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Tauranga City Council
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9th June 2006

Re: Review of Mauao Base Track Surfacing and Stability

1. Executive Summary

This report reviews the issues relating to the Mauao Base Track surfacing and stability. The result of our inspection and evaluation indicates that the aggregate used for resurfacing the track in 2005 is less than ideal. This material is one of the main causes of the high incidence of injury to visitors as well as the ongoing need for surface maintenance. The steeper track grades in places and some of the poor drainage details also contribute to the problems with the track surface.

Correction of the track gradient and drainage is recommended as well as provision of further, more appropriate track re-surfacing. The use of shell for track surfacing, if acceptable from an archaeological perspective, would be satisfactory only if other materials are blended with the shell to provide the required properties. A carefully selected crushed quarry aggregate is likely to be more effective in providing the best possible walking surface. In the long term, an asphalt surface or other hardened pavement is the only option for providing a durable surface that can sustain the very high visitor numbers.

The instability of the track bench does not yet pose a risk to visitors on the site, however coastal remedial work is recommended to reduce the rate of erosion by sea attack. Recommendations have been made on procedures to minimise the risk of incident whilst equipment is present on the track for maintenance activity.

2. Background

This report has been requested by the Tauranga City Council in response to concerns relating to the condition of the Mauao Base Track at Mount Maunganui. The Base Track is a 3.4km long walking track that follows the shoreline of Mauao from Pilot Quay to Adams Avenue near the motor camp. This track is the most popular walk on the site and visitor numbers in excess of 100,000 per month have been recorded. It is likely that over 1,000,000 visitors walk this track per annum and this number can be expected to increase as further residential development occurs within the vicinity.

The Base Track has been in existence for a long period and has from time to time been re-surfaced with aggregate material to provide a suitable all weather walking surface. Shell material from harbour dredging has been used extensively as a surfacing aggregate on the basis that it provides a good non-slip surface and that it is visually appealing. There is concern expressed in the Conservation Plan for Mauao (2004) that the archaeological integrity is compromised by the introduction of shell from harbour dredgings. The Mauao Management Plan (1998) however recommend the use of rhyolite and pipi shells for track surfacing on the basis that these materials are appropriate to Mauao.

In May 2005, a severe rainfall event resulted in numerous slips occurring on the slopes of Mauao, causing a significant amount of soil and debris to be deposited on the Base Track as well as erosion of the track in places. As part of the remedial work following this event, the entire Base Track was re-surfaced with a crushed greywake aggregate. Whilst this initially appeared satisfactory, the track surface has become loose and a large amount of the surfacing material has migrated off the track. In the period from Dec 2005 to March 2006, 15 injury accidents have been recorded on the Base Track. The majority of these are reported to be slipping accidents rather than tripping accidents, and at least 66% of these accidents have involved persons over the age of 40.

During the application of the greywake aggregate, the machinery used to transport and spread the aggregate caused rutting damage to the track surface and there was one injury incident arising from an excavator rolling off the track due to collapse of the ground from under the machine. As a result of these concerns, the remainder of the aggregate was delivered to the track by large helicopter at significant expense.

The above events and background have given rise to the following questions in relation to the Mauao Base Track:

- What is the most appropriate track surfacing material from the perspective of user safety, archaeological issues and long term maintenance?
- What action should be taken in relation to the track stability?
- What is the best methodology for applying the track surfacing material?

3. Base Track Formation

3.1. Gradient

In considering the suitability of a track surfacing material, it is worth evaluating the other track parameters that have an influence on the performance of the pavement.

The Base Track follows an elevation ranging between a few metres up to about 20 metres above sea level. Generally the track has grades of 10% or less but in some places the track gradient is up to 25%. The steep grades are mostly over a short distance, but there are some sections where the grade exceeds 15% for 20 metres or more. The steeper grade sections exist where the track climbs up or down on the undulating route around the base of the mountain and are a legacy of the original track alignment.

