GEOTECHNICAL STUDY AREA G10

AFTON DOWN, NEAR FRESHWATER, ISLE OF WIGHT, UK

Plate G10 ***High aerial view of Afton Down, Isle of Wight***

1. INTRODUCTION

The A3055 Military Road runs along the south-west coast of the Isle of Wight and forms an important communications and tourism route as part of the main road which runs around the whole of the Isle of Wight coastline. The section of road between Brook and Freshwater offers the most spectacular views of chalk clifflines to be found within the United Kingdom and forms the highlight of a "round the Island tour" for Island visitors and residents (Plate G10 and Figure G10.1). The Military Road was constructed in about 1860 to supply coastal garrisons and consisted at that time of only a narrow unmade track. In the 1930s the road was adopted by the Isle of Wight County Council and upgraded by widening, surfacing and realignment of certain sections which were threatened by cliff erosion. Since that time the road has continued to be at risk from coastal instability and cliff retreat and in several locations the road has been realigned landwards as a consequence of coastal erosion.

Since the 1970s particular sections of the Military Road have been under threat of coastal instability as a result of marine erosion at the base of the unprotected cliff which leads to cliff failure and clifftop recession. Four high risk areas were identified as part of a previous study and one of these areas has become increasingly at risk since that time (Plate G10a).

The location of concern is sited approximately 1.5km east of Freshwater Bay at Afton Down. It comprises a steep chalk cliff approximately 70m in elevation above sea-level. The Military Road is located along the top of the cliff at distances between 10 and 45m from the present cliff edge over the critical section. The slopes forming the top of the cliff are traversed by a series of fissures which are, typically in the order of 20 to 40m in length, observable depths of up to 4m and up to 5m in width at the ground surface. The fissures were also observed beneath the road during closure and repair to the carriageway undertaken by the Isle of Wight County Council in 1980/81.

In 1996 the Council initiated the study to identify the nature of the problems affecting the Military Road at this site and to develop a ground model for the area as well as to identify engineering options with broad cost estimates for improving the stability of the road in the short, medium and long term along the existing alignment and to consider safety implications.

2. THE IMPACT OF INSTABILITY - THE PROBLEM

The length of A3055 Military Road between Brook and Freshwater forms the most spectacular part of the round the Island route. The Military Road improvement was an ambitious construction project for the Isle of Wight County Council when a south coast marine drive was created in the 1930s following the transfer of the highway to the Local Authority. Quite apart from the value of the road as a communications link between some of the Island's major tourist attractions, towns and villages along the southern coast of the Island and Freshwater Bay and Alum Bay, it forms a vital part of the round the Island coach traffic route (Plates G10b and G10c).

A total of 2.5 million visitors came on holiday to the Isle of Wight in 1996 and it is believed that almost all visitors take the opportunity to explore the West Wight and this scenic route in particular by car or coach. It is also recognised that a significant proportion of both visitors and Island residents are elderly with limited mobility and their only opportunity to enjoy the spectacular scenery of the coastline is by motor vehicle and particularly by bus and coach. If the A3055 Military Road was severed as a result of instability problems and erosion, it is accepted that there would be access available for more active people, particularly those who enjoy walking and cycling. However, a significant proportion of residents and visitor would no longer be able to enjoy this great scenic route but instead would be diverted onto a less attractive inland road to Freshwater away from the coastline. It is the policy of the Council to encourage access, enjoyment and understanding of this spectacular coast and the road network plays a fundamental role in fulfilling this objective.

Tourism is the mainstay of the economy of the Isle of Wight, generating income and employment for the area which already suffers from the highest unemployment in the south-east of England. The loss of the Military Road would be a devastating blow to the local economy, both in terms of the Island's image as an accessible tourist attraction for all ages and for those with physical disabilities.

In 1996 the Council's consultants were commissioned to undertake a detailed study of the Afton Down section of the A3055 with the aim of:

1. Carrying out detailed mapping of the joint lines, discontinuities, tension gashes and cliff profiles to derive detailed information in order to carry out a stability analysis.
2. Reviewing and analysis the existing Council data from instrumentation that was installed in 1980 and planning the improvement of geotechnical instrumentation.
3. Carrying out and interpreting the results of a ground radar survey in particular in relation to any possible tension cracks found beneath the carriageway, and the safety and stability implications of their presence.
4. Developing a ground movement model identifying the mechanisms of material loss.
5. To identify options for stability works with the aim of preserving the carriageway on its existing alignment for the next 40-60 years.

