REVIEW OF EARTHWORKS PROVISIONS

HAURAKI GULF ISLANDS SECTION AUCKLAND DISTRICT PLAN

Final Report to:

City Planning
Auckland City Council

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Executive Summary

A review has been undertaken of the threshold limits for earthworks as a permitted activity in the Hauraki Gulf Islands (HGI) Section of the Auckland District Plan.

The following is a summary of the key findings of the report.

- A primary reason for the implementation of earthwork controls on the HGI is perceived to be the need to minimise erosion and sedimentation and the report has been prepared from this perspective.

- Elevated levels of sediment can arise from a number of sources. Observed activities that result in elevated levels of sediment on the Hauraki Gulf Islands include earthworks for development, cultivation (such as for viticulture or pasture renewal), road maintenance activities, works in a watercourse etc. The sediment related effects of some of these activities are regulated at a regional level, such as by the Auckland Regional Plan: Sediment Control (earthworks) or the Proposed Auckland Regional Plan: Air, Land and Water (cultivation and works in a watercourse). However these thresholds for regional consent appear to have been proposed from a mainland viewpoint and not from an island perspective where catchments are small. Thresholds of regional consent for some activities can be quite high (e.g. earthworks) and significant adverse effects can occur below this level on the small catchments of the HGI. It is recommended that this is discussed with the regional council and, in the meantime, that controls be restricted to those relating to earthworks.

- There is always some background level of sediment that occurs from natural sources. However, no sediment loss information has been found that relates specifically to the Hauraki Gulf Islands. Information from the wider Auckland region has therefore been used in this report, which although considered relevant, is still not site specific. It is suggested that a study be undertaken to more definitively establish natural sediment levels of the HGI. Limits for permitted activities could then be established with more surety.

- An assessed sediment yield of a typical HGI catchment (short, sharp slopes but with relatively stable topography) has been taken to be about 150 tonnes/km^2/year. The level when an adverse effect might occur has been assumed to occur at a slightly higher level (200 tonnes/km^2/year).

- The Universal Soil Loss Equation has been used in this report to compare sediment yields arising from different earthwork sites. Catchment derived information has not been used as this is considered to be too generic and does not take sufficient account of individual site characteristics. Potential sediment yield from earthwork sites ranging in area from 100 m^2 to 2,500 m^2 (the minimum Auckland Regional Council threshold limit), and on slopes from 1% to 25% have been assessed.

- These assessments show that slope has a dominant effect on sediment yield. Site area, in comparison, has a much lesser influence on sediment yields. The volume of earthworks is

not considered a relevant factor in determining the threshold limits for earthworks as a permitted activity.

- High levels of sediment are shown to arise even from the smallest earthwork site, and these levels can be significantly higher than that from natural sources. The only time that this will not occur is if there is no runoff from the site (e.g. runoff drains to ground such as in sand soils), or if it does not rain during the period of exposure.

- Well constructed and maintained erosion and sediment control measures should be implemented on all sites that can potentially discharge runoff because of the high levels of sediment that can be generated.

- Threshold levels for earthworks as a permitted activity are suggested. Above these thresholds, resource consents should be required. It is recommended that earthworks be provided for as a permitted activity without thresholds, on all sites that drain to ground. Furthermore, it is suggested that earthworks up to 50 m^2 be allowed as a permitted activity in most land units irrespective of slope gradient. Permitted activity thresholds recommended for all remaining sites are based on a combination of site slope and surface area, and after comparison of sediment yields from earthworks and assessed natural yields. From this it is suggested that sites up to 400 m^2 and 5% slope could be considered as permitted activities subject to sediment control. All earthworks provided for as a permitted activity should be subject to performance standards requiring erosion and sediment control measures to be implemented and maintained while soil is exposed.

  Proximity to receiving environments has not been found to play any significant part in determining these limits on the Hauraki Gulf Islands.

- On most small earthwork sites, erosion and sediment control measures can be simple, cheap and easily implemented (e.g. topsoil bunds, silt fences etc). It should be possible to achieve acceptable sediment control through techniques selected from a general "tool bag" of control procedures. Various ways of promoting these measures are suggested.

- It is recommended that Erosion and Sediment Control Plans approved by the Council be required for sites of high erosion potential. Such sites are suggested to be those with average slopes greater than 15% or where they have a catchment of 2 hectares or more. These two parameters are proposed because potential sediment yield increases disproportionally as the slope angle increases, and because above site runoff flowing through earthwork sites can generate large sediment loadings. The area of a site has not been included as a trigger because of its relatively low influence on sediment yield.