On steeper sections of track, rainwater is more likely to travel along the pavement and damage the surface. The steeper the track, the more severe are the effects of erosion during storm events. Also on steeper gradient sections of track, it is more likely that the feet of walkers will slide in wet or loose gravel conditions. Reduction of track gradient can markedly reduce the adverse effects of water erosion and the potential for visitors being injured by slipping

Best practice in track design and construction is to keep the gradient below 17% (1 in 6) and ideally less than 12% (1 in 8) for tracks that are walked by less agile people such as the elderly people commonly found on the Base Track.

The steep concrete section of track at the NW Rock has a gradient of 25%. There is a high slipping risk on this concrete section, especially when loose gravel spills onto the concrete from the track above.

Correction of the steeper gradient sections of track is relatively easy on all sections of the Base Track where a current gradient of 17% is exceeded.

This simply requires the filling of the low points with suitable fill material. It is acknowledged that cutting into the batters beside the track or excavating below the existing track level to obtain fill is unlikely to be acceptable on Mauao. The surplus slip material removed from Mauao after the May 2005 storm could be brought back onto the site and used for filling the track to reduce the gradient, provided the material is fairly dry at the time of placement and does not contain excessive amounts of organic material. Grade correction to reduce the steep grades is best carried out by surveying the existing track profile and then using simple geometric design methods to determine the depth of fill needed to achieve the required gradient. At the concrete paved area at NW Rock, the existing 25% grade could be reduced to 17% maximum by adding approx 1.2m depth of fill at the base of the steep slope. Where necessary this fill material would be retained at the outside edge with a stone retaining wall to match the other stone walls on the site.

3.2. Width

The walkway width on the Base Track is generally greater than 1.8m over most of its length. This is conducive to side by side walking which reflects the social nature of most of the small groups of people who walk this track. In a couple of isolated places the width reduces to approximately 1.2m where the edge of the track has been subjected to slippage. These localised narrow sections of track do not seriously affect the circulation of walkers on the Base Track because they are over a short distance only.

Narrow sections of track are potential impediments to equipment that could be used for track maintenance. There is increasing availability of track construction and maintenance equipment that that can pass along a 1.2m wide section of track. Use of such lighter weight equipment is preferable to minimise the damage to the track surface and the formation. The existing track width of the Base Track is considered to be satisfactory.

3.3. Drainage

The provision of good drainage on a track is a key to maintaining a good quality walking surface with low maintenance requirements. Whist the annual rainfall on Mauao is not extremely high, this site is subject to occasional high intensity localised storms such as that experienced in May 2005. During such events, good drainage can be critical in minimising damage to a track.

Parts of the Base Track are provided with a side drain on the upslope side. Such a drain is very effective at intercepting water flowing over the slopes above the track. A side drain collects this overland flow and prevents it from running over the track surface and scouring the pavement material. Some sections of the Base Track do not have a side drain on the upslope side. Provision of a side drain on these sections is recommended. This would reduce the amount of water that is currently washing across the track and eroding the seaward edge.

Provision of good pavement drainage by having a "crowned" track surface or a single slope of approximately 3% to one side is an effective means of ensuring the pavement remains free of surface water. Most of the base track currently has some cross fall to one or both sides. In places the cross fall is as much as 10% which is more than is necessary for good drainage. Excessive cross fall can create difficulty for physically challenged people to negotiate and for wheelchair passage.

In some places, groundwater is seeping from beside the track. This is generally well intercepted by side drains to prevent this flowing over the track surface. At locations of groundwater seepage, the side drain should be at least 200mm deep to ensure that the water table is lowered to well below the track pavement level to avoid the seep water from softening the track structure.

There are several culvert pipes passing under the track along the length of the Base Track. These consist of plastic pipes and corrugated steel pipes ranging from 100mm to 300mm in diameter and the occasional timber box culvert. Many of these pipes project out over the slope on the seaward side. Whilst this may be aimed at projecting stormwater flows out onto the rocky shore, in many cases the projecting culvert end directs stormwater onto ground that is likely to erode and has the potential to de-stabilise the adjacent track formation. Reducing the projection of these culvert pipes and installation of flumes or "socks" to direct water to the rocky shoreline is recommended. The outlet of the flumes and socks may need to be provided with rock scour protection.