In the development of a long term solution for this section of carriageway, it is clear that relocation of the road inland is not an option based on environmental grounds; in any case, coastal erosion at the toe of the cliff will continue since coast protection measures would be inappropriate also on environmental grounds. Furthermore, any form of coast protection works would be contrary to recommendations developed by the Isle of Wight Council and its partners in its Shoreline Management Plan (Halcrow 1997) which states that the preferred coastal defence policy option is "no action" for the south-west coast of the Isle of Wight, principally for environmental reasons.

Government funding has been approved for a £2m stabilization project for the most vulnerable section of the A3055 Military Road over Afton Down and will comprise civil engineering works that provide continuous protection in the inevitable event of future cliff recession and will consist of an anchored contiguous borepiled wall supporting a reinforced concrete deck for the carriageway. The piles conceptually will be sunk 27.5m into the Chalk beneath the centre line of the existing road over a length of 2-300m. The piles would be linked to the reinforced concrete road-deck and provision made for ground anchors into the stable hillside on the landward side of the road. The bedding orientation in the area of the anchors is low and favourable and a preliminary scheme concept is attached as Figure G10.3.

The benefits of a scheme of this kind is that the natural processes of cliff recession can continue to take place due to coastal erosion but the construction will remain unaffected. As the cliffline recedes in the longer term to approach the carriageway, a protective road edge barrier would be provided adjacent to the carriageway edge at this location. Furthermore, natural erosion could take place beneath the reinforced concrete carriageway deck itself until the face of the borepiled wall is reached. This would halt erosion over a fairly limited length of the road for a further period of 30-40 years, giving an overall life for the structure of approximately 60 years.

3. THE ROLE OF KEY AGENCIES

The key agencies involved at the Isle of Wight Council as Coast Protection Authority, Planning Authority and Highway Authority, English Nature as the Government's nature conservation advisors.

The south-west coast of the Isle of Wight is an area of Outstanding Natural Beauty and has been designated as Heritage Coast. In addition, the coastline in the vicinity of the Military Road between Brook and Freshwater has been designated as a Site of Special Scientific Interest and the foreshore is now designated also as a Special Area of Conservation under European Habitats Directive. As a result, the Isle of Wight Council is working closely with English Nature in developing the design for this scheme in order to ensure that the civil engineering works will have no impact on the environmental quality of the area.

Clearly the Isle of Wight Council has an important role to play in considering the planning application for this site and also in its role as Highway Authority in terms of maintaining and improving where necessary the Isle of Wight highway network. The Council is also responsible for the safety of road users and for this reason has provided an improved cliff stability monitoring system following a more detailed appraisal of cliff-face stability and the nature of ground movements between the seaward edge of the carriageway and the cliff itself.

4. THE STUDY AREA

4.1 Geology and Geomorphology

The site lies on the southern flank of an elongated, steep-sided ridge forming Afton Down and Compton Down. The ridge trends approximately east-west and is associated with the geological folding which extends across the whole of the Isle of Wight. The ridge rises to a maximum height of 150m OD at Compton Down to the north-east of the site and to an elevation of 125m OD directly to the north of the site at East Afton Down.

Within the study area the height of the seacliffs range from 56-72m above sea-level. To the west and east the elevation of the seacliff decreases from a central high point. The ground rises inland in a northerly direction to a maximum elevation of approximately 87m OD on the north side of the Military Road cutting.

The steep coastal cliffs are inclined at approximately 60-72° in the upper 10m and decrease in inclination to an average of 47-49° on the main face. Where talus is formed at the base of a cliff, it is generally at slopes of 32°. The beach comprises exposed rock ledges overlain by a superficial cover of large boulders and cobbles derived from marine erosion of the cliff-face and rockfalls from higher elevations of the cliff.

The geological map of the Isle of Wight published by the Geological Survey of Great Britain and the Associated Memoir indicate that the soil geology of the south-west of the Isle of Wight comprises a completes sequence of Upper and Lower Cretaceous strata. Progressively younger strata become exposed on the coast between Brighstone Bay westwards towards The Needles and include the Wealden Beds, Lower Greensand, Gault, Upper Greensands and Lower, Middle and Upper Chalk.

The strata are folded by two major, nearly-coincident folds known as the Sandown and Brighstone anticlines. The anticlines are asymetric with steep northern limbs and gentle southern limbs and are monoclinal in form. The site is located on the northern limb of the Brighstone anticline, the axis of which trends east-west and west-north-west to east-south-east and causes the beds in the coastal section to dip steeply to the north at 330^0 / 40^0 (dip direction / dip). Four sets of joints, comprising an orthogonal and conjugate pair, were recorded at the site.