- Some earthmoving activities are currently exempt from controls in the district plan. These include earthworks associated with effluent disposal systems, pile foundations for buildings, network utility trenching, domestic gardening and horticulture, and road use, upgrade and maintenance. In terms of effects and consistency of application, it is suggested that most of these exemptions be reviewed. In relation to road upgrade and maintenance works it is suggested that the sediment control implications of these works be addressed through a specifically prepared Road Maintenance Erosion and Sediment Control Management Plan.

- It is recommended that an awareness programme be undertaken to advise of acceptable erosion and sediment control practices. This could include some upgrade of the present Auckland City Council advisory diagrams, photographs or drawings showing good and bad practices, displays etc.

- A registration system is recommended for those involved with earthworks on the Hauraki Gulf Islands. Registration could require completion of a focused training course with provision for annual "top-ups". It is suggested that one such registered person should be on site at all times while the site is bare and work is occurring. It is further suggested that Erosion and Sediment Control Plans only be accepted from registered personnel. The circumstances of how registration could be curtailed should be clearly detailed.

REVIEW OF EARTHWORKS PROVISIONS

HAURAKI GULF ISLANDS SECTION - AUCKLAND DISTRICT PLAN

1.0 THE BRIEF AND METHODOLOGY

A review of the threshold limits for earthworks as a permitted activity was required for the Hauraki Gulf Islands (HGI) Section of the Auckland District Plan. A review of the work already completed was to be undertaken and typical sites and practices reviewed. A report was to be prepared.

An initial meeting was held with Auckland City Council (ACC) planning staff on 18 September 2001 to discuss the project. Selected background material was provided both at this meeting and also at later dates. This material consisted of:

- City of Auckland – Operative Plan Hauraki Gulf Island Section – 1996. Selected excerpts including relevant definitions and a description of the Land Units.
- Selected excerpts from a report prepared by Hill Young Cooper entitled "Hauraki Gulf Islands – Review of Earthworks, Indigenous Vegetation and Lot Coverage Mechanisms". Prepared for Environmental Planning Division, Auckland City Council. November 1999.
- Discussion Document: Review of Gulf Earthworks Rules. November 2000.
- Summary of comments to discussion paper. 31 September 2001.
- Auckland City Operative District Plan (Isthmus Section). Proposed Plan Modification 75 – Changes to Rules for Earthworks and Excavation. Dated 21 October 2001.

Site visits were made to Great Barrier Island and to Waiheke Island on 23 October and 1 November 2001 respectively. Attendees consisted of Ms K Dorofaeff and Mr M Dendale of ACC (Senior Planners), and B Handyside of Erosion Management Ltd. Office discussions were held with Mr L Dixon (Compliance Officer) on Great Barrier Island and Mr R Osborne (Senior Planner) on Waiheke Island. Mr J Griffith (Compliance Officer) attended three of the site inspections on Waiheke Island. Four earthwork sites were inspected on Great Barrier Island (estimated sizes of 200m^2, 1000 m^2, 2500 m^2 and 1 hectare), and six on Waiheke Island (with estimated sizes of 200m^2, 1000 m^2 [2 sites], 2500 m^2 [2 sites], and 1 hectare).

2.0. REVIEW OF PREVIOUS REPORTS

Relevant conclusions from the documents reviewed are summarised as follow.

Report: *Hauraki Gulf Islands – Review of Earthworks, Indigenous Vegetation and Lot Coverage Mechanisms. Hill Young Cooper 1999.*

1. A volume basis is not the most appropriate when identifying when adverse sedimentation or visual / landscape effects may occur on the HGIs. Controls based on surface area and slope were suggested.
2. Current trigger thresholds were considered to be lower than necessary to control sedimentation effects.
3. Permitted activity cut-off thresholds of 100 m^2 (in erosion prone or sensitive areas) and 200 m^2 elsewhere were suggested on slopes less than 25%. It was suggested that a resource consent be required for earthworks outside these thresholds

Discussion Document: *Review of Gulf Earthworks Rules. Auckland City Council*.