Culvert pipes should be located wherever there is a storm watercourse leading down the slope above the track and otherwise at intervals not exceeding 25m spacing. The side drains should slope to the culvert locations and wherever possible, be arranged such that if any one culvert were to block, water can flow along the side drain to the next culvert. This is not be possible for culverts located at dips in the track. Any new culverts that are installed should be 250mm or 300mm in diameter so that they have capacity to cope with major storm events.

4. Base Track Pavement

4.1. Existing Pavement

Prior to 2002, the Base Track was surfaced at 4yr to 6yr intervals with dredged shell material. Our exploratory excavation of the track surface in two places revealed that a layer of shell still exists below the pavement surface layers to a depth of about 100mm. This shell layer is effective in providing a sub-base pavement layer, and where it has become mixed and compacted with other ash, it has provided a well bound waterproof layer.

After the May 2005 storm, most of the Base Track pavement was resurfaced with a crushed greywake aggregate having a 7mm maximum particle size. We have been advised that this was spread in a layer of approximately 50mm thickness and then an application of lime mixed in before wetting and compacting. This was applied in the belief that it would bind the aggregate. We understand that no lime reaction testing with the particular aggregate has been carried out. Based on the small stockpiled sample, the aggregate appears to have very little silt and clay fines content. Consequently it is unlikely that the added lime was effective in binding this material, because of the lack of clay fines which are necessary for lime stabilisation.

Currently the Base Track pavement is characterised by a layer of loose, unbound gravel consisting of particles in the 5mm to 7mm range. A large amount of this material litters the ground at the sides of the track and has been washed off the surface in places where water has flowed over the track. It is probable that as much as 50% of the aggregate that was applied has, in the 12 month period since application, migrated off the track and is wasted. This particular greywake aggregate is poorly suited for walking track paving. It is likely that this aggregate is produced as a free draining filter material for building work rather than as a pavement material. The loose gravel surface has probably been a significant factor in a high recorded number of the injury incidents caused by slipping.

The small amount of fines that was present in the aggregate has been washed to the bottom of the layer and in some places has bound with the larger aggregate below. In these places, sweeping away the loose gravel reveals a well bound track pavement. This has a much better skid resistance in dry conditions than the loose gavel surface. Where larger aggregate particles are appearing on this well bound surface, the skid resistance is likely to be good in both wet and dry conditions. Hence, sweeping the loose aggregate off the track is recommended on all sections where the gradient is greater than 8% and in other locations where it exists as a thin layer over a compacted base. This swept material should be retained in stockpiles for future blending and use as surfacing.

Any aggregate track surface will erode over time. This is because of losses of material from foot traffic wear, water erosion and wind erosion. On tracks that have a high level of foot traffic, the loss of surface material could be 50mm or more of depth per year. This loss is evident on some of the steeper sections of track where large rocks provide a reference to track level. The loss of surface will be faster when the track surface aggregate consists of poorly bound small gravel particles. On tracks that have very high foot traffic numbers, the only way of overcoming the loss of surface material is to provide a hardened track pavement such as asphalt, concrete, chip seal or paving blocks.

The evidence of shell midden in the ground adjacent to the Base Track is plentiful. In several places some of this shell midden has migrated across the track to become interspersed with the track aggregate. Such mixing of material from beside the track is likely to continue. The migration of ash and leaf litter onto the track surface in some places has provided the missing fines in the aggregate, and on these sections the track surface is better bound and less prone foot slippage.

4.2. Pavement Functions

For a surfacing material to perform effectively as a walking track pavement, the following attributes are required:

- Slip resistance. This is necessary to provide traction for footwear and reduce the risk of slipping incidents causing injury. Angular surfacing particles or broken shells that provide a roughened surface are better than fine, smooth or rounded particles. A well bound surface will provide better slip resistance than loose gravel.
- Water proofing. The strength of the underlying pavement sub-grade and formation is very dependant on how dry the lower pavement layers can be kept. A well bound waterproof aggregate pavement or a waterproof asphalt or concrete layer is much more effective at keeping the sub-grade dry than a loose permeable aggregate layer.

