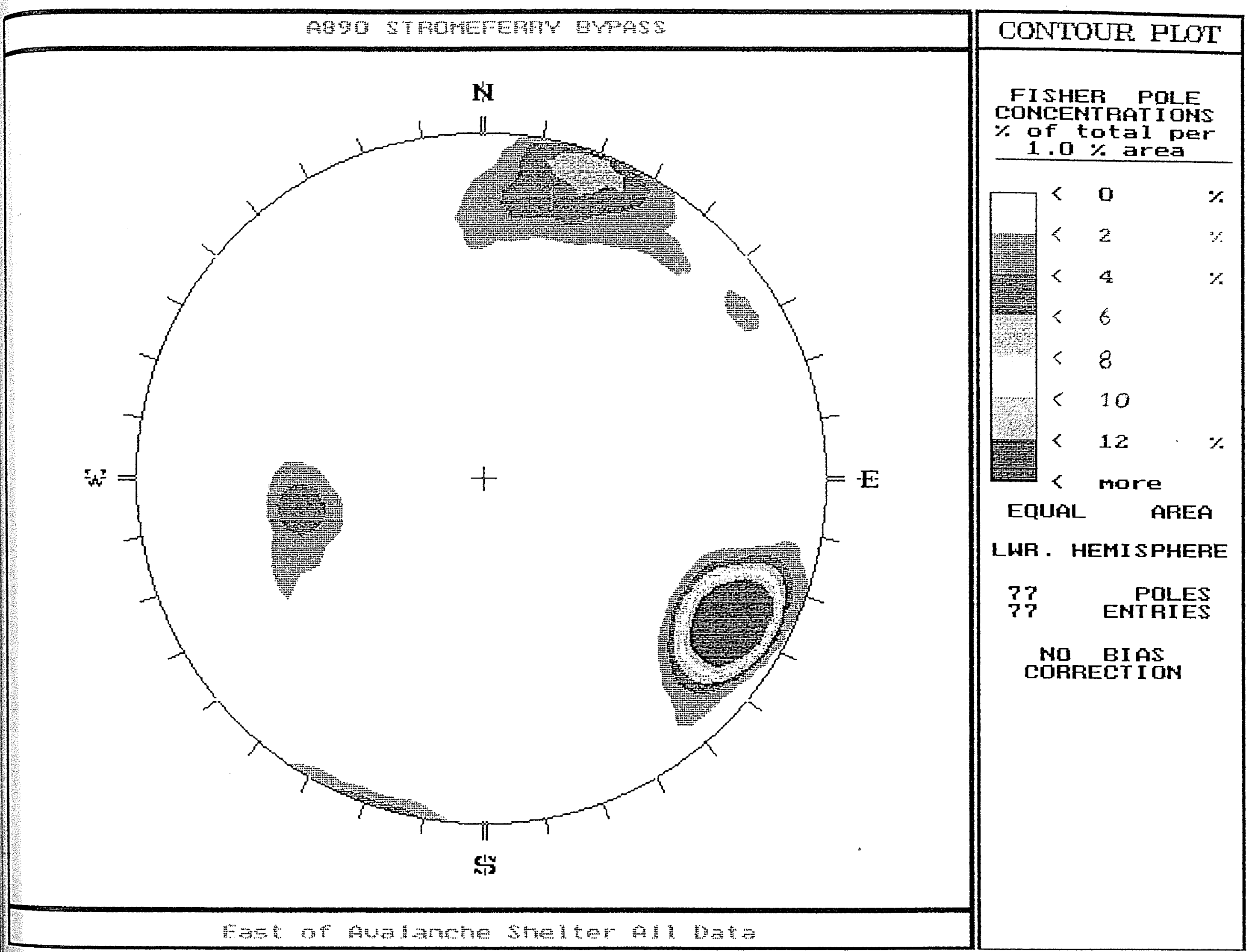
Type	Dip	Azimuth	Trace Length
JO	54	289	0.2
JO	70	300	2.5
JO	66	093	1.4
JO	79	015	1.6
JO	73	122	1.9
JO	79	103	0.2
FO	46	172	1.2
JO	80	116	1.5
JO	60	303	0.5
JO	88	176	1.0
JO	69	282	0.3
FO	24	087	0.7
JO	86	178	1.0
JO	66	299	0.8
JO	49	279	0.7
JO	81	223	0.4
JO	86	222	0.4
JO	59	197	1.0
JO	82	123	0.6
JO	39	289	0.4