Within the study area the geology comprises Lower Chalk, which is exposed in the lower section of the coastal cliff down to beach level. This is overlain by Middle Chalk with marl seams and Upper Chalk at the top of the cliff. The solid geology is overlain by a layer of weathered Chalk (0.5-7m thick) and an irregular cover of chalky head of Pleistocene periglacial origin (0.5-2m thick). A description of the lithology of the full stratigraphic sequence is presented in Figure G10.2 and Figure G10.4 shows the general cross-section of the cliff.

Surface drainage features are evident to the north of the Afton Down and Compton Down ridge and comprise small streams and drainage ditches which drain northwards. The only features which drain to the south are two small streams located in Freshwater Bay to the west of the site and to the east at Compton Chine. No surface drainage features or seepages within the cliff face were observed within the study area. In view of the high relative permeability of the chalk sequence it is anticipated that groundwater levels would be well below ground level and possibly approaching sea-level.

4.2 Instability Mechanisms

There are two modes of failure in the Afton Down cliffs, one of which is specific to the layer of soil mass at the top of the cliff and the other to the rock mass comprising the bulk of the cliff (Figure G10.5). The soil mass layer is composed of a solifluction layer and weathered Chalk, whilst the rock mass comprises blocky Chalk. The geology is specific to the site and changes beyond both the east and western boundaries.

In addition to the site's specific geology the inclination of discontinuity plays a critical role in the nature of cliff stability. In the Lower and Middle Chalk the bedding is relatively shallow so that the joints tend to be steep and parallel to the cliff profile. However, in the lower part of the Upper Chalk, which dominates the upper cliff, the bedding is steep so that the joints are shallow and tend to daylight. In the mid part of the Upper Chalk (which is only exposed in the cliff to the west of the site) and in the soil mass layer, the bedding returns to a very shallow angle. Sections drawn through this part of the cliff illustrate the general mechanisms of failure in the soil mass layer. It is envisaged that translation of the soil mass is induced in the soil mass layer due to the presence of low angled daylighting joints, predominantly of orthogonal orientation in the lower part of the Upper Chalk. The area within which the fissures occur corresponds with the presence of the lower part of the Upper Chalk in the upper section of the cliff.

The upper part of the Upper Chalk is described as white, rough, nodular chalk with flints and a few marl seams. Owing to the diagonal trend of bedding across the cliff face, this stratigraphy produces a layer of weathered chalk which increases in thickness as it crosses the site. This soil-like Chalk layer is overlain by solifluction material and together they form a vertical cliff top along part of the frontage in response to the joint-induced translational movements. Once translation begins, the movements become more complex and may follow one of two possible mechanisms to arrive at the present day cliff top topography.

The first scenario involves the greater movement of the two cases. Here, translation of the soil mass coincides with rock mass failure and the resulting undercutting leads to a toppling failure. Fissuring allows toppling blocks of soil mass to form, which produces a steepened clifftop profile near the cliff edge. The ground space remaining upslope may allow limited circular failure to occur so that flat or back tilted plateau areas are formed along with a lesser series of fissures.
A second scenario involves undercutting of the soil mass by failure of the rock mass and is not as significant as outlined above with the amount of movement being more limited. This allows limited circular failures to occur in the translational soil mass. Eventually erosion produces a narrow column at the cliff edge, which then fails by toppling.

It has long been recognised that undercutting by the action of marine erosion is an important mechanism in cliff recession. At the Afton Down site two significantly different sub-mechanisms of undercutting are recognised, dependant on the joint spacing. Where the spacing is relatively wide (greater than 0.8m) the sea erodes material to form pillars of rock which eventually collapse in a single event. Where the jointing is very closely spaced (0.02-0.1m) pillars do not form and the cliff is uniformly undercut as a progressive process.

In the upper part of the cliff, the role of discontinuities in progressive recession is further complicated by the existence of a mechanism termed ‘hinged rock mass failure’. Along part of the frontage three convex shaped post-failure areas have been recognised. The failure process in each of these areas has involved an overall planar slippage on one side of the ‘cirque’ which has been hinged in rock mass on the other side. In other words, a dominant joint set has allowed failure to initiate, but then in order to proceed further, failure through intact rock has been induced. The resulting cliff failure is characterised by one side of each ‘cirque’ being a relatively smooth and discrete joint surface while the hinged side is irregular and very blocky.

5. MONITORING

Following an investigation of instability problems on the Military Road at Afton Down in December 1980, a fully automatic monitoring system, employing a series of five tiltmeters, was commissioned in May 1981 to provide early warning of landslide movements in the fissured area of cliff top at Afton Down. The decision to install the system followed the discovery of open fissures in the road pavement of the A3055 and whilst the overall rates of cliff recession since 1861 can be calculated to have been slow (at 0.05m per year), and the failures have usually involved only the fissures nearest to the cliff edge, the view was taken that further recession could take the form of a catastrophic cliff edge failure resulting in serious deformation of the road, or indeed its loss.

