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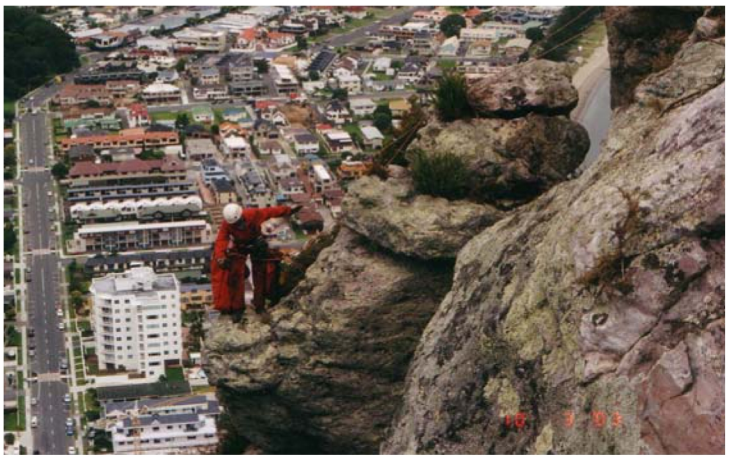
Report on:

# Mauao Rock Slopes & Rockfall Hazards



**Client: Tauranga District Council**

**July 2003**

**Avalon Report No: 0314**

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# EXECUTIVE SUMMARY

An engineering geological rock slope investigation and rockfall hazard assessment was undertaken on the rock slopes of Mauao, by Avalon Consulting, in March 2003, on behalf of Tauranga District Council. This report presents the findings of the investigation and gives some recommendations for further works and ongoing hazard management.

The investigation revealed a marginally stable rock mass (up to 500m³) on the bluff directly above the camp ground. This is considered a potentially severe hazard due to its size and location. Further investigation and consideration of remedial stabilisation works is very highly recommended in this area.

Much loose and unstable rock exists on other areas of the slopes. Some potential failures are large (100's of m³) but small failures of individual rocks will be far more frequent and present a greater hazard to track users. The loss of vegetation following the January 2003 fire has greatly exacerbated the rockfall hazard; the scrub no longer exists to slow or trap small rockfall and the loss of root binding has left the sandy slopes prone to scour.

Future rockfall will affect the walking tracks. The hazard may be within acceptable limits in many areas, however, where gullies cross the northern slopes the hazard is locally concentrated and can probably be significantly and cost effectively reduced by the installation of a small number of basic catch fences. It is recommended that this be investigated further. Temporary closure of the northern Oruahine track is recommended while vegetation re-establishes and catch fence options are reviewed.

Erosion will be occurring relatively quickly in areas where vegetation has been lost. It is recommended that Mauao's Park Ranger regularly looks for and reports any indications of instability.

Natural erosional processes and human activities will continue to affect the slopes. Survey markers were installed across open joints to monitor future movement of a few of the larger potential failures.

Considering the potential rockfall hazards and high profile / visitor numbers to Mauao, it is recommended that an ongoing program be established for; annual geotechnical inspection, monitoring of survey markers, targeted rock scaling and reporting.

To summarise, the main recommendations in this report are:

- Detailed investigation of the hazard above the camp ground.
- Consider remedial works to reduce the hazard above the camp ground.
- Close the northern Oruahine track, investigate possibilities for catch fences.
- Annual geotechnical inspection & scaling program to be set up.

Any remedial stabilisation works proposed on the slopes will require careful investigation and design to achieve a practical, cost effective, environmentally and culturally acceptable end result.

Avalon Consulting would like to offer our services to continue with this work.

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# 1 INTRODUCTION & BACKGROUND

At Avalon Industrial Services Ltd we specialise in offering high quality and high safety geotechnical and engineering services in difficult and high access environments.

A fire on the slopes of Mauao (Mt Maunganui) in January 2003 revealed unstable looking slopes and bluffs which were previously partly hidden under scrubby vegetation.

s 7(2)(f)(ii) with Tauranga District Council -TDC) and Laurie Richards (Rock Engineering Consultant to TDC) visited the site on 19 February 2003, Laurie's report dated 20 February[1] advised that specialist rock scaling and further stability investigation was recommended.

In early March 2003 s 7(2)(f)(ii) contacted s 7(2)(a) Privac s 7(2)(a) ... Privacy Avalon Industrial Services Ltd) regarding a proposed rock scaling and geotechnical investigation contract on the steep rock & soil slopes of Mauao

Avalon Industrial Services Ltd was awarded a contract, site works were carried out in March 2003. An interim report was presented to TDC on 21 March 2003[2]. This report is a follow up to that interim report.

The purpose of this report is to provide a record of the condition of the rock slopes at March 2003 and give some proposals for possible remediation/stabilisation works and a future rock scaling/monitoring regime.

This report is concerned with rockfall from the steep slopes which burned off in the January 2003 fire and its scope does not include colluvial/mass slips on the lower angles slopes or the bushed areas.

The potential rockfall hazard to the public on the very popular walking tracks around Mauao has been of concern to TDC previously, a stability assessment report was prepared for by Laurie Richards in May 1999[3].

1 Richards L. Mauao rockfall review. Letter to TDC. 20 February 2003.

2 Avalon Industrial Services Ltd. Mauao slope remedial works interim report (draft). Report to TDC, 21 March 2003.

3 Richards L. Mauao stability assessment, Mount Maunganui, Tauranga. Report to TDC, 31 May 1999.

# 2 SITE WORKS: MARCH 2003 INSPECTION & ROCK SCALING

Avalon Industrial Services Ltd carried out a rock scaling, rubbish collection, weed spraying and engineering geological investigation contract, on behalf of Tauranga District Council, from 10th to 21st March 2003.

The scope of the works included:

## *2.1 Rock Scaling*

1) Scaling of unstable rock from the cliff faces and steep slopes

2) Removal of many loose surface rock debris from the summit areas

The areas covered included all those burned off in the recent fire; a total of over 10 hectares of slope ranging from 15m vertical cliffs to colluvial slopes.

The quantity of unstable rock in some locations was significantly greater than had been anticipated; the workscope was targeted to minimise the existing rockfall hazards, as far as was possible in the time available.

One large boulder (approximately 17tonne and rated as presenting a severe hazard) was scaled from the bluff above the campground. TDC coordinated isolation of the affected areas during scaling, security and media interest.

The total quantity of unstable and hazardous rock scaled is estimated to have been over 500 cubic metres.

Inevitably the tracks were locally damaged by the rockfall.

Later sections of this report describe the rockfall processes observed during the scaling operation.

## *2.2 Engineering Geological Investigation*

s 7(2)(a) Privacy Avalon Industrial Services Ltd (author of this report), assessed all areas of the slopes at close range and observed the rockfall processes during the scaling operation.

The resulting findings are described later in this report.

At some of the more prominent potentially unstable bluffs stainless steel survey markers were installed into blocks across open joints. These markers are 8mm diameter stainless steel friction anchors with ID discs.

Tape measurements of the survey marker spacing's were taken providing a baseline against which to measure any future movement across critical joints.

The survey markers were generally installed in locations relatively easy to access, however, rope access or a means of fall arrest is required to access all these locations in compliance with the HSE Act.

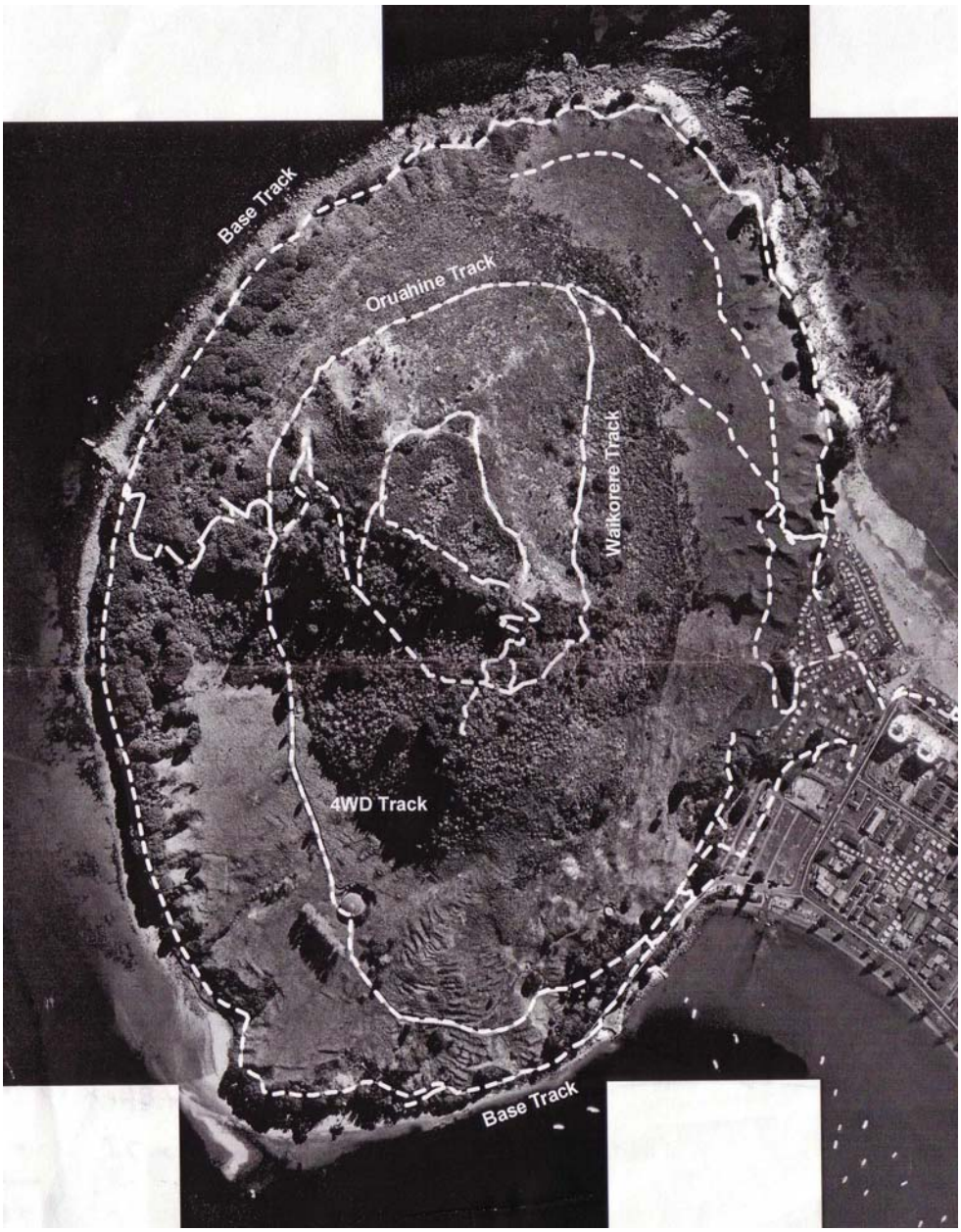
# 3 BRIEF DESCRIPTION OF THE SLOPES & TRACKS

Mauao is a volcanic dome 232m in height. Lower angled colluvial slopes around the base rise to near vertical bluffs below the summit.