A890 STROMEFERRY BYPASS ROAD IMPROVEMENT
FEASIBILITY OF WIDENING THE EXISTING ROAD ALIGNMENT

APPENDIX 2

STEREOGRAPHIC PROJECTIONS

Job Title; A890 Road Improvement	Fig. No.	Date
Section; Domain 1 Contoured Discontinuity Plot	A2.1	Nov. 1993



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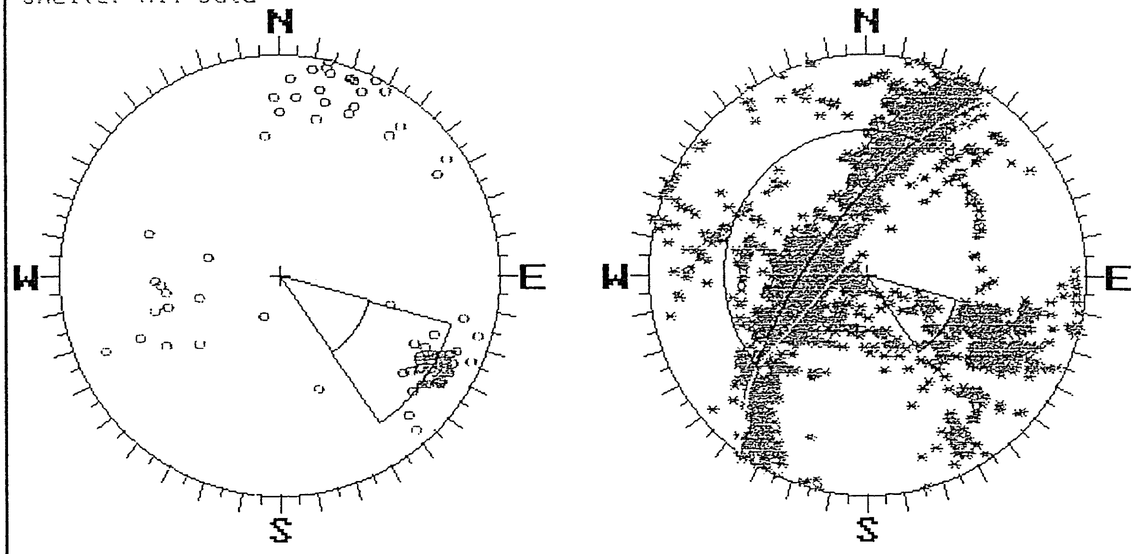
Job Title; A890 Road Improvement	Fig. No.	Date
Section; Domain 1 Slope Geometry Evaluation Plots	A2.2	Nov. 1993

TRRL - Rock Stability Assessment

A890 Gully East of Avalanche
Shelter All Data

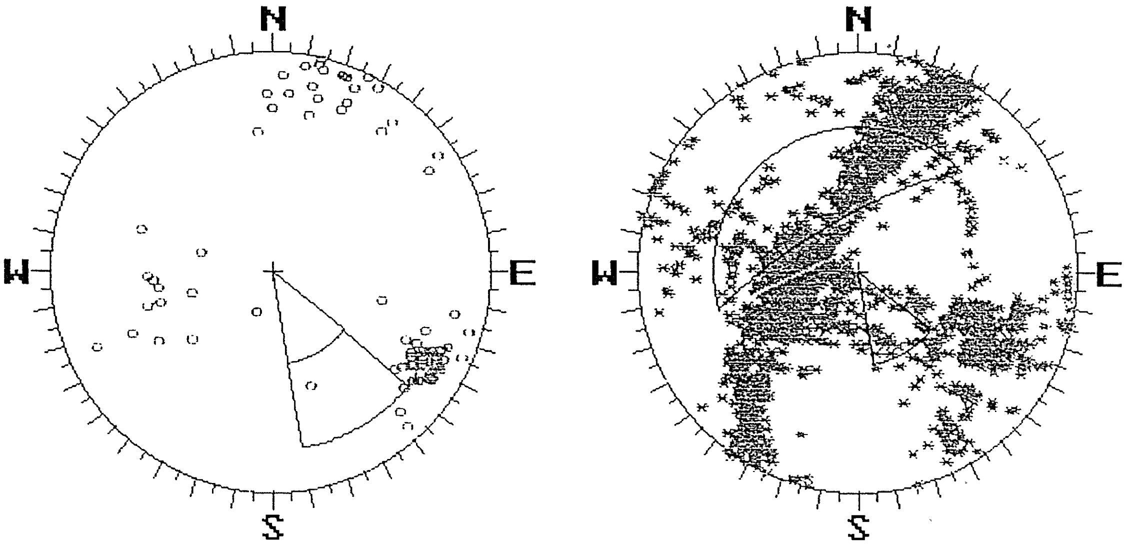


Poles (76) Intersections (2848)
24 11 1993

			Unweighted	Weighted (0)
Design Azimuth : 306	Plane	:	15/76	15/76
Design Dip : 70	Wedge	:	545/2848	545/2848
Bulk Friction : 35	Toppling	:	0/216448	0/216448