Each tiltmeter sensing station in the original early warning system consisted of an electro-level earth tilt unit with an associated signal conditioning unit. These were connected to a central controller, the system being powered by mains supply. In the event of the tilt at any station exceeding pre-set ‘inner limits’ an automatic telephone alarm was activated at the Newport Police Headquarters and a taped message played. If the tilt continued to increase and the pre-set ‘outer limits’ were exceeded then ‘road closed’ signs were illuminated at either end of the Afton Down cliff section of the A3055.

When the alarm was activated the Police usually contacted the Isle of Wight Council’s Highways Inspector under normal emergency highway procedures. The Inspector would visit the Military Road and check whether the road signs were lit. If they were, a visual check for cracks in the road and verge was made. If the Inspector considered he could not proceed to the control cabinet he would arrange emergency diversion signs to be placed and contact the Council's Engineer. However, if the Inspector considered it safe, or if the warning lights were not on, then he would proceed to the control cabinet. At that stage any illuminated reset button warning lights, which indicate power or wiring faults, or module lights, which arise from tilt exceeding the limits, are noted; in the event of a false alarm, the system is reset.

In terms of regular monitoring, the tiltmeter readings have always been taken manually by visiting the control cabinet. The inner and outer limits themselves were selected arbitrarily. Barton and McInnes (1988) stated that "the limits selected initially were 250 and 500 seconds of tilt respectively. In keeping with the progressive increase of tilt and because it is important that the alarm is triggered only by a sudden movement, rather than by slow gradual movements the limits were raised, firstly to 500 and 1000 seconds and, secondly, to 1500 seconds".

The original early warning system had been in place in fifteen years when cliff stability was reviewed at Afton Down in 1997. During this time the cliff had continued to recede so that the cliff edge was by then in a horizontal distance only 11m from the seaward verge of the carriageway at the nearest place. In view of this, a number of recommendations for upgrading and improving the early warning system were made.

A fundamental aspect of the review of monitoring equipment was to highlight that the tiltmeters only recorded rotational and not translational movements. From a more detailed geotechnical investigation it was clear that the inclinometer data could detect translational as well as toppling movements, whereas tiltmeters only detect toppling. For this reason, and taking account of the variety of instability scenarios in the area, a range of new instrumentation was provided in 1997.

It had always been recognised that the primary purpose of the original tiltmeter system was to permit safe passage for road users by functioning as an early warning alarm system for instability problems. The experience obtained over its first few years of operation gave confidence that the system would in fact function satisfactorily in this respect, although ten false alarms were recorded (mostly due to electrical power supply failure, vibrations of significant magnitude from traffic and sea storms, and also lightning discharge from electrical storms). The remaining alarms related to an average of approximately one per year, considered a tolerable level of inconvenience, and taken as proof that a developing landslide could activate the telephone alarms and traffic signs if it occurred.

A secondary purpose of the system was at that time to show the characteristics of movement of the ground supporting the tiltmeters. These movements were shown to be increasingly seawards tilting / rotation of the chalk around the open fissures in the cliff face due to stress relief. Steady increases have ranged from 20-80 seconds per year with a marked increase in 1987. Frequent minor oscillations and occasional surges of tilting were superimposed on the steady increase in tilt. Notable surges occurred during the winter months (January-February 1985, December 1985 and January 1987). It is considered that the movements represent insipient toppling failures. The winter seasonal character of the surges in movement suggest their relation to ground moisture content, with either swelling of the superficial soils or ponding of perched water. Subsequent shrinkage of the soils or drainage of the perched water would permit the reversals of the tilting movements occasionally observed (Barton and McInnes 1988).

The new telemetric system includes the five tiltmeters originally supplied, as well as six wire extensometers which have been placed at intervals perpendicular to the road. These extensometers allow measurement of translational movements as well as tilt. Cables run from the extensometers at the roadside down the slope, and if the attached concrete blocks move as a result of land movement, the cable extends, and it is this movement that is recorded by a data logger at the location. An extensometer was also placed across the road to see if the whole cliff is moving seawards.

In support of this LIFE Project a settlement cell was also placed on the seaward side of the road to improve monitoring of settlement and to obtain additional data at a key location. All the monitoring equipment, including the tiltmeter system, is linked to a data logger with readings automatically recorded every thirty minutes. Data from the logger station at Afton Down is down loaded to the Isle of Wight Council's computer by a modem link. The alarm system operates as before with the data logger autodialler phoning the Isle of Wight Council with a pre-recorded emergency message if movement occurs above the present limit level 1. The system also telephones the Council if movement occurs above level 2, in addition phoning Newport Police Station and activated red warning lights and illuminated signs at either end of the affected stretch of road.