The geometry of the slopes is well described in L. Richards May 1999 report.

The bluffs and rock outcrops are controlled by sub vertical and sub horizontal jointing resulting in horizontally split columns up to 5m in plan and 15m high. Extensive colluvial slopes are littered with rockfall debris.

Highly frequented walking tracks traverse the slopes. The names and locations of the tracks are shown on the following plan.



# 4 GEOLOGY & MATERIALS

The geology of Mauao has been well described in detail by others (see L. Richards May 1999 report) and is outside the scope of this report.

In engineering geological terms the typical rock description is:

> Reddish pink, slightly weathered, flow banded, locally brecciated, typically extremely strong (locally moderately strong where vesicular and slightly weathered), RHYOLITE.
>
> Vertical & sub-horizontally jointed, joints are typically very widely spaced (3 to 5m), persistent >10m and extremely wide open (often 10mm to 1m). Joints behind the outer block set are often infilled with sandy colluvium.
>
> [MT MAUNGANUI RHYOLITE] locally shows spherulitic textures and vesicular areas.

The colluvial (debris) slopes range from extensive planar slopes to uneven ‘gully and bluff’ areas. The colluvial material is typically;

> Brown, unbedded, silty SAND and GRAVEL with some boulders.
> Loosely packed and heterogeneous, clast supported in some areas, matrix supported in others.
>
> [COLLUVIUM]. Angular, tabular clasts of RHYOLITE (rockfall debris) in a matrix of wind blown silty SAND.

# 5 GROUNDWATER

The upper slopes, where the majority of the rockfall considered in this report originates, show no signs of being affected by groundwater pressures.

The high rock bluffs are well drained (open joints or sandy infill), show no signs of seepage, and pore water pressures would not be expected to be a destabilizing factor.

The lower slopes are known to have localised springs and so show indications of mass slips, however, these are outside the scope of this report.

Periods of heavy rainfall are expected to cause scour problems on the colluvial slopes. Scour effects are expected to be particularly important until vegetation re-establishes on the burned off areas.

# 6 VEGETATION

This investigation was initiated following an extensive fire (January 2003) which completely burned off large areas of the northern and eastern slopes.

The majority of the lost vegetation consisted of scrub and grass, the roots of which had a very beneficial effect on colluvial slope stability.

The matrix of the colluvium is extremely loose wind blown sand and the roots of grass and scrub vegetation bound the sandy surface together.

Following the fire the resulting sandy colluvial surface is extremely loose and prone to scour by rain and wind.

Although the vegetation cover has been completely lost in many places, in others, a low cover of burned and dead shrub branches remains. Gorse seems to have been particularly resistant. On the steep slopes (particularly the northern areas) many cobbles and small boulders lie at rest against these remains. As the dead wood decays, rockfall be released. If the scrub regenerates before the old wood decays this may not be too much of a problem.

Vegetation with larger root systems can reduce stability of rock masses due to root jacking effects. The rock slopes in question have very few trees (mature or immature) and this is generally not a problem at present.

# 7 ROCKFALL MECHANISMS

The summit rock bluffs/columns and colluvial slopes of Mauao are inherently unstable and natural rockfall will continue to occur.

The aim of this investigation is to better understand the rockfall mechanisms involved and to give suggestions for further investigation into means of monitoring and reducing the hazards.

Rockfall mechanisms can be subdivided into the following:

## *7.1 Mass/large block failure from the steep columns and bluffs.*

In extreme cases these could involve masses up to 500m³ in single events. Larger individual boulder blocks are frequently 3x3x3m in size.

These failures are essentially controlled by the rock mass jointing.

The failure mechanism is generally toppling of overhanging/marginally stable columnar masses or a combination of toppling and planar sliding on steeply inclined random joint planes.

The triggers for major failure appears most likely to be earthquake loading but could also be by ongoing erosion increasing overhangs (sometimes exacerbated by the natural flow structures and gas pocketed nature of the rhyolite) to the point where failure occurs.

Water pressures are unlikely to be a failure trigger due to the open nature of the joints and the free draining infill (sandy).

Erosional scour of sandy material supporting rock blocks will be a trigger for failure although this is more frequent on the colluvial slopes (see the following section).

Failure of large masses will be infrequent but are an ongoing process as evidenced by the extensive colluvial boulder fields on the lower slopes.

Although there is little historical record of failures, there do appear to have been a few natural boulder failures over the last, say 50 years. One example noted during this investigation was a boulder approximately 1m³ resting against a Pohutakawa below the northern base track.

## *7.2 Failure of smaller rock fragments from the outcrops and bluffs.*

This process is the continuous ‘raveling’ of rocks, typically 100mm to 300mm in size, failing from the rock outcrops.

Failures are initiated by normal erosional (wind, rain, temperature) processes. These rock fragments are typically split along joints, flow banding, and random fractures in the rock material.

## 7.3 Failures from the colluvial slopes.

The colluvial (debris) slopes range from extensive planar slopes to deeply incised gullies and irregular boulder slopes between outcrop bluffs.

Much gravel to boulder sized rock lies on the surface of and embedded in the sandy colluvium. Following the fire the root binding effect has been lost and the surface is loose and prone to rain scour.

Many of the mid to upper slope areas lie at around the natural angle of repose (for this variable colluvial material) and some rockfall initiated in these areas will often only roll short distances before loosing energy and coming to rest.

However; once movement has been triggered, suitably shaped rocks can roll down slope accelerating quickly and do present significant hazards.

In some upper slope areas the colluvium is overly steep (lies at angles well above the natural angle of repose) and masses can be 'chocked' up in the upper gullies. Failures from these areas will also not come to rest; they will gain energy quickly and even cobble sized rocks can sometimes travel at high velocity all the way down to the base track.

Triggers for failures from the colluvial slopes will include seismic, rain, wind, wildlife and decay of supporting vegetation.

These failures present a much more serious hazard now the sandy surface is devoid of vegetation, which can otherwise contain or slow at least some of the smaller rock falls.

## 7.4 Discussion of rockfall processes

During the March 2003 rock scaling work much empirical evidence was gained of the speed of and distances traveled by Mauao's falling rocks (and of the extremely marginal stability of many areas).

The rhyolite tends to split along its internal shears and flow banding fabric (in addition to the jointing and fractures). The resulting rocks tend to often be tabular (even 'disc' shaped) rather than blocky.

Tabular shaped rocks (dimension from 0.1 to 3.0m across the 'flat'), once failure is initiated, tend to straighten their roll in the vertical plane whilst gaining velocity. Their angular momentum keeps them vertical whilst bouncing and hitting minor obstructions.

Spinning tabular rocks maintain high energy and can roll far greater distances than idealized spherical boulders.

Whilst the low coefficients of restitution of the relatively soft ground and lower bush do have some beneficial effect in slowing rockfall (particularly the smaller rocks), rocks can and do gain sufficient energy to easily reach the lower slopes.

A very high percentage of scaled rocks reached the upper tracks (Waikorere & Oruahine). A significant number of larger rocks traveled well below the upper tracks and occasional rocks reached or almost reached the base track.

Obviously larger rocks and steeper ground increase the probability of rockfall reaching the base track. Smaller rocks (say $<0.5m^3$) often impact on the upper tracks but tend not often reach the lower tracks, the exception being in the northern areas.

The observations during the scaling operations suggest that the analysis in section 4 of L Richards May 1999 report (which was made using the "RocFall" computer model, before the loss of vegetation and close inspection revealed the marginal stability of some areas) may have been optimistic in suggesting that "most of the boulders would come to rest on the middle part of the slopes and that none would will reach the Base Track, Camp Ground or Hot Pools complex".

During scaling operations in the northern areas we observed quite a number of rocks crossing the Base track.

The large boulder scaled above the camp ground came to rest only a few metres above the Base track; however, had it followed a slightly different trajectory it appeared it could easily have entered the camp ground. Some other boulders scaled from the eastern slopes area also almost reached the base track.

As far as % of rocks reaching the various tracks is concerned the scaling operation observations were generally consistent with L Richards May 1999 report estimate of "75% of boulders crossing the upper tracks and 1% reaching the lower areas", however, the 1% that reach the lower areas tend to be the larger boulders and might well represent over 1% of the failed material (and hazard).

# 8 ROCKFALL HAZARDS; GENERAL COMMENTS

When assessing the severity of the hazards in this section, 'best engineering judgment' has been qualitatively used to take into account the risk relative to exposure time (see L. Richards May 1999 report for a quantitative approach).

The scaling operations proved that a very high percentage of rockfall reaches the upper tracks (Waikorere & Oruahine), a significant percentage (mostly but not exclusively the larger rocks) travels well below the upper tracks and occasional rockfall reaches or almost reaches the base track, and that there is potential for rockfall to enter the camp ground.

A significant marginally stable mass of rock was identified on a fall line directly above the camp ground.

Any potential rockfall into the campsite deserves serious attention. The campsite is occupied 24hrs all year round and the effective risk exposure time is very high in comparison with persons walking the tracks.