- Resistance to water and wind erosion. Under severe storm events, it is inevitable that water will find its way onto the track surface and needs to flow over the surface before draining off. A well bound aggregate surface or a hardened paved surface will be more resistant to water and wind erosion than a loose pavement.

4.3. Pavement Options

The following pavement options are evaluated:

- Shell. Crushed shell pavement aggregate provides good slip resistance. Raw shells are however poor at providing a waterproof layer over the underlying track surface, unless the shells are mixed with finer soil particles, to bind them and reduce permeability. Crushed shell can release lime which has the effect of binding the layer, provided a portion of fine material is present. Hence, if shell material is used, it should have a high proportion of broken shell and should be blended with finer materials. A satisfactory mix is likely to consist of approximately 75% crushed shell, 15% dune sand and 10% ash or clay (the slip material removed from Mauao may be suitable if it is free of vegetation). If this approach is proposed, preparation of a trial mix is recommended because the optimum mix will depend very much on the nature of the shell material available.

  Shell based surfacing materials are unlikely to be as durable as good quality aggregate materials for track surfacing because shells tend to break down under foot traffic and become finer and hence more prone to water and wind erosion. As a rough indication, shell surfacing on Mauao may have a life of only half that of a good quality aggregate surface. This may mean that the shell surfacing layer would need to be re-applied every two years.

  The use of dredged shell based track surfacing on tracks is subject to addressing concerns over the potential compromising of the archaeological integrity of Mauao.

- Crushed Aggregate. For a track surfacing material, the aggregate grading (range of particle sizes) is more important than the mineral type from which the aggregate is sourced. The key requirements are to ensure there is a portion of 3% to 5% of clay fines and a well graded range of particle sizes up to the maximum particle size. The maximum particles can be up to 40% of the aggregate layer thickness to be applied (ie 20mm diameter for a 50mm thick pavement layer).

Angular broken stone particles are preferred to rounded river or beach gravel. When the above properties are met, and the pavement is compacted in place, a waterproof and slip resistant pavement results. Such a pavement will resist water erosion but under high foot traffic will loose material from the surface over time due to wear.

The source of the mineral aggregate may influence the durability of the aggregate and the rate of surface wear. A crushed andesite material is likely to be quite durable whilst a crushed rhyolite material may weather fairly quickly and suffer from faster loss of surface due to wear on high use tracks. A partly weathered crushed greywake aggregate is often ideal because it tends to have the required clay portion and angular particles as well as the required range of aggregate sizes.

A good quality aggregate surface consisting of a durable material, could be expected to have a life of 3 to 4 yrs on Mauao before re-surfacing becomes necessary. An aggregate surface material is recommended in preference to a shell surface because of this better durability and reduced future maintenance.

- Asphalt: Provision of a hardened track surface is likely to become necessary in the medium future if the pedestrian numbers on the Mauao Base Track continue to increase. Asphalt offers a versatile and durable pavement surfacing option for the Base Track in the long term. It can provide a wear resistant waterproof surface that has good slip resistance and is easily repaired in the event of storm damage or tree root movement. The key advantage to the Council from providing an asphalt surface would be a significant reduction in maintenance costs. The benefit to users would be a safer and more pleasant walking surface. An asphalt surface would be more suitable for wheelchair use than the current aggregate surfacing. There may be some public resistance to the use of a hardened surface on Mauao, however any adverse comment is likely to be offset by the favourable response from most users of the Base Track who appreciate the better walking surface. Any installation of asphalt or other hardened surface should not be carried out until the grade correction and drainage issues are first dealt with.

  An asphalt track surface could be expected to last for 10 to 15yrs before re-surfacing becomes necessary.

4.4. Pavement Aggregate Sourcing

The selection of the best aggregate for re-surfacing the Base Track is a matter of evaluation of the possible sources of material within the Bay of Plenty area and assessing these against the desired properties. As indicated above, the aggregate grading is more important than the actual mineral type.