6. CURRENT STATUS AND APPROACH

The Council has now obtained planning consent to carry out highway stabilization works at Afton Down on the Military Road (Figure G10.3). It is expected that work will commence in the spring 2001. A key part of the Council's strategy for management of this part of the coastline will be on-going monitoring, which will be much aided by the improved equipment installed at this location in 1998.

6.1 Coastal Defence

As described above, coastal defence is not an option at this location because of the high environmental quality and landscape value of this part of the Isle of Wight coastline. In addition, although protection of the toe of the cliff would provide a reduction in the rate of cliff recession there is no doubt that the highway would be lost before the cliff had reached an equilibrium situation in terms of cliff stability.

7. EXPERIENCES, SUCCESSES AND PROBLEMS WITH CURRENT APPROACH

Problems associated with the ongoing weathering and marine erosion of the chalk cliffs at Afton Down adjacent to the A3055 Military Road at Freshwater on the south-west coast of the Isle of Wight first came to public attention in December 1980. A series of cliff falls had brought the cliff face within 15 metres of the edge of the highway and this had led to the discovery of tension cracks in the roadside verge and beneath the carriageway itself.

At that time ground movement monitoring instrumentation was in its infancy and a 'state of the art' system of tiltmeters was installed to provide warning to motorists in the event of a catastrophic failure of the cliff and the road. This system has worked well for over 18 years. However, a more detailed geotechnical investigation commenced in 1998 arising from concerns relating to the proximity of the road to the cliff edge. This further study revealed that mechanisms other than tilt were not being monitored seaward of the A3055 Military Road and that the existing instrumentation required upgrading to take account of settlement and translational movements. Concerns about public safety and the liability of the Isle of Wight Council as Highway Authority and Coast Protection Authority led to the funding and installation of equipment costing a further £60,000, which now provides the necessary safeguards sought by the Council pending the development of an engineered solution to the road stability problem.

Although the affected length of road runs along the top of a coastal cliff, it would be inappropriate to carry out any form of coast protection works because of the environmental sensitivity of the area which is designated as a Site of Special Scientific Interest and a candidate Special Area of Conservation. The development of schemes of this kind in environmentally sensitive areas involves the preparation of an Environmental Statement to accompany the application for planning consent from the Council and agreement with statutory consultees including English Nature and the Environment Agency.

8. LESSONS LEARNT

The tiltmeter system provided at Afton Down adjacent to the Military Road was installed in 1980 at a cost of £35,000. It operated effectively as a monitoring and warning system for 18 years before being upgraded. This demonstrated that even in a relatively hostile marine environment, subject to annual maintenance, a system of this kind can represent good value for money.

During the course of the development of the stabilization scheme for the Military Road the coastline became designated as a site of European importance under the Habitats Directive. Despite explanations by the Council and English Nature many residents cannot understand why more major engineering measures are not proposed. Many property owners are sceptical about the special importance of certain species of plant and insect and believe people should come first. There is a clear lesson that more time and effort must be given to explaining the importance of issues such as biodiversity and sustainability by English Nature, the Council and environmental groups and for government to weigh up the significance of their commitments for areas at risk from landslides particularly in coastal areas.

The instrumentation at Afton Down has provided a means of keeping this important road open for a further 20 years (1980 to present day). The data provided and the alarm system have therefore made valuable contributions to scheme design and to safeguarding the local economy respectively, pending the raising of the necessary funds for implementing the engineering solution.

It is important to review the requirements for monitoring instrumentation periodically particularly as the as the knowledge-base increases. A review of the monitoring equipment at Afton Down, for example, highlighted the fact that settlement and translational movements were also relevant in addition to tilt. All these mechanisms are now being examined and the results of this monitoring is contributing to an engineered solution to the problem as well as improving the risk management working system. Further examples of warning systems are described at Ventnor (Study Area G4), Bonchurch (Study Area G3), Salins-les-Bains (Study Area G17) and at Seychilinne (Study Area G19).

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Figure G10.1 Afton Down location map.

LITHOSTRATIGRAPHY PRESENT AT THE AFTON DOWN SITE, AFTER WHITE (1921) AND BARTON (1987).