1. The discussion document identified sediment as being one of the main adverse effects that can result from earthworks.
2. A change was promoted from the volume-initiated triggers of the existing earthwork rules to ones based on exposed surface area and slope angle.
3. Permitted activity thresholds varied from zero to 100 m^2 to 200 m^2 provided that the slope angle was less than 25%.
4. Non-notified discretionary and discretionary categories were proposed. The upper limits of the non-notified discretionary category varied from 500 m^2 to 1000 m^2 provided that the slope angle was less than 25%. The discretionary category covered the remainder.

3.0. THE ISSUES

A wide range of matters can be considered by those processing resource consent applications for earthworks. A summary of those identified on the Auckland Isthmus included the following:

- water quality
- tracking of sediment onto roads
- traffic management
- noise
- dust
- depth of cuts/fill, surcharge (stability issues)
- volume of fill (through increased magnitude of works e.g. longer duration therefore more impact on traffic, dust, etc.)
- effects on infrastructure
- flood plains/secondary flow paths, off site stormwater etc.
- effects outside the site or on neighbouring sites
- history of the site e.g. deposited fill on site
- soil erosion on site (e.g. creep)
- contaminated sites

Although discussions with HGI staff did not go into these matters in such detail, it could also be expected that the matters identified above would apply equally on the HGI. Particular issues identified on the HGIs included the control of sediment and those relating to the natural landscape, archaeological sites, traffic and noise.

There is therefore a wide range of matters that can potentially be assessed as part of an application for earthworks consent. The primary reason for the implementation of earthwork controls on the HGIs is understood (from the ACC discussion document) to be the need to minimise erosion and sedimentation. Protection of the landscape and natural environment are also considered to be significant issues.

This report focuses on the sediment related issues associated with earthworks.

4.0 SOME BACKGROUND INFORMATION ON SEDIMENT

4.1 Soil Type

If there is no discharge of sediment from an earthworks activity, then there will be no off-site sediment related effect. Sediment related regulatory measures are therefore not required where stormwater is retained on site such as occurs through infiltration to ground in high percolation soils (e.g. sand).

4.2 Volume of Earthworks

Sediment yield from earthworks arises from the erosive influences of raindrop impact or runoff on exposed soil. It is a reflection of the surface area that is exposed, the slope of that land and the time of exposure. The actual volume of soil to be worked is irrelevant in this context except perhaps as an indicator of the duration of soil exposure (a project involving large volumes conceivably will take longer than one with smaller volumes). Volume has therefore only an indirect effect on sediment yield, and regulatory controls based on volume are not well related to the effects of sediment runoff.

4.3 Land Slope

Steeper slopes have much more impact on sediment generation than do gentle slopes. For example, an increase in slope from 5 % to 10 % for a 200 m^2 earthworks site increases the potential of sediment generation by more than two and half times (see Table 7 in the USLE calculations in Appendix A). Slope is therefore a critical factor in sediment yield.

4.4 Area of Earthworks

Larger earthwork sites have more surface area exposed and available to be eroded than do smaller sites and therefore have more potential to generate sediment. However, the area of exposed soil by itself does not have the same influence on sediment yield as does slope angle. For instance, increasing the size of earthworks from 200 m^2 to 400 m^2 on a 5 % slope increases potential sediment yield by only 13 % (see Table 7 in the USLE calculations, Appendix A). The area of a site is therefore not, by itself, a particularly critical factor in sediment yield. Slope is far more influential.

4.5 Representative Sediment Yields from Different Land Uses

Some generalised sediment yield information relevant to the Auckland region is presented in the table below.

TABLE 1 ANNUAL SOIL YIELD IN THE AUCKLAND REGION*

Land-use	Measured (Tonnes/km^2/year)	Predicted Average Annual Soil Loss (Predicted over 20 year period) (Tonnes/km^2/year)
Pasture	49	46
Developed Urban - Industrial	107	100
Developed Urban - Residential	24	24
Earthworks	6,600	16,800

* Reference: Auckland Regional Plan: Sediment Control, November 2001

The sediment yields in the "Measured" column indicates the sediment yield actually recorded at the sampling site. The "Predicted" column extrapolates the data over a 20 year return period because the larger storms, which generally contribute more sediment, were not considered to be adequately represented in the actual period of record. The report which this data is taken from (ARC 1994) acknowledges the uncertainties that this created but considered that the predicted average yield figure was more indicative of actual sediment yields than that actually measured.

The information above in Table 1 indicates that sediment yield from established land uses (pasture, industrial and residential) varies from about 24 to 100 tonnes/km^2/year. However there is considerable variation in sediment yield around the region. Another example of different sediment yields from different rural catchments in the Auckland region is presented below in Table 2.