The natural rockfall hazard from the colluvial slopes has been significantly increased by the loss of vegetation in the recent fires. The scrub was retaining many surface rocks which, after the fire, were revealed resting loosely on the sandy surface (or caught up in dead vegetation).

Rain scour of sand around rocks lying on the colluvial slopes is likely to initiate rockfall (particularly in the northern gullies) during periods of heavy rainfall.

On the northern slopes gullies tend to guide rockfall into certain channels and hence concentrate the hazards.

Although much of the worst of the potential rockfall was scaled in March 2003 and the short term hazards were certainly reduced, inevitably many marginally stable masses still exist and much surface/partly embedded rock remains littered over the slopes.

# 9 DETAILED SLOPE DESCRIPTION & HAZARD ASSESSMENT

The following sections contain detailed descriptions of the slopes and qualitative assessments of the hazards present.

For the purposes of this report the slopes have been subdivided into five zones of similar characteristics.

These zones 1 to 5 are indicated in photographs No's 1 to 7, vertical aerial photographs. These aerial shots were taken in January 2003 immediately following the fire.

Specific hazards and features of interest have been designated 1a, 3b, 4c etc and are labeled on the aerial photographs (No's 1 to 7) within each zone.

Photographs No's 8 to 29 show typical views and specific features were taken at the time of our investigation in March 2003.

## *9.1 Zone 1; the area above the camp ground*

### 9.1.1 General

This area includes 1a; the camp bluff (corner of the outcrop directly over the campsite) and 1b; the small vertical outcrop to the southwest, which remains mostly hidden behind trees.

This area can be seen at the extreme left of the outcrop in photograph No 8.

### 9.1.2 **1a**; the camp bluff

A rock mass of up to 500m³ and 10 to 15m in height.

This mass on the corner of the bluff appears marginally stable. The jointing here is somewhat wider spaced than typical. Release joints are wide open up to 1m and some blocks are severely overhanging.

Photograph No 9 shows a view from below and No 10 from above.

Photograph No 11a shows the wide open nature of the joints behind the main blocks (the joint on the left is open enough to walk down), 11b shows a view out to daylight looking under the largest overhanging block (the central block in 11a).

The two large blocks forming the upper front of the bluff appear to have moved forward and tilted slightly before locking up again (flow banding & joints in the blocks dip at 15° steeper than the in-situ outcrop).

A dead old tree is present on a ledge a few metres down; this may have historically had some 'root jacking' effects.

When a major failure occurs here it might include individual boulders up to 70m³ each. The upper mass which might fail is comprised of approximately 7 main blocks ranging in volume from 7 m³ to 70 m³. Larger failures might also involve other lower blocks.

A large portion of this mass could potentially fail in a single event and it represents a severe hazard to the camp ground, which lies on the fall line directly below.

These blocks are of such size and in such a location that failures would be highly likely to enter the camp ground.

This high hazard rating takes into account the high risk exposure time for camp ground users (relative to track users). 1a is at the present time considered the highest priority hazard on Mauao, even though similarly unstable and even larger masses exist on the northern slopes.

Having said the above; these are large blocks which appear possibly to have been in the same position for decades (if not 100's of years) and overreaction should be avoided until full assessment has been carried out.

This report does not attempt to accurately quantify the risk, see L. Richards 1999 report for approaches to this (please read in conjunction with section 7.4 of this report).

However; to get some quantitative appreciation of the potential hazard; the stability of this mass appears so marginal that failure might be expected to be initiated by erosion within, say, 100 to 500 years? When a major failure occurs, at least some of the boulders will be very likely to enter the camp ground.

On this basis we might have a, say, 1 in 100 to 1 in 500 (?) annual risks of boulders entering the camp ground, before factoring in any seismic risk.

The bluff appears to be in such a condition that a relatively small earthquake might also be able to initiate failure.

Further investigation is required and could include an attempt to measure the geometry and quantitatively calculate stability. Remediation options such as rock reinforcement, scaling, catch fences etc could then be considered.

At this early stage the most culturally appropriate and cost effective remedial option appears likely to be some form of remedial cable strapping anchored by rock dowels.

Eight survey markers have been installed in this area to allow future deformation monitoring. Their locations are indicated on photographs No's 9 & 10. The measurements taken in March 2003 are given in section 13 of this report.

### 9.1.3 **1b**; the outcrop to the south west of the camp bluff

This small vertical rock face was checked and appears reasonably well keyed together.

A long term check should be kept on tree growth on this outcrop to avoid future 'root jacking' problems.

## *9.2 Zone 2; the eastern slopes*

### 9.2.1 General

These are the slopes comprising the linear high bluffs/columns and planar mid slope on the eastern side of Mauao (the cliff line visible from main beach). Photograph No 8 shows a general view up from the base track.

From the summit track a few metres of convex colluvial slope generally drops off to near vertical rock outcrop bluffs. The bluffs are typically around 10m in height.

The slope between the bluffs and the Oruahine track is relatively planar colluvial slope lying at approximately 40˚. The slopes immediately below the Oruahine track tend to still have good bush cover and initially lie at approximately 40˚ before breaking out into the paddock, and falling at shallower angles down to the shoreline.

All rockfall from this zone presents a serious hazard to the Oruahine track. Larger boulders can reach the Base track. All lower slopes, below the bush, are littered with boulders although none appear to have failed in recent events (being typically well bedded and lichen covered).

The outcrops and upper slopes were covered by Avalon Industrial Services Ltd's scaling team in March 2003 and significant quantities of loose and potentially unstable rock were scaled along the entire bluff line.

Although some of the worst of the unstable rock was removed in March 2003. The scaling operation was targeted and covered a large area in a relatively short time. Much loose rock remains and all slopes will continue to degrade.

It is recommended that this area of slope be subject to regular monitoring and occasional targeted scaling as required.

### 9.2.2 **2a**; a large unstable column

See photographs No's 12, 13 & 14.

A 'detached' column standing forward of the main outcrop line, the joint between it and the main bluff is open by up to 500mm. This column is approximately 4m wide, 1.5m thick and 7m high, a potentially failing mass of maybe 100 tonnes.

The column appears reasonably stable at present and unlikely to fail in the short/medium term, other than in a seismic event. However, if this column were to fail the resulting boulders would of such a size, and in such a position, that they would pose a severe hazard to the camp ground.

If remedial measures were being taken to address the hazard at 1a it may be prudent to extend the scope of work to also address this hazard.

Survey markers were installed between the top of this column and the outcrop behind, to monitor any opening of the joints. Distances measured are given in section 13 of this report.

### 9.2.3 **2b**; large boulder scaled March 2003

See photographs No's 15, 16 & 17. This hazard is no longer present.

An extremely unstable boulder (approximately 17t weight) was found on the crest of the slope at this location.

This was scaled by hand (using a 2m bar) in March 2003 and came to rest near the Base track.

### 9.2.4 **2c, 2d, 2e, 2f,** and **2g**

Viewing this zone from the tracks below; a number of boulder and columns features which project above the slope crest are immediately noticeable and appear potentially unstable.

All of these were checked and most were quite stable. Although none appear to be particularly hazardous at the present time, monitoring is recommended.

### 9.2.5 **2h**; wide open joint behind block

Survey markers were installed in either wall, across a 1m open joint to monitor any down slope creep of the block.

### 9.2.6 **2i**; the tower/block slightly down-slope

This very obvious block is massive, was checked, and appears stable.

## *9.3 Zone 3; the northern slopes; gullies & bluffs*

### 9.3.1 General

Photograph No 18 shows a general view up into this zone from the Oruahine track.

This zone consists of an upper level of very broken gullies and high bluffs below which are colluvial slopes littered with rockfall debris. Approximately mid-slope between the high bluffs and the Oruahine track is a line of occasional (broken) outcrop bluffs.

A wide (bowl shaped) gully channels rockfall from much of the western half of this zone. This large catchment creates a greatly increased rockfall hazard at one point on the Oruahine track (3e).

The upper areas of the gullies between bluffs tend to contain steep 'chocks' of colluvium. Following the fire the loss of grass and scrub roots has rendered these areas extremely unstable.

Zone 3 is high, wide, and generally time consuming and difficult to safely access and scale effectively.

All rockfall in this zone threatens the Oruahine track. Larger rocks falling in this zone can easily bounce all the way down to sea level, at high velocity, creating a hazard to both the Oruahine track and the Base track.

Until vegetation is re-established, heavy rainfall appears very likely to scour sand and silt from the steep colluvial surface. This process appears likely to create more loose cobbles and small boulders, which will present hazards.

During the March 2003 scaling operation very large quantities of rock were easily scaled, including a few major masses (12m$^3$ in single events).

Following the March 2003 assessment, the hazard to persons using the upper north western Oruahine track was considered unacceptably high, at least until vegetation was to become re-established. The track was closed pending re-inspection in the spring.

It is recommended that this slope zone be subject to regular monitoring and occasional targeted scaling as required.

A limited length rockfall catch fence in gully 3e, approximately 10m above the Oruahine track, could be very cost effective to reduce the rockfall hazard. Further investigation is recommended.

### 9.3.2 **3a**; unstable bluff

A very broken bluff exists at 3a.

Although not greatly different to other bluffs in this zone, the top is relatively easy to access.

Survey markers were installed to monitor any movements. Marker locations are indicated on photograph 19 and distances measured are recorded in section 13 of this report.

### 9.3.3 **3b**; a typical large bluff forward of main outcrop

See photograph 20. A good view of the upper ground in this zone.

### 9.3.4 **3c**; mid slope outcrop

See photograph No 21.

### 9.3.5 **3d**; an unstable column

See photograph No 22. A column approximately 6m in height. Approximately 18m$^3$ of rock was very easily scaled from behind this column.

The remaining column appears quite unstable having a small and degraded base support.

### 9.3.6 **3e**; gully guides rockfall

A wide rain scoured gully catches and channels rockfall from much of the western half of zone 3, greatly increasing the rockfall hazard to the Oruahine track at the point where it crosses the gully.

A limited length rockfall catch fence could be very cost effective in this gully. Further investigation is recommended.