TRRL - Rock Stability Assessment

A890 Gully East of Avalanche
Shelter All Data



Poles (76) Intersections (2848)
24 11 1993

			Unweighted	Weighted (0)
Design Azimuth : 330	Plane	:	3/76	3/76
Design Dip : 70	Wedge	:	454/2848	454/2848
Bulk Friction : 35	Toppling	:	0/216448	0/216448

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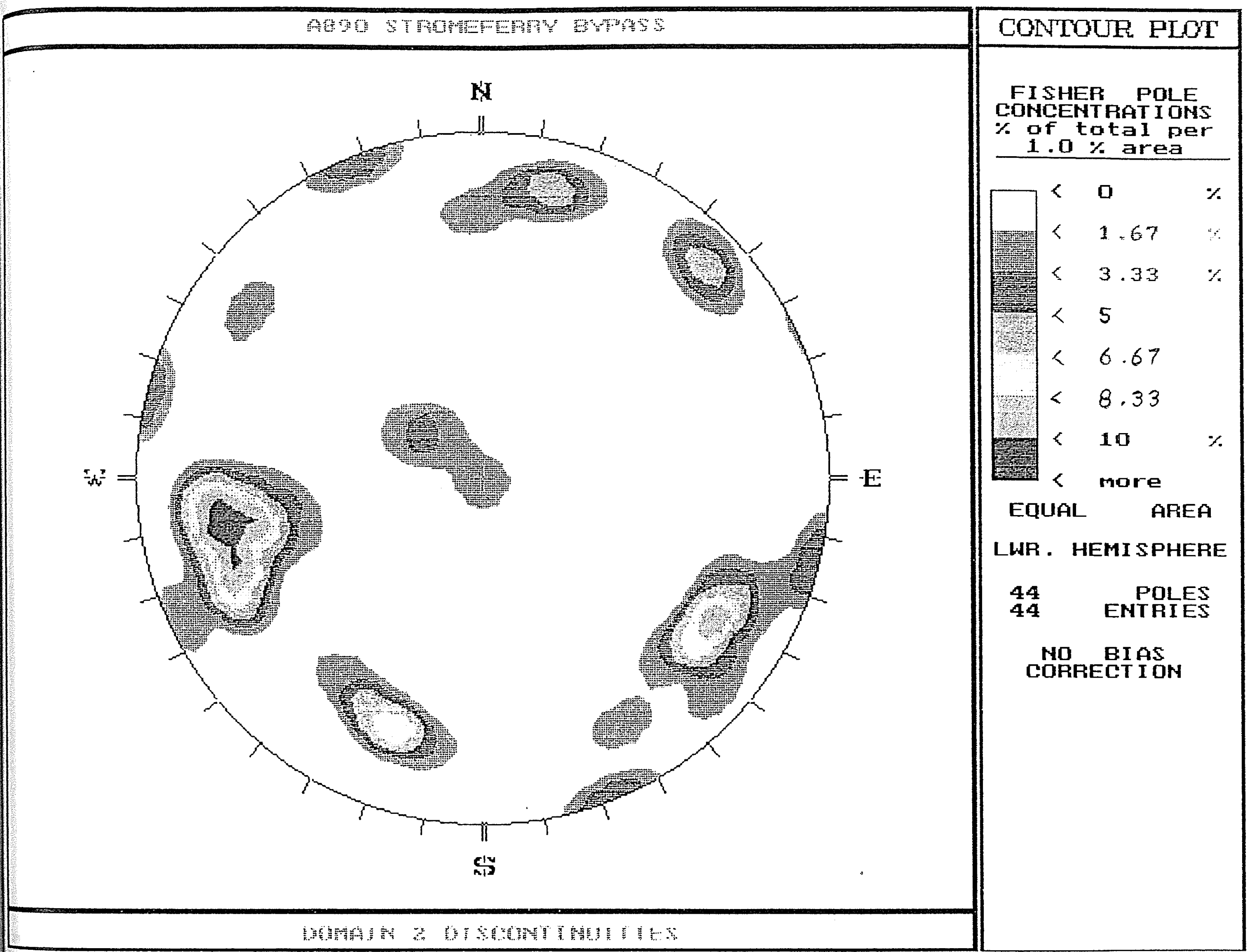
Job Title; A890 Road Improvement	Fig. No.	Date
Section; Domain 2 Contoured Discontinuity Plot	A2.3	Nov. 1993