TABLE 2 REPRESENTATIVE SEDIMENT YIELDS FROM RURAL CATCHMENTS IN THE AUCKLAND REGION*

Catchment	Catchment Area (km^2)	Period of Record (years)	Sediment Yield (t/km^2/yr)	Comments
Hoteo (Kaipara and Wellsford)	268	13	354	Mix of pastoral and forestry
Rangitopuni (Upper Waitemata)	46.8	8	134	Mix of pastoral and forestry
Papakura (South Auckland)	51.6	21	80.7	Pastoral catchment
Oteha (North Shore)	12.2	11	388	Active earthworks in catchment

* From ARC files

These figures have been derived from ARC baseline water quality monitoring. These figures underestimate the actual sediment yield because storm influences were not fully factored in. However they do reflect the variation that can occur between different catchments and are generally higher than that presented for a pastoral catchment in Table 1 (46 tonnes/km^2/year).

This information refers to other catchments in the Auckland region where geology and rainfall is reasonably similar to that of the HGI. No information however has been found that is specific to the HGI.

4.6 Felling of Vegetation

Vegetation has beneficial effects on land stability through tree roots binding blocks of soil and through drying of soil by transpiration. The removal of this vegetation exposes the soil to erosion by raindrop and runoff. However the sediment related effects of this are often minimal. Usually only the topsoil is exposed and topsoil is more resistant to sediment wash because of its aggregated form. In addition there is usually large quantities of waste vegetation (slash) lying on the ground and this can often have a sediment retention role. Current thinking in the Auckland region is that the felling or the removal of vegetation by itself does not have a great effect on sediment yield; the main contributor in this respect is considered to be the earthworks associated with the vegetation felling activity (roading, haul routes, skid sites etc).

4.7 Soil Loss Estimation Models

The sediment yield information in section 4.5 above is catchment derived and generalised information. That from Table 1 is commonly quoted, such as the figure of 168 t/ha/year representing sediment yield from earthwork sites (taken directly from 16,800 t/km^2/year). However, this figure, being catchment derived, does not take any account of particular site characteristics such as soil type, slope etc. Soil loss estimation models are more commonly used to reflect this. The main model used to estimate soil loss around Auckland is the Universal Soil Loss Equation (USLE). This is a simple formula and is promoted by the ARC as the preferred sediment yield estimation tool in the Auckland region.

The general form of this equation is: $A = R K LS C P$ (Goldman et al)

Where
- A = soil loss (tonnes/hectare/year)
- R = rainfall erosion index (J/hectare)
- K = soil erodibility factor (tonnes/unit of R)
- LS = slope length and steepness factor(dimensionless)
- C = vegetation cover factor (dimensionless)
- P = erosion control practice factor (dimensionless)

The derived soil loss figure is an estimate only. It represents an average annual yield of sediment and is given in tonnes/hectare/year.

It should be noted that the model contains a number of assumptions and has not been verified for New Zealand conditions. Despite this, it is widely used in the Auckland region. Its main value is in a comparative sense and this is the way that it is used in this report.

The model makes no allowance for any sediment that may be retained by sediment retention measures or of that which may naturally be retained between site and receiving environment.

4.8 Effectiveness of Sediment Control Measures

A properly designed, constructed and maintained sediment control facility will generally retain all coarse textured sediments generated from an earthworks site. In this context, coarse textured sediment would include sand and medium silt sized particles (soil usually contains various proportions of sand, silt and clay sized particles). Fine textured sediment takes much longer to settle out than do the larger particles, and can still be in suspension by the time the associated stormwater has moved through to the outlet of a sediment retention facility. In addition, clay material (which is less than 0.002 mm in diameter) can carry an electrostatic charge that actively repels other clay particles and therefore makes settling of this small sized material even more difficult. As soon as there is any significant discharge of stormwater from a sediment retention facility, then it is likely that some fine textured material remaining in suspension will also be discharged.

Different sediment control measures have different capabilities to retain sediment. Earthwork sites that are greater than about 0.3 hectares in area usually employ sediment retention ponds to treat sediment-laden runoff. The efficiencies of well constructed sediment retention ponds in the Albany area have been assessed by the ARC (Winter R) to range from 70 to 99 % through storms. The larger storms resulted in the lower efficiencies. A figure of 75 % is commonly used to reflect the efficiency of a well constructed and maintained sediment retention pond (ARC Landfacts S-05).