A potentially very good catch fence site was noted approximately 10m above the footpath at 3e, where the slope eases slightly and rock outcrops either side of the gully could provide excellent anchorage opportunities. To avoid ugly visual impact any fences could be camouflaged by planting. The possibility for a fence requires further investigation.

### 9.3.7 **3f**; slipped boulder

A boulder of approximately 3 x 3 x 2m has slid forward, tilted, and come to rest in a very unstable looking position. It can be seen in photograph No 18.

This was checked and is not as critical as it appears (it could not be moved by hand).

### 9.3.8 **3g**; overhanging boulder

A 2 x 2 x 2m (approximately) is detached and overhangs a rock ledge. It can be seen in photograph No 18. This was checked; it is stable.

## *9.4 Zone 4; the north west; the climbing crag & gullies/bluffs above*

### 9.4.1 General

The cliff face immediately above the north western Oruahine track is a popular rock climbing venue.

This zone includes the rock climbing crags and the slopes and steep gully/bluff areas above. It includes, at its westernmost extent, the loose colluvial slope traversed by the ‘zig zag’ track (the track linking the lookout on the 4WD track directly with the summit).

Many of the gullies & bluffs above the climbing crag are not easily (or at all) visible from the tracks.

The slope between the Oruahine track and the Base track in this zone is steep. All rockfall in this zone threatens both the Oruahine track and the Base track although the percentage of rock reaching the Base track is obviously much less than the Oruahine.

As per zone 3; following the March 2003 work the natural rockfall hazard to persons using the upper north western Oruahine track was considered to be unacceptably high, at least until vegetation was to become re-established. The track was closed pending re-inspection in the spring.

Rock climbing activities increase the rockfall hazard. It could be argued that rock climbing be permanently prohibited, but to be pragmatic it might be more realistic to install good signage (and contact clubs etc) stating that for the time being (post March 2003) the track and climbing is closed.

When the Oruahine track is reopened it is recommend that signage be established to the effect that climbers enter and climb at their own risk and that traversing the slopes above the crags is prohibited, along with climbing of routes where lowering off is not possible (giving the reasons why) and reinforcing this by stating that all climbers must use the 'lowering off to track level' technique.

It is recommended that this slope zone be subject to regular monitoring and occasional targeted scaling as required.

Limited length rockfall catch fence on the slopes immediately above the rock climbing crag, in gullies 4c and 4e, possibly also at a higher level in gully 4d, could be very cost effective to reduce the rockfall hazard. Further investigation is recommended into this.

### 9.4.2 **4a**; a very steep gully

See photograph No 23. This is a good example of the steep (well above the natural angle of repose) colluvium just below the slope crest.

The gully surface is littered with extremely unstable loose surface rocks up to small boulder size, there are areas where the sandy matrix has been scoured and loose rocks are 'chocked' against one another. It is almost impossible not to cause rockfall when walking across this type of feature.

This gully channels rockfall down to join with gully 4c before crossing the Oruahine track.

### 9.4.3 **4b**, **4f** & **4h**; the climbing crags

The climbing crags are up to around 15m in near vertical height, locations 4b, 4f & 4h are indicative only as the rock faces are more or less continuous directly above the Oruahine track across this zone.

Photograph No 24 shows the crag at 4b and photograph No 25 at 4h.

The rock on the climbing routes themselves is reasonably sound as far as climbers are concerned, having been regularly climbed for a number of years. A significant hazard comes with climbing routes from which the normal exit is a 'walk-off' from the top of the route, rather than a 'lower-off' on ropes.

The colluvial slopes immediately above the climbing cliff at March 2003 are burned off and almost all root binding has been lost. The surface is extremely loose and sandy and littered with surface rocks. Although the worst of the loose surface material was scaled in March 2003, much remains.

When looking down into these slope areas from above, localised patches of dense rock debris can be seen. These are accumulations of rockfall on localised shallow angled 'ledges', were checked, and are reasonably stable.

Climbers exiting via the colluvial slopes above the climbing crag, and all users of the 'zig zag' track, probably present an unacceptable hazard, at least until vegetation is re-established.

### 9.4.4 **4c, 4d** & **4e**; gullies channel rockfall

At 4c a gully immediately above the climbing crag has a wide rockfall catchment on the slopes above.

During the March 2003 scaling operations much rockfall was channeled to 4c, destroying the track. See photograph No 26.

Much material failing around 4d is channeled to 4c, although some breaks off and follows a more minor gully which crosses the Oruahine track at 4e.

Photograph No 27 looks from the slope crest into the steep head of gully 4d.

### 9.4.5 **4g**; steep colluvial slope

Photograph No 28 shows a view over a colluvial slope (centered on 4g). The 'zig zag' track traverses the upper section of this slope.

The slope is typical of the more open areas of slope above the climbing crag in zone 4. It is littered with loose surface rock and is likely to be susceptible to further destabilisation by rain scour.

The large surface boulder at 4g, in the centre of the photograph, was checked and could not be moved.

## *9.5 Zone 5; the western slope; above and below the 4WD track*

### 9.5.1 General

This zone includes the burned off areas of slope above the 4WD track (this rockfall assessment covers only the areas of slope burned off in January 2003).

See photograph No 29 for a view of the upper areas of this zone.

The lower slopes are colluvial debris slopes, for the most part at the natural angle of repose.

Avalon Industrial Services Ltd's scaling team covered these areas in March 2003. The worst of the loose surface rock was removed at that time but much remains and the loose colluvial nature of the slope means that future scour and erosion will increase the hazard.

Rockfall from these slopes is a hazard to users of the 4WD track, the westernmost end of the Oruahine track and the link track between the Oruahine & Base tracks.

Although outside the scope of this report it was noted that some cut batters (into the colluvium) at the side of the 4WD track are at steep angles and can be expected to fail occasionally (high rainfall will be the most frequent trigger).

It is recommended that this slope zone be subject to regular monitoring and occasional targeted scaling as required.

### 9.5.2 **5a**; small degraded rock outcrops

See photograph No 29. Shows general nature of the upper slopes in this zone.

### 9.5.3 **5b**; bluff below Oruahine track

A small rock bluff below the level of the Oruahine track is a potential rockfall hazard to Base track. This was checked and found to be acceptable in March 2003.

## *9.6 Zone 6; all summit areas above the slope crests*

### 9.6.1 General

The March 2003 scaling team picked over the loose rock on the summit areas. The aim of this work was to remove any temptation for persons to pick up loose cobbles and throw them over the bluffs.

Large quantities of loose surface rock were removed, however, it is impossible to remove 100% of loose rock and scour and erosion could create new hazards before vegetation cover re-establishes.

It is recommended that this slope zone be subject to regular monitoring and occasional targeted scaling as required.

Another concern is paragliders and hanggliders launching from the summit, possibly dislodging surface rocks over the bluffs.

Signage could be installed (and clubs etc contacted) asking launchers to take great care not to kick rock over the cliffs. It might also be possible to designate safe launch locations? Platforms or soil reinforcement (matting) might be an option depending on the quantity of traffic?

# 10 RECOMMENDATIONS FOR FURTHER WORK

## *10.1 Zone 1; the area above the camp ground*

### 10.1.1 Short term

Further investigation is required of the geometry the marginally stable rock mass at 1a. Consideration should be given to remediation options to increase stability & reduce the hazard.

Detailed design & installation of remedial works could follow.

### 10.1.2 Ongoing (see section 11)

Annual geotechnical inspection, reporting and rock scaling programme.

This includes monitoring of survey markers across open joints at location 1a. Safe access must be ensured using industrial roped access techniques.

Further planting/seeding may be required to help vegetation re-establish.

TDC to carry out a monthly 'walk round' monitoring, viewing the slopes from the walking tracks.

## *10.2 Zone 2; the eastern slopes*

### 10.2.1 Short term

Further investigation of the column at 2a. Consideration of remediation measures if work is being undertaken at 1a.

### 10.2.2 Ongoing (see section 11)

Annual geotechnical inspection, reporting and rock scaling programme.

To include monitoring of survey markers across open joints at locations 2a and 2i. Safe access to be gained using industrial roped access.

Further planting/seeding may be required to help vegetation re-establish.

TDC to carry out a monthly 'walk round' monitoring, viewing the slopes from the walking tracks.

## *10.3 Zone 3; the northern slopes; gullies & bluffs*

### 10.3.1 Short term

Closure of the Oruahine track between the 4WD track and the Waikorere junction, and the steep 'zig zag' track linking the northern (lookout) corner on the 4WD track to the summit.

Possible reopening late November/early December pending results of a (rope access) site inspection in to investigate the stability, vegetation re-growth and rain scour over winter.

Investigation and consideration of possibilities for rockfall catch fence in the gully at 3e, above the Oruahine track. This could be a very cost effective means of reducing the hazard at one particularly rockfall prone point on the track.

Detailed design & installation of catch fence in gully 3e.

### 10.3.2 Ongoing (see section 11)

Annual geotechnical inspection, reporting and rock scaling programme. Safe access to be gained using industrial roped access.

Further planting/seeding may be required to help vegetation re-establish.

TDC to carry out a monthly 'walk round' monitoring, viewing the slopes from the walking tracks.

## *10.4 Zone 4; the north west; the climbing crag & gullies/bluffs above*

### 10.4.1 Short term

As per zone 3; Close the Oruahine track between the 4WD track and the Waikorere junction, and the steep 'zig zag' track linking the northern (lookout) corner on the 4WD track to the summit.

Possible reopening late November/early December pending results of a (rope access) site inspection in to investigate the vegetation re-growth and rain scour over winter.

Investigation and consideration of possibilities for rockfall catch fences in the gullies above the climbing crag at 4c and 4e, possibly also at a higher level in gully 4d.

This could be a very cost effective means of reducing the hazard at one particularly rockfall prone point on the track.

Detailed design & installation of catch fences in gully 4c, 4e & 4d.

### 10.4.2 Ongoing (see section 11)

Annual geotechnical inspection, reporting and rock scaling programme.

Safe access to be gained using industrial roped access.