A possible approach is to prepare a specification for track surfacing aggregate which defines the particle size grading curve, clay content, particle shape and other properties. Suppliers could then be invited to provide samples and prices for aggregate products that they can supply that are within the specification. Council can then evaluate the options and could either enter into a bulk supply contract with a single supplier, or establish a register of approved track surfacing materials. Such an approach has been used successfully by other Councils.

It should be noted that maintaining a consistency of material grading and properties for supply of aggregate over a period of time is difficult for a quarry because of the typically changing nature of quarried rock as quarry faces are worked. There is merit in retaining a sample of the approved material for comparison with future deliveries to ensure the required properties are maintained.

4.5. Pavement Thickness

The thickness of a track surfacing layer required is generally determined by the strength of the underlying ground and the amount of foot traffic. In the case of the Base Track, the formation is in most places a reasonably firm.

For a good quality aggregate pavement, a compacted layer thickness of 50mm would suffice. To achieve this, a loose layer of approx 60mm would need to be applied. If a blended crushed shell mix is to be used for surfacing, a thicker layer is recommended given that it is expected to be less durable than aggregate. A shell layer is also likely to compact more under compaction equipment, hence if a compacted layer of 75mm thickness is required, a loose layer in excess of 100mm is necessary.

4.6. Pavement Placement

The application of track surfacing material involves transportation to the site and the placement and compaction. The application of a 50mm surface on the Base Track would require over 300 cubic metres of aggregate having a weight of approximately 500 tonne.

For the relatively short cartage distances from the road at each end of the Base Track, transport of the surfacing metal by small dumper is likely to be the most cost effective method. The type of cartage equipment should be selected taking into consideration the following:

- Width of equipment. Much of the track can safely accommodate vehicles up to 1.5m in width, however in the locations where track width is limited, the equipment width may need to be limited to 1.2m maximum.
- Ground pressure. Because the existing track pavement is relatively thin, it does not have the capacity to carry heavy wheel loads. Vehicles that have low pressure, large footprint tyres or crawler tracks will cause less rutting than vehicles with conventional road tyres.
- Manoeuvrability. Some parts of the track have limited turning areas. Equipment that can spread aggregate easily and can turn in a small space or be driven easily in both directions have advantages over use of less manoeuvrable equipment such as a quad bike and trailer.
- Cost effectiveness. Slow, small capacity equipment such as power barrows are unlikely to be economic for this site because of the long cycle time needed from load point to delivery point.

Use of a helicopter to deliver aggregate to the western side of Mauao may be the most economic method. Careful planning and selection of the best aircraft is necessary. Use of a very large helicopter as was the case for the re-surfacing carried out in 2005 is unlikely to be efficient. The efficiency of helicopter transport is very dependant on minimising cycle time and placement time. Larger helicopters tend to be less manoeuvrable and take longer to pick up and accurately place each load. Smaller aggregate bags placed at regular intervals along the track using a smaller helicopter are likely to involve less helicopter cost and will require less spreading and placement cost on site. A Squirrel type helicopter with a lift range between 900kg and 1200kg is often used for this type of work by the Department of Conservation.

Once delivered to site, a system should be put in place to ensure the spreading rate is uniform. This may be as simple as marking the length of track over which a dumper load is to be spread or placing helicopter lifted bags at pre-determined spacings. Spreading of aggregate should, if possible, be by tipping from the back of a dumper. Where manual shifting of material is necessary, this should be done with a blade or shovels rather than rakes, so that the risk of segregating the aggregate particles is minimised.

As soon as practicable after placement, the spread aggregate should be compacted with appropriate equipment. On this site, use of a self propelled vibrating roller would be ideal. Allowance should be made for a compaction factor in the aggregate quantities supplied and spread. Depending on the type of material being used, an additional 10% to 20% of "loose volume" aggregate is necessary to provide the required compacted volume.

Lime stabilisation of a well graded aggregate for track surfacing should not be necessary if it is properly placed and compacted. Stabilisation with lime may reduce the rate of wear of the surface, however any attempts to lime stabilise an aggregate should be based on specific lime reaction tests with the material being used. It is also noted that proper mixing equipment is necessary.