The efficiency of a silt fence, which is a common form of sediment control on smaller sites, e.g. less than 0.3 hectares in size, can vary from 70% down to zero depending on whether the fence is fully effective or breached (Centre for Watershed Protection 1997).

Because fine textured sediment can be hard to retain, or if control measures are inappropriate or inadequate, then some sediment will usually discharge from an earthworks site. The only time this doesn't occur is if all runoff drains to ground or if it doesn't rain. Although the measures may be 70 % plus efficient, the quantity of sediment discharged from the control measure can still have an adverse environmental effect.

There are also cumulative effects to consider. The sediment from a small earthworks site may not have any significant effect by itself, but the cumulative effect from a number of similar sites can be very different.

4.9 Sediment Delivery Ratio

The quantity of sediment produced at source is not the same as that which arrives at some lower reference point such as a watercourse. Sediment will be retained in depressions, by different types of vegetation, by slopes of lesser angle etc. Generally the quantity of sediment measured at the bottom of a catchment will be less than that generated in the catchment.

Sediment delivery ratio is the ratio of sediment yield to gross erosion in the catchment. Sediment yield rates range mostly from 10-70 %, depending upon topographic characteristics and size of drainage areas (New York Guidelines for Urban Erosion and Sediment Control).

5.0 THE HAURAKI GULF ISLANDS CONTEXT

The HGI have particular characteristics that make the area distinctive and unique in terms of sediment generation and yield. The more important of these characteristics are expanded upon below.

5.1 Types of Earthworks

The term "earthworks" has been generally taken to refer to those machine initiated activities that expose the subsoil as part of land development. However other activities also expose soil and can result in elevated levels of sediment. These activities could include that associated with land cultivation (such as the relatively large scale pasture cultivation observed on Motutapu Island at the time of the site visits), viticulture, road maintenance, drainage and works in watercourses etc. These are all capable of generating elevated levels of sediment.

5.2 The Extent of Earthworks

There is significantly more earthworks occurring on Waiheke Island than on Great Barrier Island. The earthworks are those associated with access roading, infrastructure works, and both small and large lot development. In comparison, earthworks on Great Barrier Island are currently much more limited in extent.

In both situations, earthworks are modest in comparison to the Auckland mainland as would be expected (because there is vastly more development on the mainland). Earthwork sites are also relatively small in size. They are usually less than the current thresholds for ARC resource consent, which can mean the relatively infrequent involvement of specialist ARC sediment control staff.

5.3 Cumulative Effects

A key issue in large urban areas is that of cumulative effects. At any one time, there can be a large number of earthwork sites on the mainland, which, although small by themselves, can have a profound effect when considered on a cumulative basis. On the HGI this appears to be much less of an issue because of the reduced scale and extent of earthworks.

5.4 Slope

As discussed in section 4.3, slope is an influential factor when considering sediment yield. Because there is relatively little flat land on the Islands, most earthwork sites will have slopes of varying steepness, particularly at the commencement of the works prior to re-contouring. One positive aspect is that earthworks associated with developments such as housing etc generally lessen land contours and so reduce erosion potential.

5.5 Receiving Environments

Some general comments on receiving environments are offered as background information. These are not intended to replace specialist ecological advice and input.

Four broad types of waterbodies or receiving environments are identified for this assessment. These are watercourses, wetlands, estuaries and the open coast.

The effect of sediment on watercourses varies depending whether the watercourse is ephemeral (having seasonal or occasional flow only and therefore of low sensitivity because of poorly developed ecology) or has a permanent flow and therefore can support permanent aquatic communities. Wetlands are prevalent and their sensitivity to sediment varies. Submerged wetland species (such as raupo) are comparatively insensitive to inputs of sediment whereas emergent wetland species are more sensitive. Estuarine environments have a high risk to sedimentation because of low energies and because saline water naturally clumps fine grained particles of sediment together causing them to precipitate out. Open coast waters surrounding the islands are relatively insensitive to elevated levels of sediment (unless inputs are very localised and heavy) because of the high levels of coastal energy which can rapidly disperse sediment.

The most sensitive environments are therefore perceived to be watercourses with permanent flow, wetlands and estuaries. The visual nature of sediment discharges, and its effect on amenity values, can apply to all waterbodies.