Further planting/seeding may be required to help vegetation re-establish.

TDC to carry out a monthly 'walk round' monitoring, viewing the slopes from the walking tracks.

## *10.5 Zone 5; the western slope; above and below the 4WD track*

### 10.5.1 Short term

No action recommended.

### 10.5.2 Ongoing (see section 11)

Annual geotechnical inspection, reporting and rock scaling programme.

Safe access to be gained using industrial roped access.

Further planting/seeding may be required to help vegetation re-establish.

TDC to carry out a monthly 'walk round' monitoring, viewing the slopes from the walking tracks.

## *10.6 Zone 6; all summit areas above the slope crests*

### 10.6.1 Short term

No action recommended.

### 10.6.2 Ongoing (see section 11).

Annual geotechnical inspection, reporting and rock scaling programme.

Further planting/seeding may be required to help vegetation re-establish.

TDC to carry out a monthly 'walk round' monitoring, viewing the slopes from the walking tracks.

# 11 ONGOING HAZARD MONITORING RECOMENDATIONS

This report provides baseline information for all future inspection and monitoring.

An ongoing annual geotechnical inspection and targeted rock scaling programme is recommended.

This would include:

1. Visual inspection of all areas
2. Measurement of movement at survey markers
3. Targeted rock scaling
4. Presentation of a written report including recommendations for any further investigation work or remediation.

The scope of annual scaling will include a relatively quick ‘once over’ of all slope areas. Perhaps it could be combined with annual weed spraying of those areas otherwise not safely accessible without industrial roped access.

The inspection work would have to be undertaken by an Engineering Geologist using industrial roped access techniques. The results of the inspection will update this report.

Ongoing rockfall & slope condition monitoring is recommended to be carried out by TDC staff.

This monitoring would probably consist of a walk round of the tracks looking for evidence of fallen rocks and scour etc. A ‘check sheet’ type form could be prepared, to be completed during the walk round to provide a permanent record. Perhaps monthly might be appropriate until vegetation re-establishes (bi monthly thereafter?).

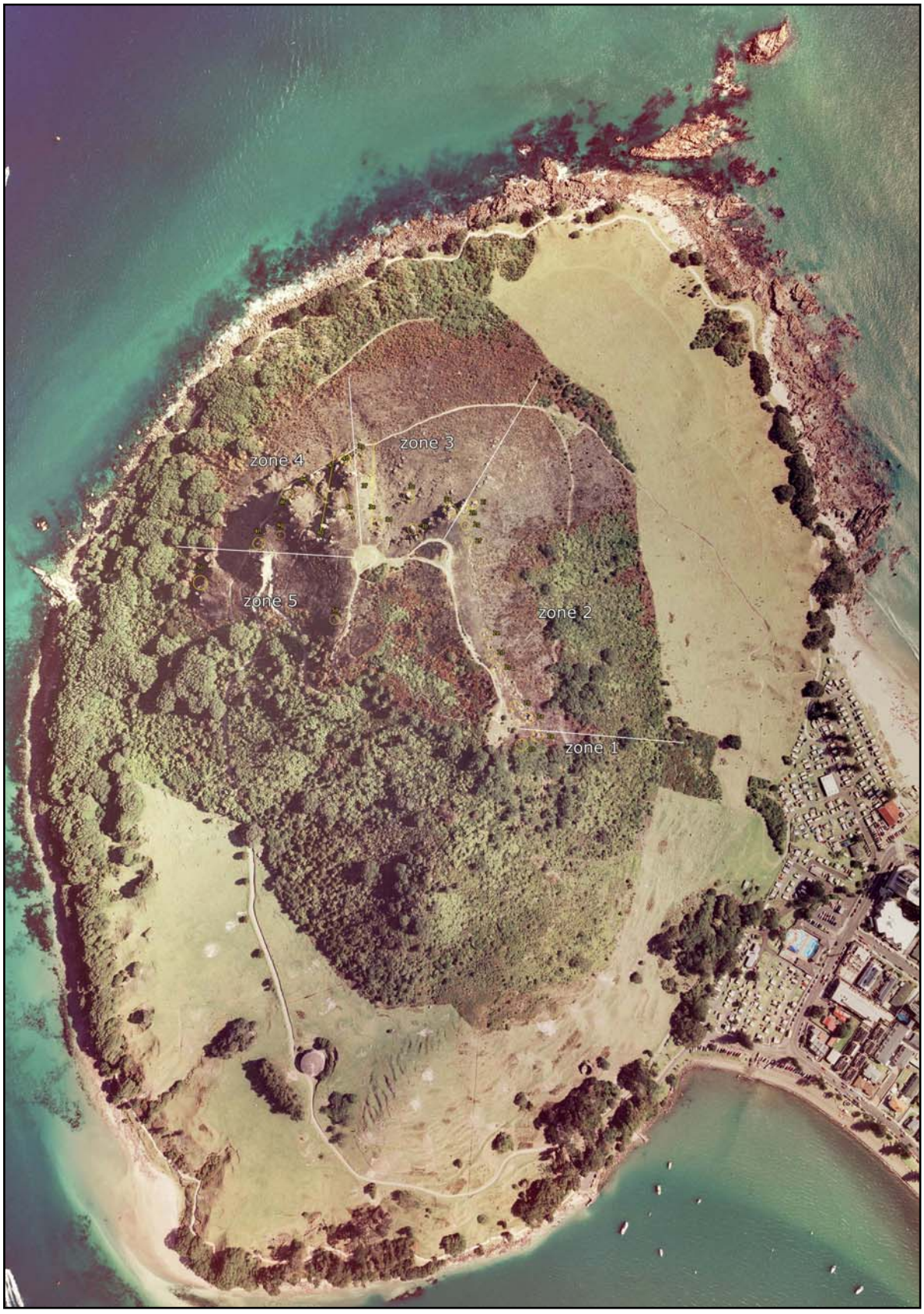
Any arising concerns could be raised with the Engineering Geologist commissioned to carry out the annual inspection.

# 12 PHOTOGRAPHS

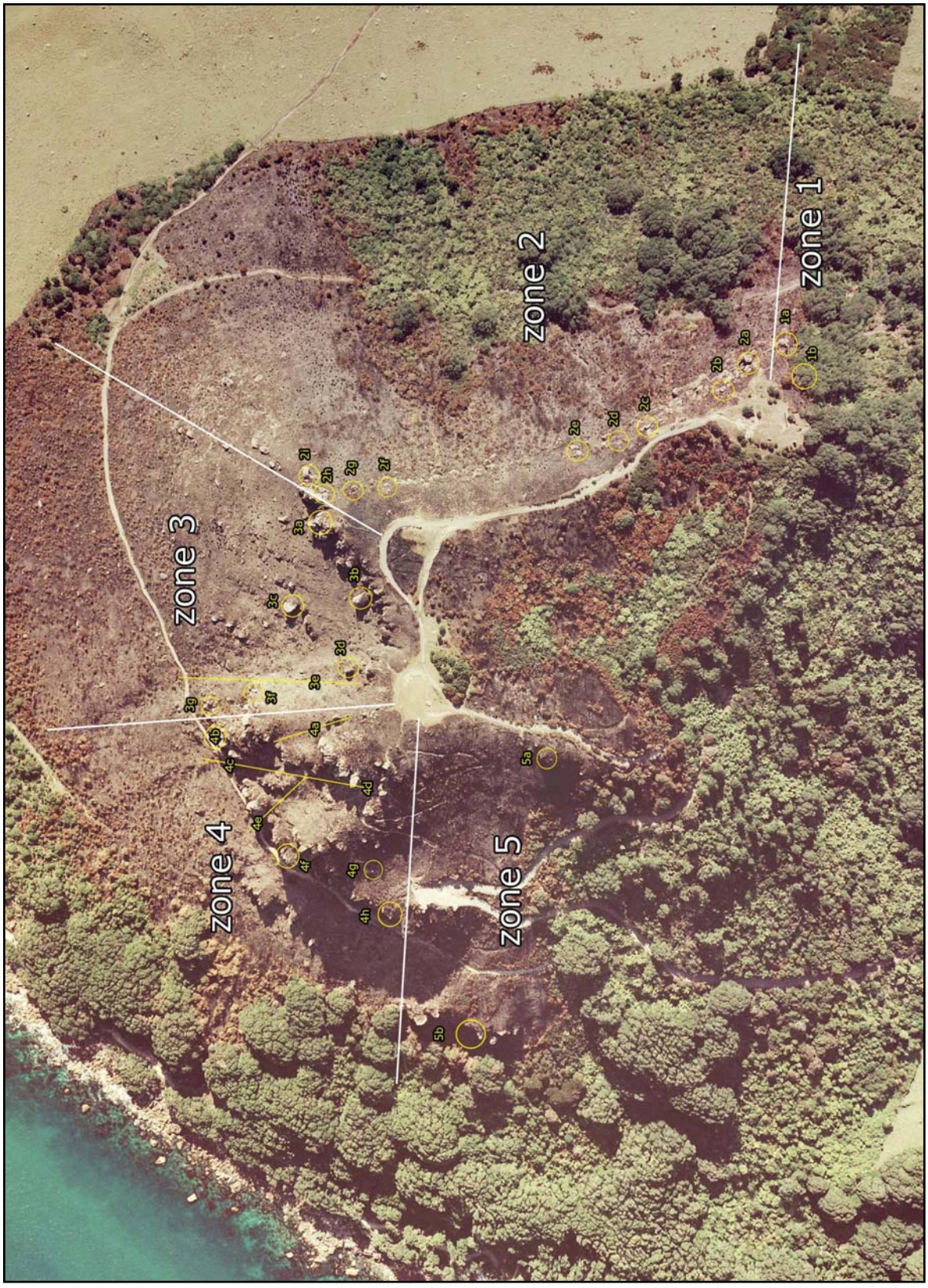
 

Photograph No 1; Aerial view of Mauao.