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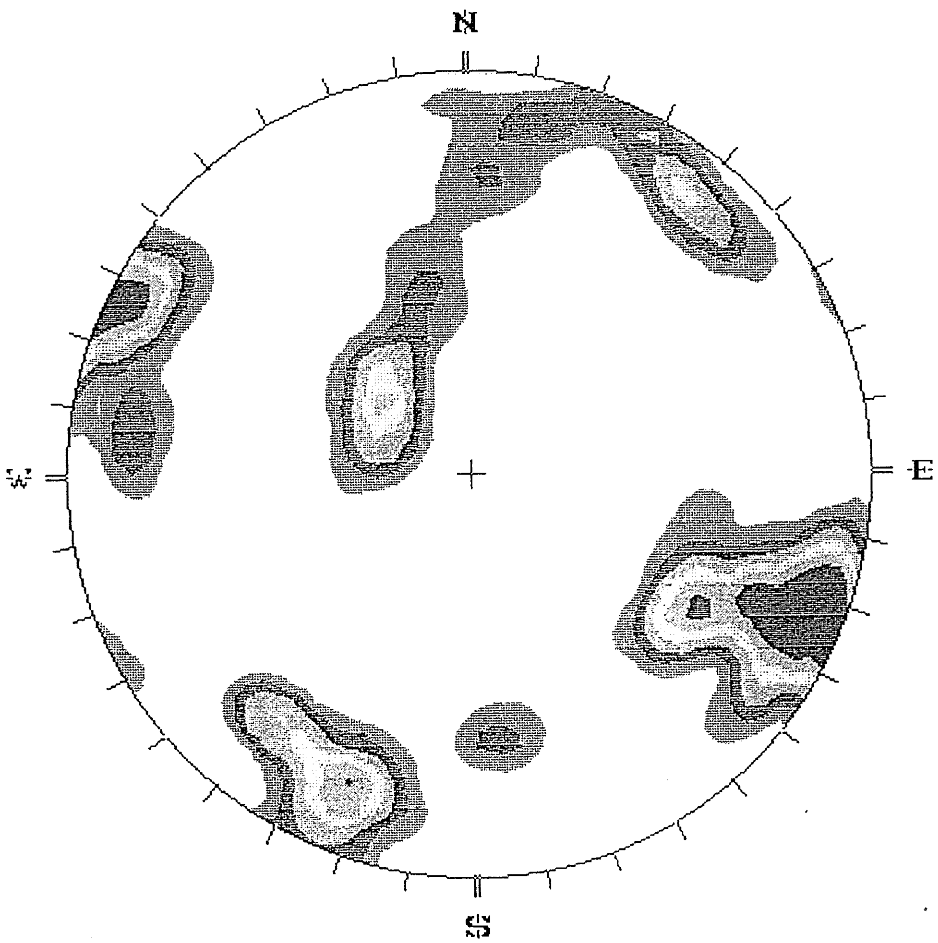
Job Title; A890 Road Improvement	Fig. No.	Date
Section; Domain 3 Contoured Discontinuity Plot	A2.4	Nov. 1993