5.6 Proximity to Receiving Environments

On the mainland, almost all sites are serviced by stormwater reticulation systems that very efficiently convey stormwater and sediment to lower receiving environments. Because of the effectiveness of this connection system, almost all earthwork sites on the mainland can be considered close to receiving environments.

On the HGI however, runoff is not channelled into stormwater systems but is discharged overland to enter waterways. Not all earthwork sites are therefore equal when assessing relative inputs of sediment to these receiving bodies. The further an earthworks site is from a waterbody or ephemeral watercourse then so will the yield of sediment lessen as sediment is naturally retained in depressions, long grass etc i.e. the sediment delivery ratio will reduce.
[Note: an ephemeral watercourse with a defined channel can be considered a conveyance system for these purposes because if there is sufficient rainfall to result in site runoff, then it is probable that the ephemeral water course will also be conveying runoff].

On the HGI then a sediment delivery factor will apply for sites that are located away from waterbodies and this factor will vary due to the factors mentioned in section 4.9. After consideration of the relatively fine textural size of sediment expected from sediment control measures (from section 4.8), the relatively small catchment sizes, and the relatively steep local topography, a sediment delivery ratio of 0.7 has been selected (interpreted from ARC Landfacts S-05).

6.0 EARTHWORK CONTROLS ON THE HAURAKI GULF ISLANDS

Controls on earthworks should ideally commence when a potentially significant adverse effect could result from an activity. This requires an appreciation of naturally occurring sediment loads and environmental values, and an assessment of sediment yield from representative earthwork sites.

Each of these is further discussed below.

6.1 Assessment of Natural Sediment Yields

There is always a level of erosion and sediment that occurs naturally and which receiving environments have evolved with. Natural sediment yield can vary enormously with precipitation being the main contributing factor (Waters of New Zealand 1992). The other two major factors are geology and land use. Although there is no sediment yield data specific to the HGI, the sediment yields reproduced in Tables 1 and 2 in section 4.5 are from catchments in the Auckland region and with conditions considered to be reasonably similar to those of the HGI. The variability that can occur is illustrated by the sediment yields ranging from 46 to 354 tonnes/km^2/year.

Hill country is the predominant terrain on the HGI. More sediment can be expected from steeper slopes than from more gentle contours. However, in most parts of HGI soil slip erosion and similar forms of mass movement erosion are not expected to contribute significant ongoing sources of sediment because of the reasonably stable nature of the hill country (soil slips occur occasionally but are not generally widespread). Erosion of watercourse channels, which can be a big sediment contributor, is also not particularly widespread, particularly on Waiheke Island, because of the prevalence of wetlands.

After consideration of these factors, and in the absence of specific local information, a "best fit" assessment of natural sediment yield is considered to be in the order of about 150 tonnes/km^2/year. A higher yield would be expected from areas with other sources of sediment such as from earthworks, soil cultivation and viticulture.

6.2 Assessment of Sediment Yield from Earthwork Sites on the Hauraki Gulf Islands

Similarly to natural sediment loads, no specific data relating to sediment yields from specific HGI earthworks has been found. The ARC information of 168 tonnes/ha/year (interpreted from Table 1) could be used but this is general information derived from catchment derived data and does not well represent different site circumstances that occur. The USLE is far better from this perspective but has not been verified for New Zealand conditions. Despite this, the USLE has been used in this report to generate estimations of sediment yield from different sites because individual site characteristics can be varied and accommodated.

Sediment yield assessments are presented in terms of tonnes of sediment per square kilometre of earthworks per year. The estimate reflects the cumulative input from a number of equivalent sites over an annual period. This will obviously never occur on the HGI in the foreseeable future (for instance this would require 400 sites each of 2500 m^2 in area to be exposed for a year).

However, it allows the sediment yield from different sites with different characteristics to be compared to a standard.

The USLE comprises five factors, which together give an estimate of sediment yield for a set of given circumstances (see section 4.7). The factors are rainfall, soil type, site slope length and angle, soil cover and surface roughness. They each have a varying influence on sediment yield. However, once the soil is exposed, many of these parameters become constant. For example, once a site on the HGI is exposed, then generally rainfall, soil type, soil cover (or lack of) and surface roughness will remain the same while the site is exposed. Between adjacent sites, and assuming the soil type remains the same, then the only variables are those of site area and slope.