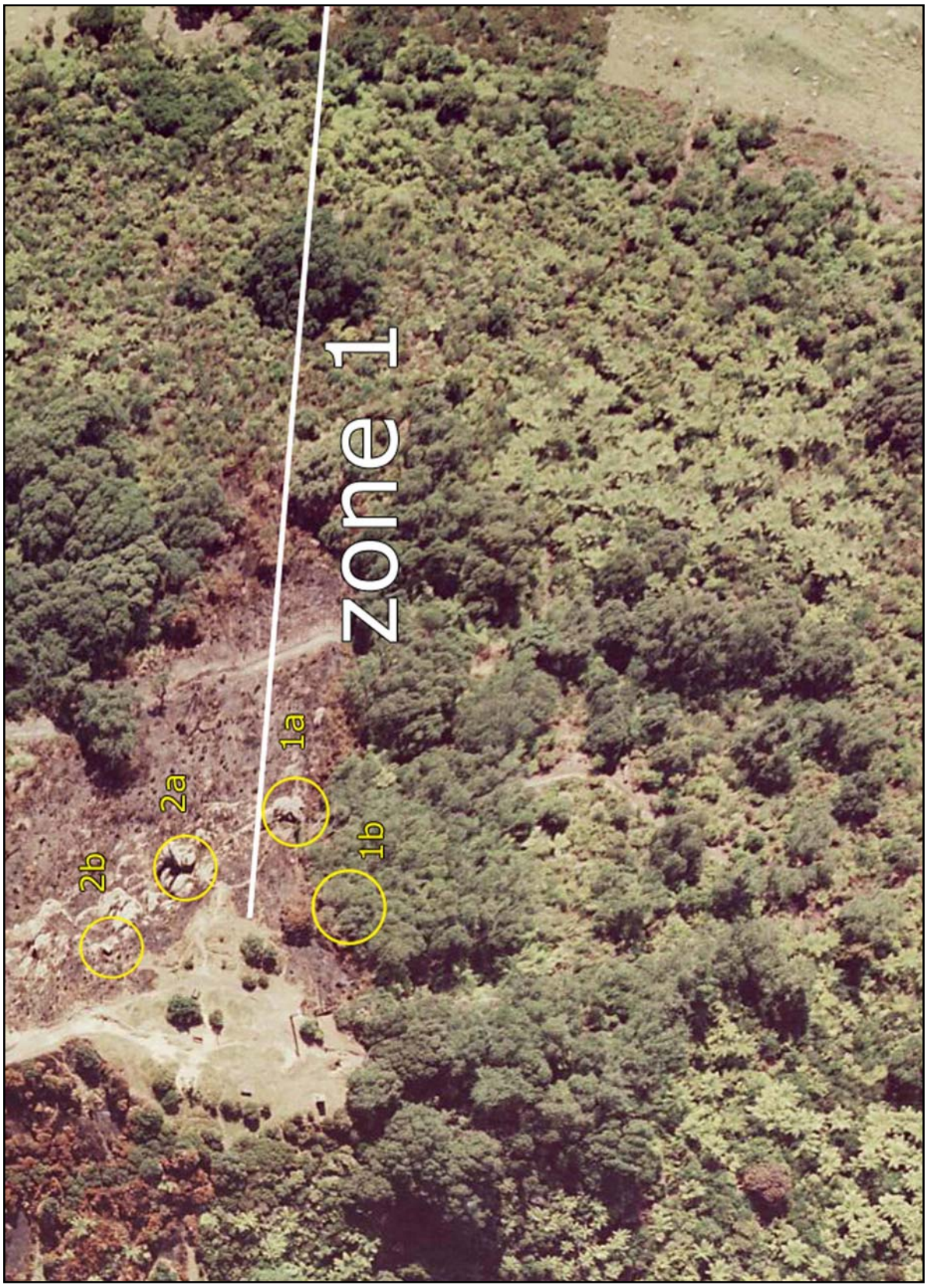


Photograph No 2; Aerial view of the rock slope zones.



Photograph No 3; Aerial view of zone 1.

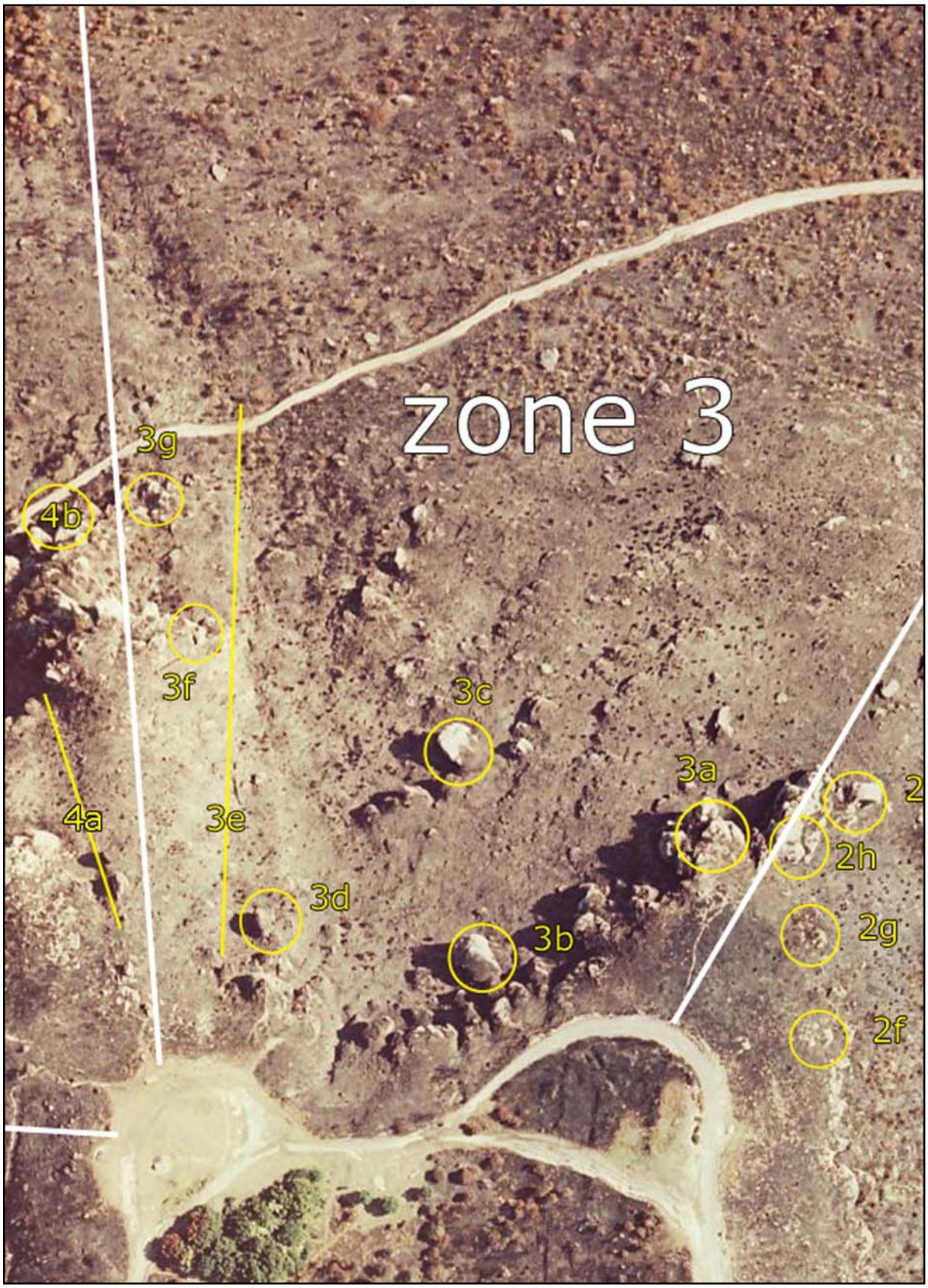


Photograph No 4; Aerial view of zone 2.