A890 STROMEFERRY BYPASS



WEST OF SHELTER ALL DATA

CONTOUR PLOT

FISHER POLE CONCENTRATIONS
% of total per
1.0 % area

< 0	%
< 1	%
< 2	%
< 3	
< 4	
< 5	
< 6	%
< more	

EQUAL AREA

LWR. HEMISPHERE

357 POLES
222 ENTRIES

NO BIAS CORRECTION

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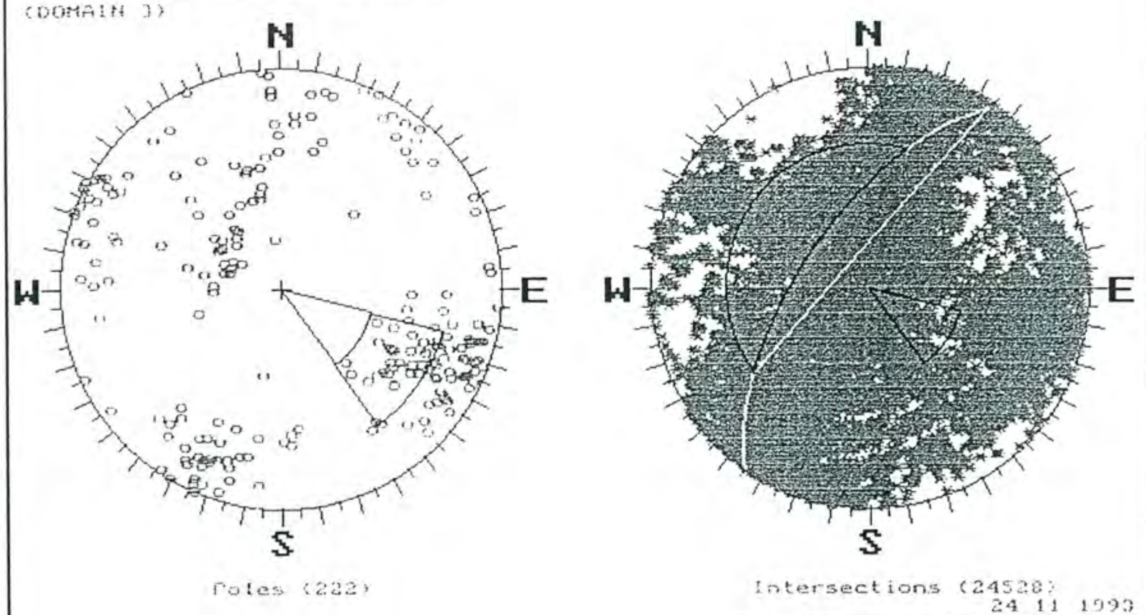
Job Title; A890 Road Improvement	Fig. No.	Date
Section; Domain 3 Slope Geometry Evaluation Plots	A2.5	Nov. 1993

TRRL - Rock Stability Assessment

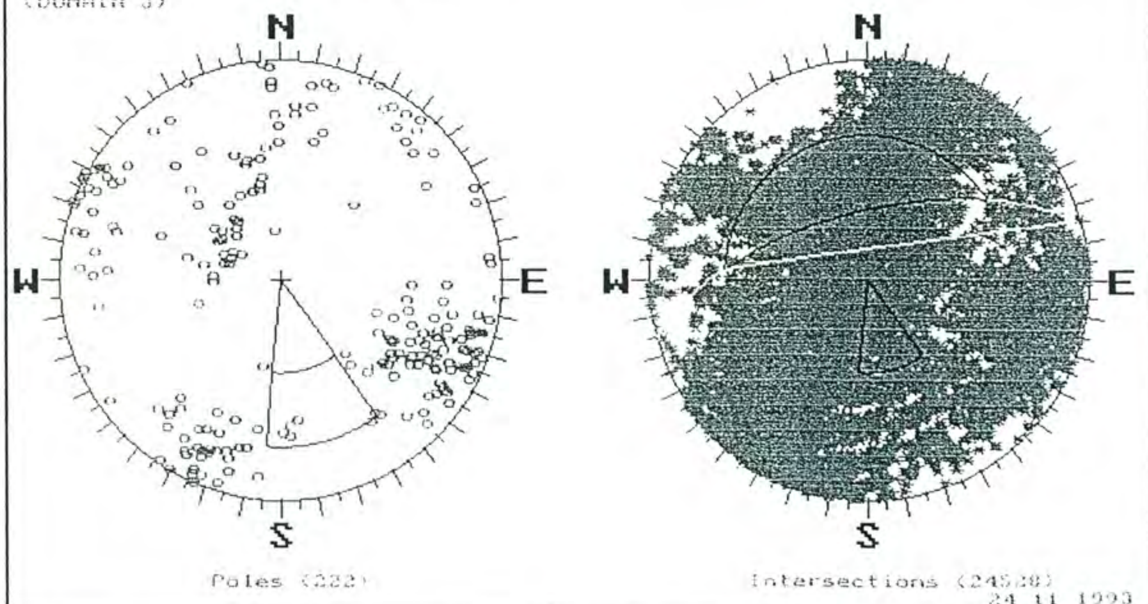
A890 WEST OF SHELTER ALL DATA
(DOMAIN 3)



Design Azimuth :305		Unweighted	Weighted (0)
Design Dip :65	Plane :	30/222	30/222
Bulk Friction :35	Wedge :	3830/24528	3830/24528
	Toppling :	0/5445216	0/5445216

TRRL - Rock Stability Assessment

A890 WEST OF SHELTER ALL DATA
(DOMAIN 3)



Design Azimuth :345		Unweighted	Weighted (0)
Design Dip :65	Plane :	4/222	4/222
Bulk Friction :35	Wedge :	4008/24528	4008/24528
	Toppling :	0/5445216	0/5445216

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