5. Base Track Stability

5.1. Slope stability

Parts of the Base Track are benched on ash soils and slope debris at the base of the mountain above the high tide zone. This relatively loose material is prone to landslide, especially when it becomes saturated with water. Slipping occurred in several locations during the May 2005 storm. It is likely that similar slipping will continue to occur occasionally. Such slips will be relatively infrequent and they are not a risk to visitor safety any more than the other natural hazards that are present on this site or other parkland sites.

The risk of future landslide can be reduced by providing good track drainage as noted above. This is aimed at preventing water from running over the seaward edge of the track as well as reducing the amount of water that can saturate the soils under the track formation.

Provision of rock filled gabion basket walls along the edge of the track is not recommended. Such walls are inconsistent with the natural character and environment of the site, and even plastic coated wire gabion baskets will have a limited life in these exposed coastal conditions. Where use of retaining walls is required, a stone wall similar to the existing walls on the site would be more appropriate.

There is a risk of landslip occurring under the weight of equipment on the track during maintenance activity. Such an incident resulted in injury to an operator in 2005. From the description of this incident, it appears that the ground collapsed under the equipment whilst it was stationary. To minimise the risk of injury from such hazards, the following recommendations are made.

- Maintenance work requiring the passage of heavy equipment on the track should be carried out during the drier summer months rather than when the ground is saturated.
- Prior to undertaking maintenance work that requires equipment access, the track formation should be inspected by a qualified geotechnical engineer who may recommend maximum equipment weights and other conditions on access.
- Vehicular equipment used on the track should be fitted with roll cage protection and seat belts.

5.2. Coastal attack

A section of track between NW Rock and North Rock follows the high tide margin closely and consists of an eroded soil edge above a rocky intertidal zone. The shore edge is characterised by mature pohutukawa trees with exposed roots over the eroding ash at the toe of the slope. In places the track bench is undercut by up to 500mm with a risk of partial collapse of the track formation.

The erosion and loss of this coastal edge is part of the natural coastal erosion process and is inevitable at the coastal fringes of a relatively young volcano such as Mauao. Eventually the sea will reclaim more of this exposed side of Mauao and the pohutukawa trees and track bench may be lost. Prevention of this would require extensive heavy coastal protection which is inappropriate for a natural parkland site.

The rate of erosion of this exposed coastal section could however be slowed by carrying out non intrusive armouring of the exposed toe of the ash slope. The intertidal zone in this location is littered with large rocks that have rolled from the upper slopes of the mountain or have been dislodged from the base of the slope. We believe it would be possible in calm sea conditions for an excavator to access this section of shore by working from a barge. This would be used to re-locate some of the shoreline boulders to the high tide line where they can be backfilled to provide protection to the pohutukawa tree roots and reduce the rate of track bench erosion. An excavator of 30 tonne size fitted with a long reach boom and a rock grab is likely to be best suited for this work. A coastal consent would be necessary for such work.

The track surface along this low section is prone to wave splash in stormy weather. Consideration should be given to stabilisation of the aggregate surfacing on this section of track or the hard surfacing of this section with asphalt after the coastal protection has been carried out.

6. Recommendations

6.1. Short Term Recommendations

- Sweep the loose aggregate from the track surface where grades are greater than 8% and elsewhere where a thin layer of loose gravel overlays a bound track surface.
- Carry out coastal rock protection between NW Rock and North Rock using rocks from the site. Backfill the rocks with soil/ash material to cover the tree roots.
- Modify the drainage culvert outlets to ensure they are not encouraging erosion of the ash soils at the outlets.

6.2. Long Term Recommendations

- Remove the steep grade sections of the track by bringing in fill material to ease the longitudinal track profile. (The concrete track section at NW Rock is the highest priority).
- Improve the track drainage and profile to facilitate water runoff.
- Provide a well graded aggregate surface to the whole track
- Consider instigating a programme of progressively providing an asphalt surface to the full Base Track to minimise future track maintenance and the risk of injury to visitors.

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