Formation	Zone	Description	Thickness (m)
Upper Chalk	Zone of Micraster Coranguinum	{ Smooth massive { chalk with flints	84.8
	Zone of Micraster Cortestudinarium	{ Hard nodular chalk with flint { red colouring	16.1
	Zone of Holaster Planus	{ Rough nodular chalk with grey { tinge	18.2 -----
		Sub Total	119.1 ===
Middle Chalk	Zone of Terebratulina lata, (64ft 9in).	{ Grey marl	0.03
		{ Hard nodular chalk	2.3
		{ Grey marl (= the "Black marl")	0.03
		{ Hard nodular chalk, containing yellowish band with { green nodules at top (so-called "Chalk Rock") and { passing into firm white chalk below: fossils { abundant	3.9
		{ Marl-seam { Firm white chalk with frequent marl-seams, two of { which, 6 to 6 metres apart, contain siliceous { concretions	13.4
	Zone of Inoceramus labiatus, (84ft 7in).	{ Firm white chalk with yellow nodules at base	14.8
		{ Hard white lumpy chalk	7.9
		{ Hard rough nodular chalk with seams of grey marl { ("Melbourn Rock")	3.0 -----
		Sub Total	45.5 ===
Lower Chalk	Zone of Holaster subglobosus	{ Actinocamax plenus Subzone: firm grey marl, { laminated	2.7
		{ Greyish-white chalk in definite courses, divided by { seams of marl	27.4
	Zone of Schloenb Varians	{ Grey chalk in alternating soft and harder courses	12.2
		{ Grey chalk with small brown phosphatic nodules	0.5
		{ Bluish-grey chalk, slightly glauconitic {	3.0
		{ Chloritic {c, Glauconitic marl with many { Marl phosphates and cephalopods	1.8
		{b, Sandy marl without phosphates	1.1
		{a, Nodule bed, with phosphatised concretions	0.3 -----
		Sub Total	49.2 ===
Upper Greensand		{ Greenish grey glauconitic sands (or sandy marls) with { phosphate nodules {	1.4
		{ Chert beds: Glauconitic sandstone with layers of chert {	2.1
		{ Grey sandstone above with yellowish fine sand below. { Calcareous concretion "doggers"	22.9 -----
		Sub Total	26.4 ===

Figure G10.2 Stratigraphical column for the Afton Down area.