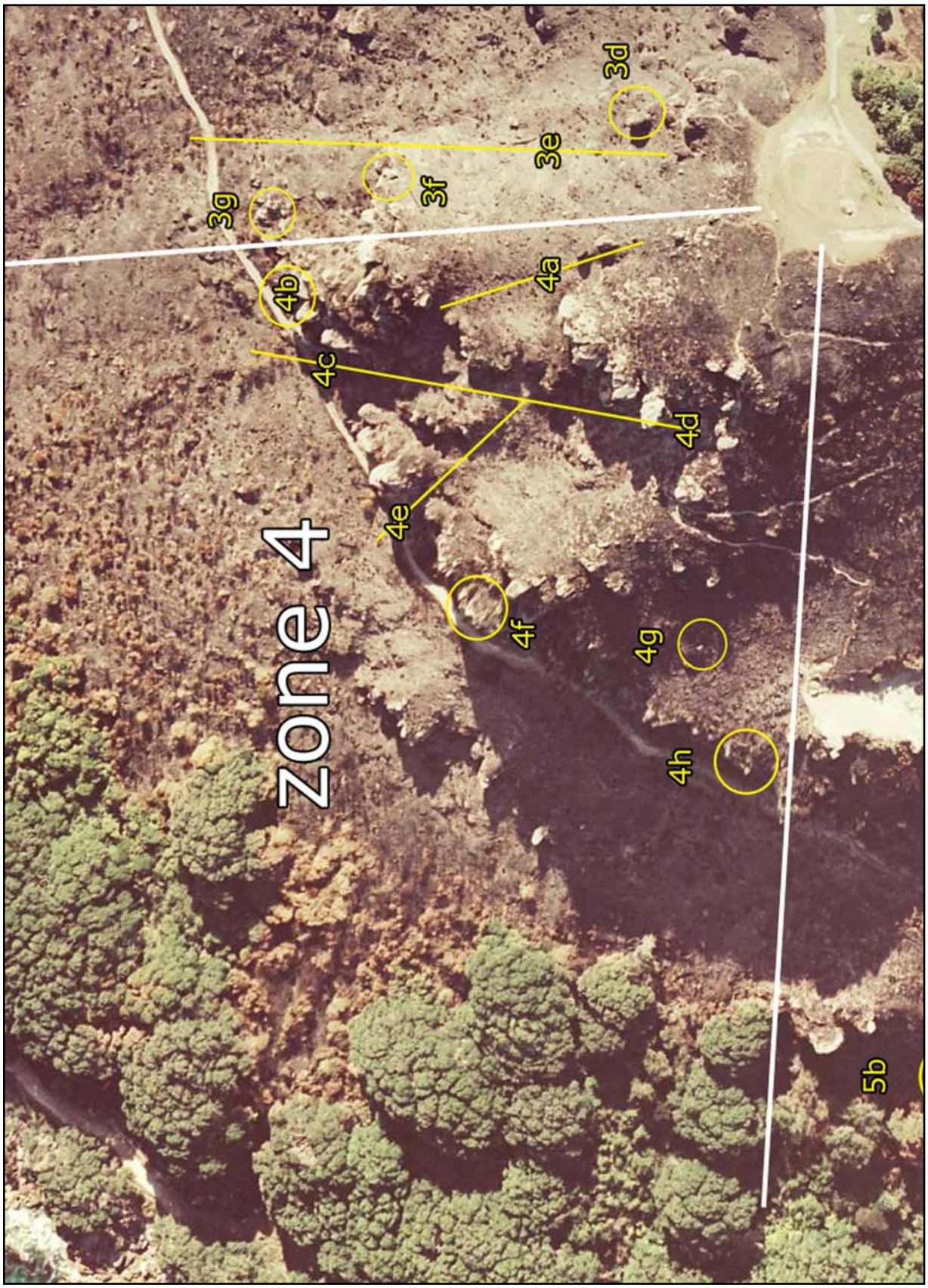

 

Photograph No 5; Aerial view of zone 3.

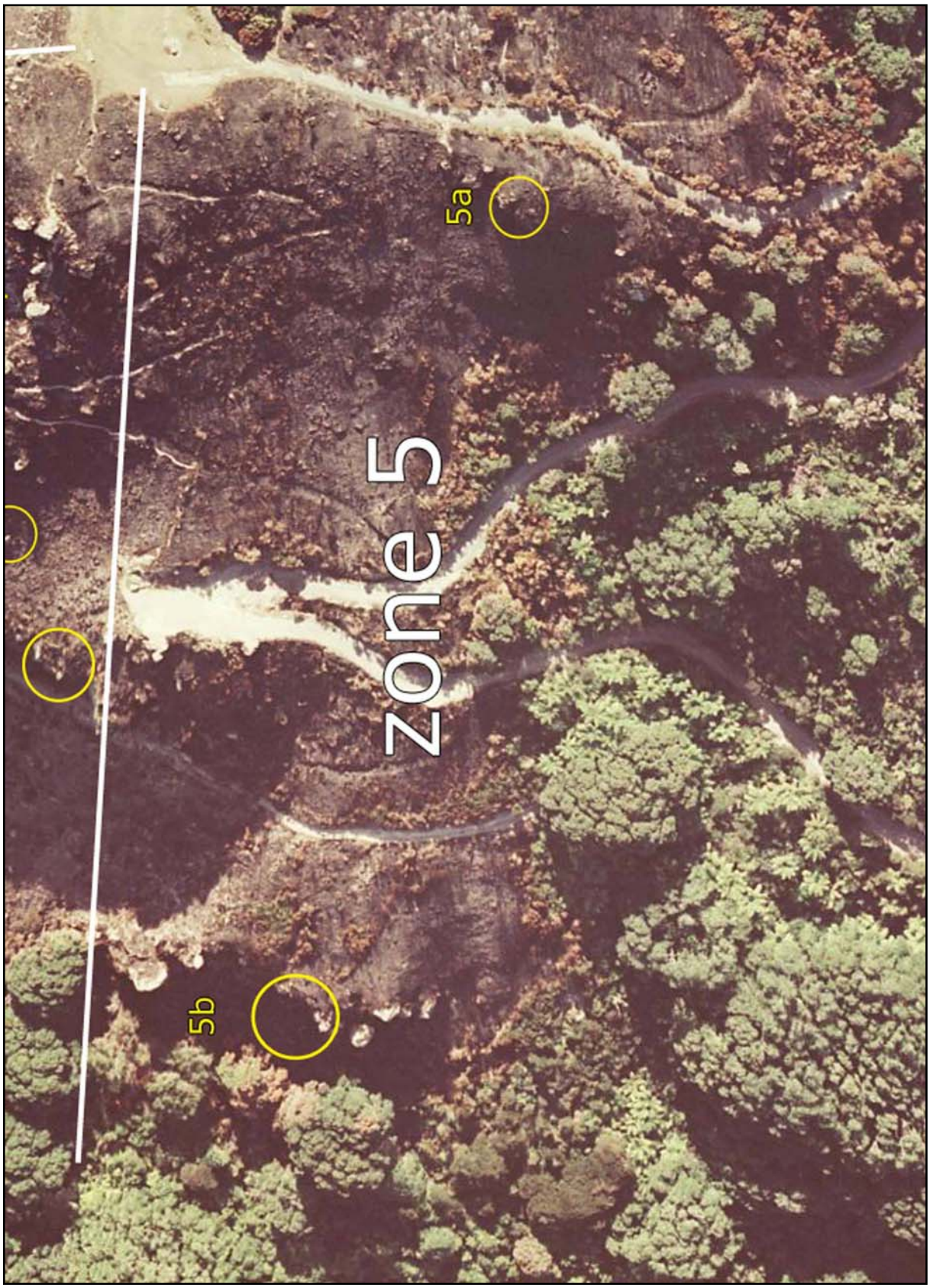


Photograph No 6; Aerial view of zone 4.



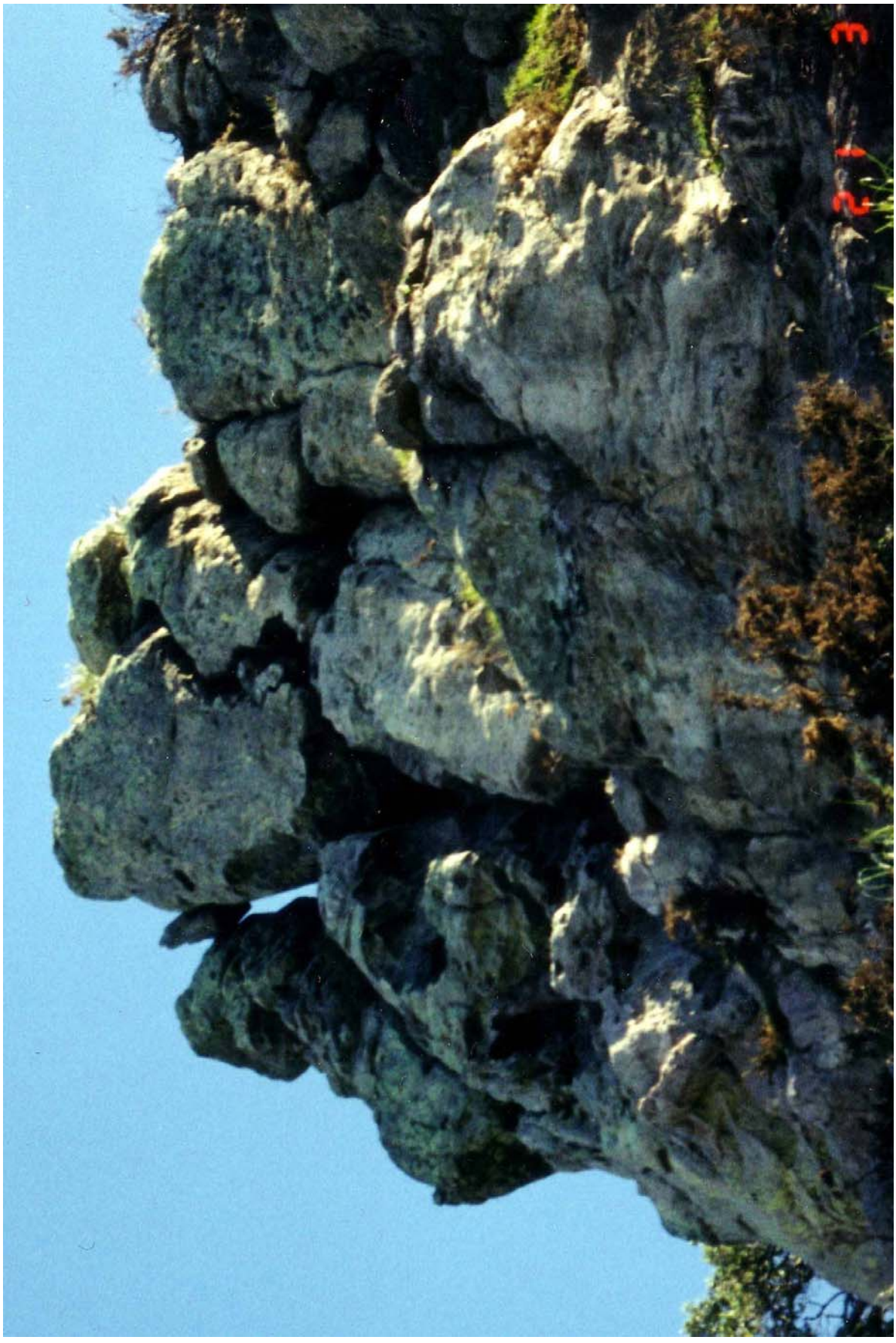
Photograph No 7; Aerial view of zone 5.



Photograph No 8; View to zone 1 & 2 from Base track.

Photograph No 9; *1a* east elevation.



Photograph No 10; *1a* view from above.


Photograph No 11a; *1a* view into rear joint.

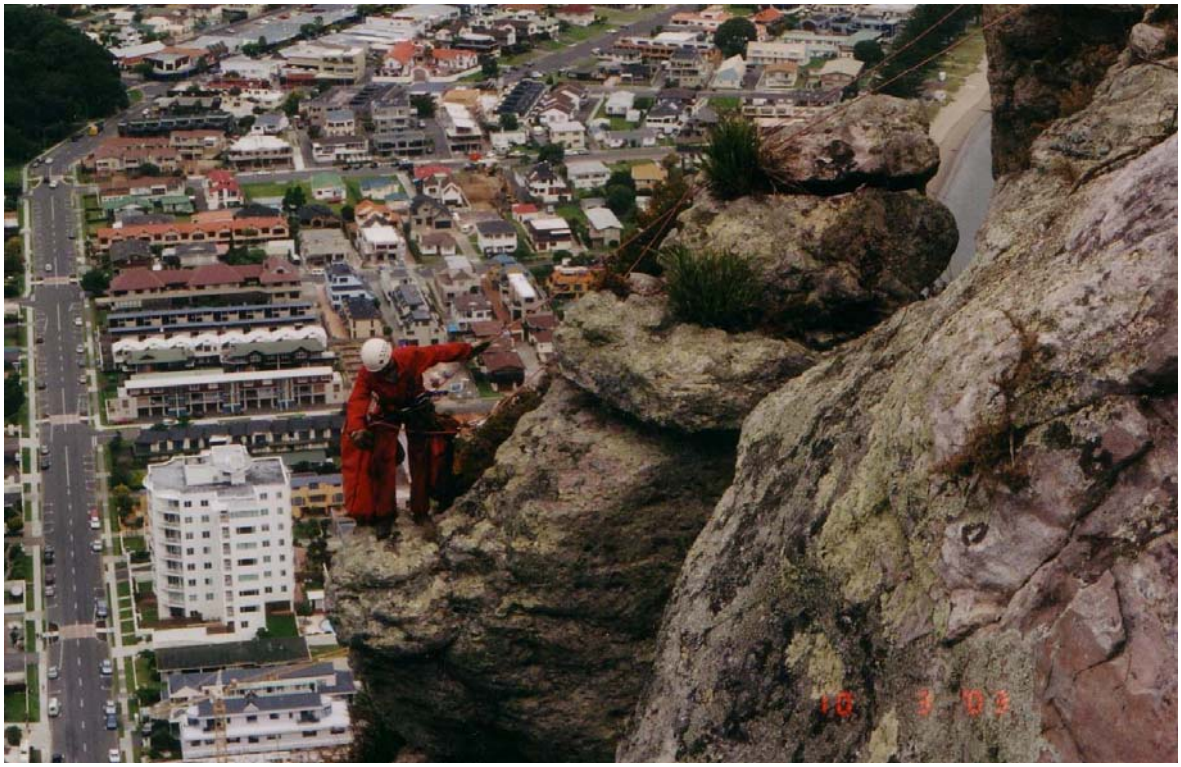
11b; *1a* view under centre block.

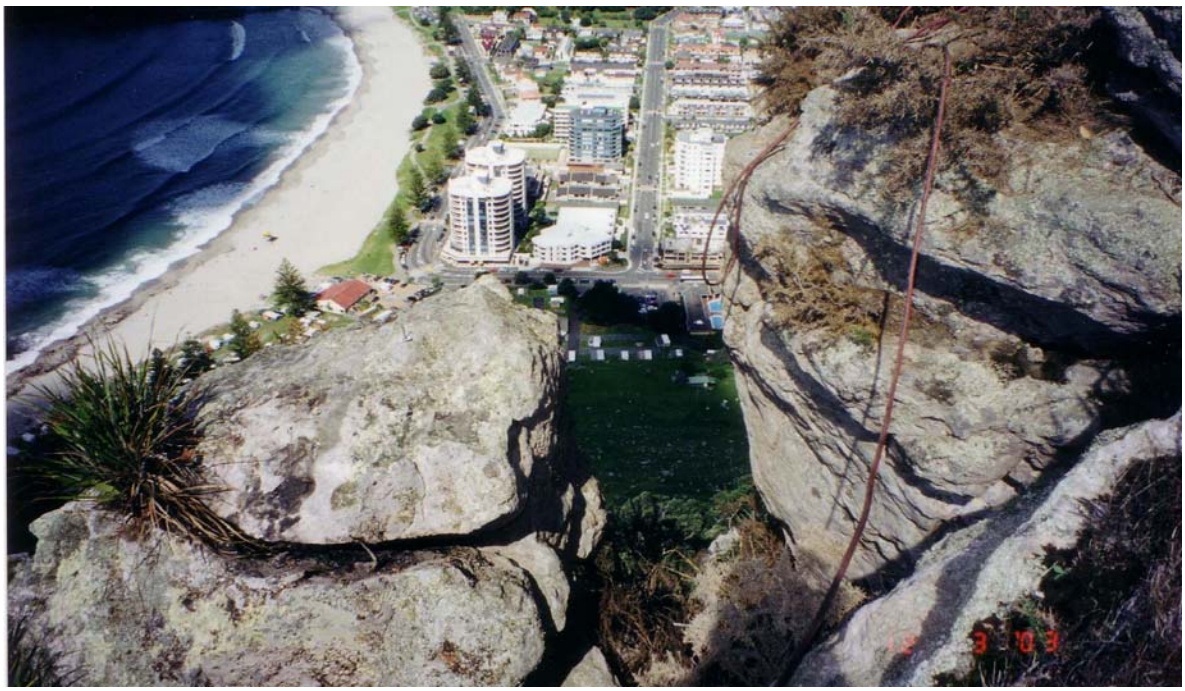
Photograph No 12; *2a* view from rock face to south.

Photograph No 13; *2a* view from north.



Photograph No 14; *2a* view from above.



Photographs No 15 & 16; *2b* being scaled, March 2003.

Photograph No 17 (sequence); *2b* falling towards Base track..

Photograph No 18; View up into zone 3 from the Oruahine track.

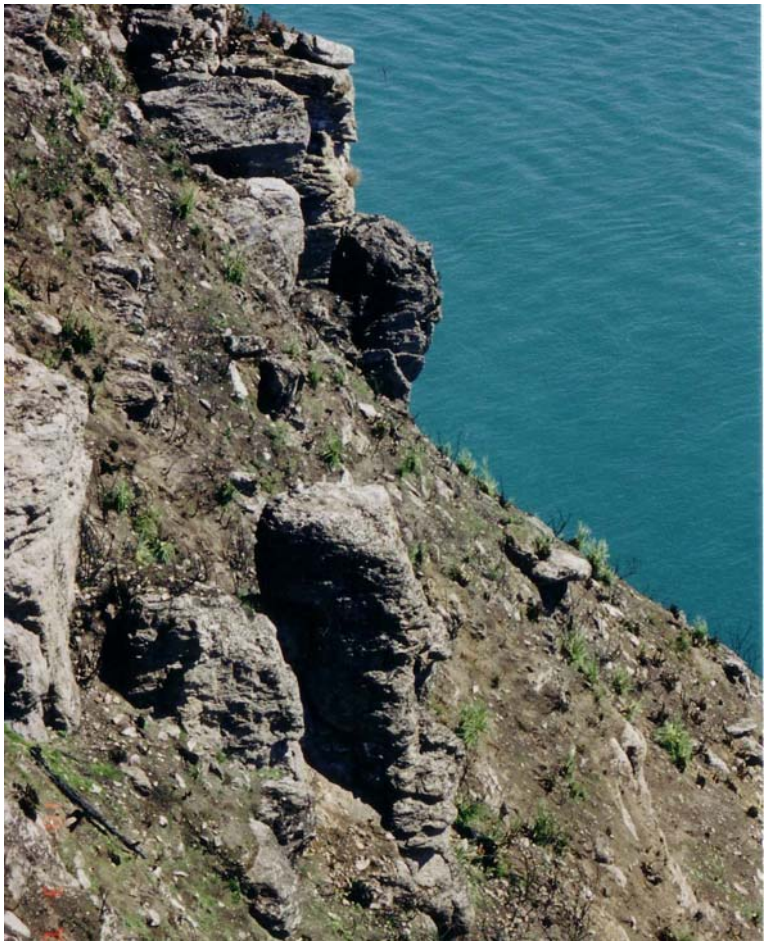
Photograph No 19; Top of bluff at *3a*.

Photograph No 20; View down to *3b*.

Photograph No 21; View down to *3c*.

Photograph No 22; Unstable column at *3d*.



Photograph No 23; View into gully at *4a*.

Photograph No 24; Rock climbing crag at *4b*.

Photograph No 25; Rock climbing crag at *4h*.

Photograph No 26; Oruahine track hit by rockfall at *4c*, March 2003.

Photograph No 27; View into gully at *4d*.

Photograph No 28; View to slope at *4g*.

Photograph No 29; Upper area of zone 5.

# 13 SURVEY MARKER DISTANCE RECORDINGS

## *13.1 Survey area at zone 1a; the camp bluff*

Refer to photographs 9 & 10 for marker locations.

Distances measured at March 2003 were:

Front Markers

| 1 | | | | |
|---|---|---|---|---|
| 3170mm | 2 | | | |
| 2220mm | 3500mm | 3 | | |
| 3702mm | - | 1823mm | 4 | |
| 5512mm | - | - | 1980mm | 5 |

Top Markers

| 6 | | |
|---|---|---|
| 2362mm | 7 | |
| 5702mm | 4469mm | 8 |

## *13.2 Survey area at 2a; a potentially unstable column*

One marker is installed in the top of the column and two on the outcrop to allow triangulation.

Refer to photographs No's 13 & 14 for locations.

Distances measured at March 2003 were:

Markers

| | | | |
|---|---|---|---|
| | 9 | | |
| 1961mm | | 10 | |
| 3457mm | 3350mm | | 11 |

## *13.3 Survey area at 2i; between the walls of a gully*

The gully behind a potentially unstable bluff at the northern end of zone 2.

Markers

| | | |
|---|---|---|
| | 12 | |
| 2885mm | | 13 |

## *13.4 Survey area at 3a; top of a potentially unstable bluff*

Four markers are installed around the tope of the bluff and the outcrop to allow triangulation.

Refer to photograph No 19 for locations.

Distances measured at March 2003 were:

Markers

| | | | |
|---|---|---|---|
| | 14 | | |
| 7560mm | | 15 | |
| - | 3575mm | | 16 |
| 8110mm | 5050mm | 4868mm | 17 |