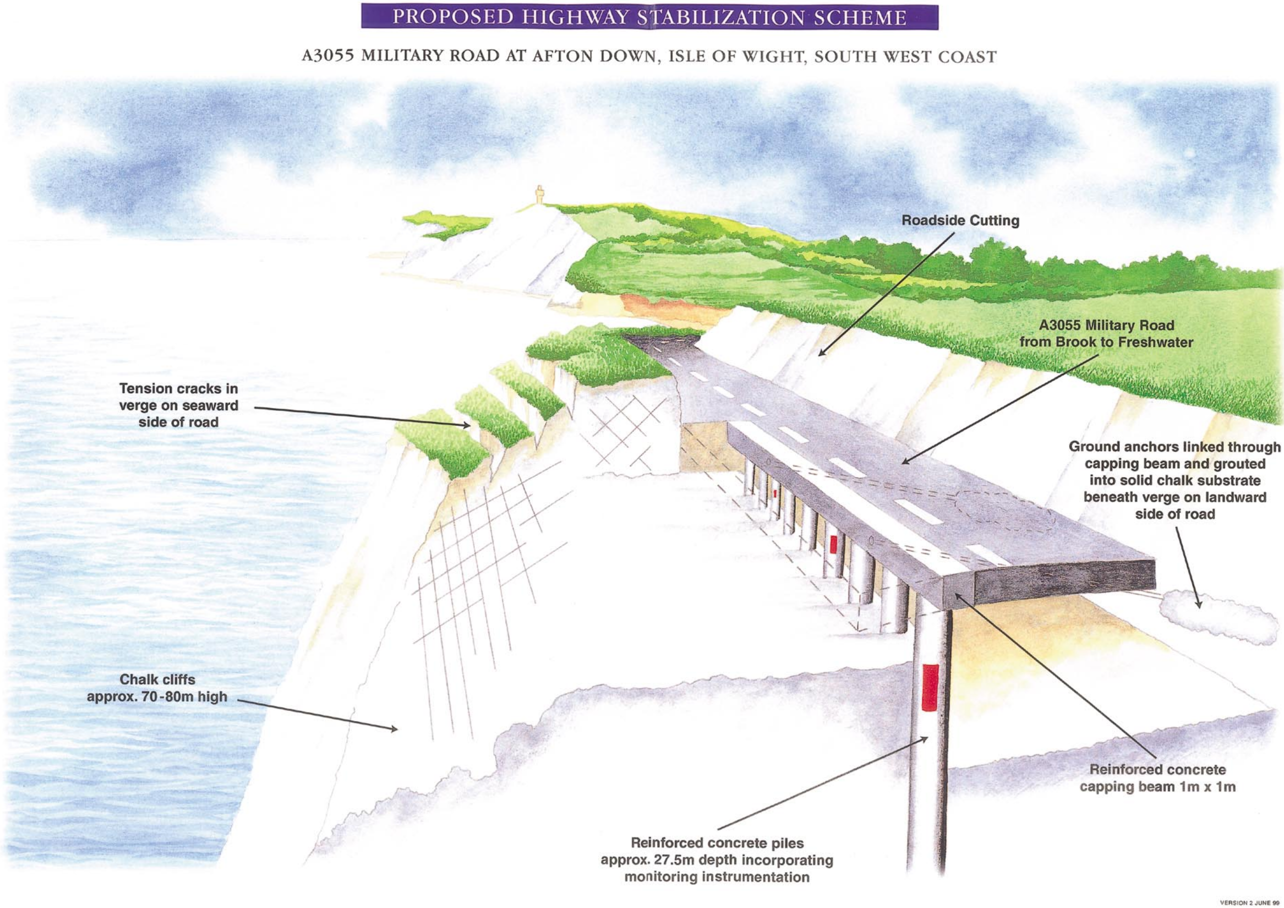

Figure G10.3 The proposed stabilization scheme.

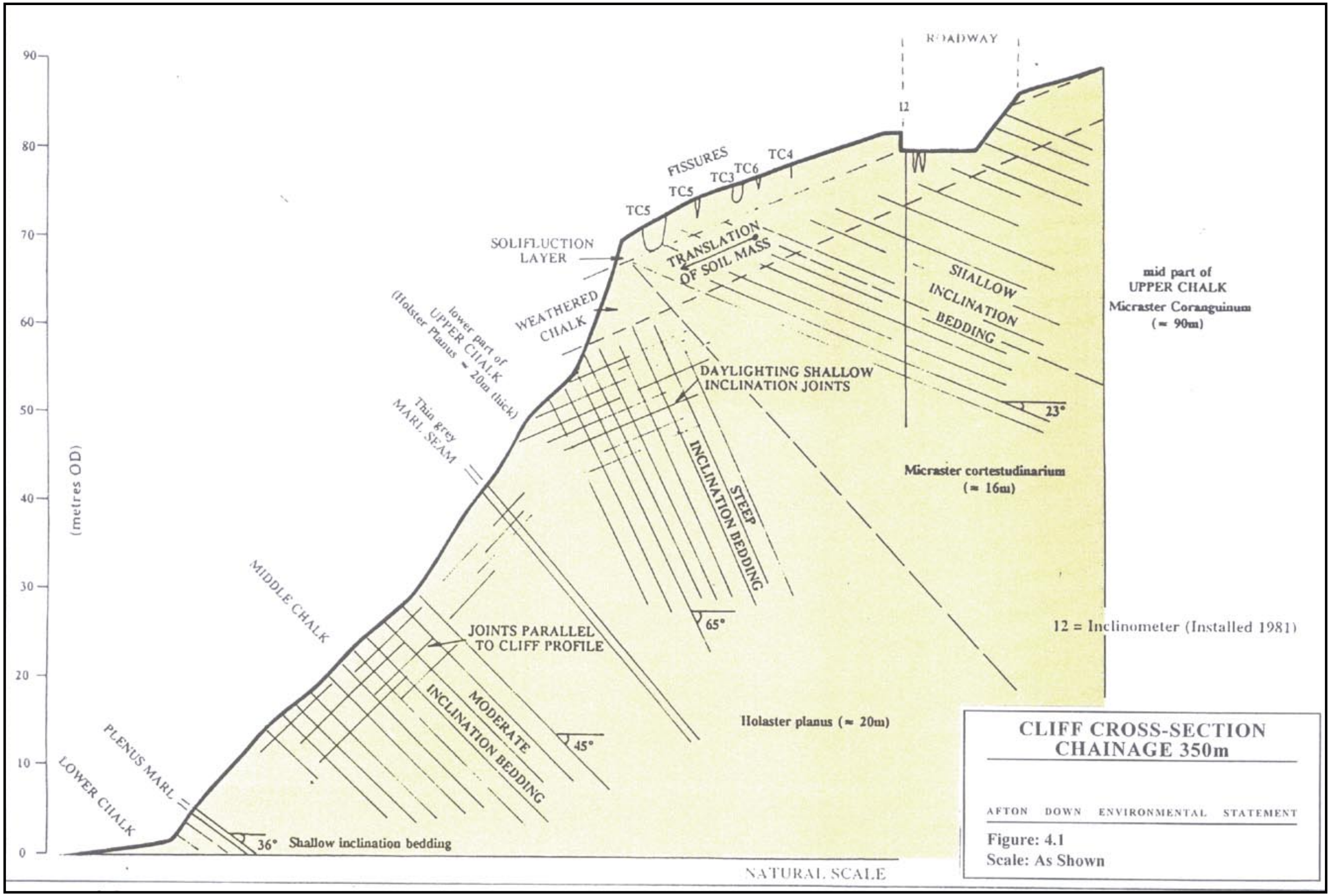

Figure G10.4 Cross section through the Afton Down cliff.

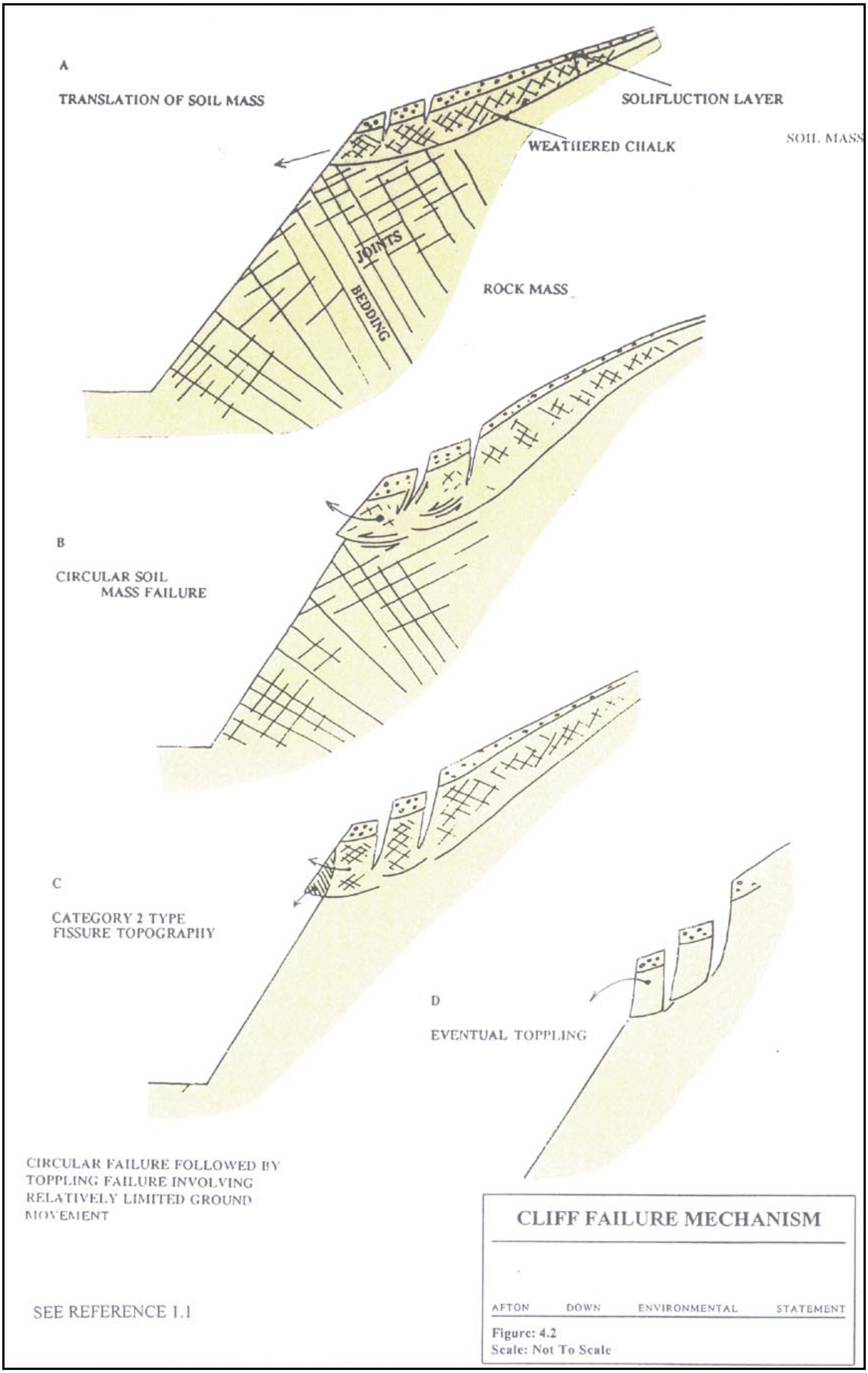

Figure G10.5 Cliff failure mechanisms.

Plate G10a ***High aerial view of the Military road over Afton Down showing fissures***

Plate G10b ***The Military road looking west***

Plate G10c ***The Military road, looking east***