Assessments of potential sediment yield from sites of different size and slope has been undertaken to assess their relative contributions. Bare sites ranging in area from 100 to 2,500 m^2 are compared along with site slopes that range from 1 to 25% in gradient. USLE values considered typical of HGI conditions have been used in these calculations. A sediment delivery ratio has not been used when assessing on-site sediment yield because the small size of the sites approximate the standardised plot size of 22.1 metres length used in the original USLE research work.

Because the USLE does not take any account of sediment retained in sediment control measures, or of that which may be naturally detained between site and a receiving environment, then allowances for each of these two factors must also be made. Sediment control measures have been assumed to be 70 % efficient, and a 0.7 sediment delivery ratio has been assumed for sites located away from watercourses (from sections 4.8 and 5.6 respectively).

Full assumptions and calculations associated with these assessments are shown in Appendix A. The assessed sediment yields for the different sized sites and slope gradients are summarised below in Table 3. The effects of sediment control measures are also indicated in the Table.

TABLE 3 ESTIMATED SEDIMENT YIELD FROM EARTHWORK SITES OF DIFFERENT SIZE, SLOPE AND WITH AND WITHOUT SEDIMENT CONTROL

	Estimated Soil Yield* - Tonnes/km^2/year											
Slope angle (%)	Bare Area 100m^2		Bare Area 200m^2		Bare Area 300m^2		Bare Area 400m^2		Bare Area 500m^2		Bare Area 2500 m^2	
	No sed control	Sed control	No sed control	Sed control	No sed control	Sed control	No sed control	Sed control	No sed control	Sed control	No sed control	Sed control
1	335	100	410	123	410	123	410	123	560	167	630	190
2	520	156	595	167	595	179	670	202	860	257	970	290
5	1153	350	1450	424	1450	435	1600	480	2570	771	3100	938
10	2900	780	3720	1080	3720	1116	4090	1227	6510	1953	8000	2400
15	5470	1641	7200	1899	7200	2154	7600	2299	12200	3661	15000	4487
20	8710	2613	11200	3015	11200	3349	12200	3661	19500	5838	23800	7143
25	12600	3780	16200	4470	16200	4867	17600	5291	28100	8427	34400	10324

*Sediment controls assumed 70 % efficient. No sediment delivery factor applied.

This table shows that potentially high levels of sediment can be generated as soon as soil is exposed. This sediment yield increases rapidly with slope angle and, to a lesser extent, with site size. Levels of sediment are markedly reduced through the implementation of on-site sediment control.

Table 4 shows the reduction in sediment yield that can occur when an earthworks site is more than 20 metres away from a receiving environment.

TABLE 4 ESTIMATED SEDIMENT YIELD FROM DIFFERENT EARTHWORK SITES SHOWING PROXIMITY TO RECEIVING ENVIRONMENTS

	Estimated Soil Yield* - Tonnes/km^2/year											
Slope angle (%)	Bare Area 100m^2		Bare Area 200m^2		Bare Area 300m^2		Bare Area 400m^2		Bare Area 500m^2		Bare Area 2500 m^2	
	< 20 m	>20 m	< 20 m	>20 m	< 20 m	>20 m	< 20 m	>20 m	< 20 m	>20 m	< 20 m	>20 m
1	100	70	123	86	123	86	123	86	167	117	190	133
2	156	109	167	117	179	125	202	141	257	180	290	203
5	350	245	424	297	435	305	480	336	771	540	938	657
10	780	546	1080	756	1116	781	1227	859	1953	1367	2400	1680
15	1641	1149	1899	1329	2154	1508	2299	1609	3661	2563	4487	3141
20	2613	1829	3015	2111	3349	2344	3661	2563	5838	4087	7143	5000
25	3780	2646	4470	3129	4867	3408	5291	3703	8427	5899	10324	7227

*Assumed 70 % efficient sediment control measures. 0.7 sediment delivery factor applied to sites more than 20 metres from a receiving environment.

6.3 Threshold Levels for Earthworks

District Plan controls on earthworks should commence when there is likely to be an adverse effect from the activity. This relates directly to natural sediment yields, which, in the absence of specific information, has been taken to be about 150 tonnes/km^2/year (from section 6.1). From section 5.5, the most sensitive receiving environments have been assumed to be watercourses with permanent flow, wetlands and estuaries. A level at which a significant effect might be expected on these environments has been assumed to be about 200 tonnes/km^2/year.

The following table combines the information presented in Tables 3 and 4. It shows the estimated sediment yield from sites 100 m^2 to 500 m^2 in area, on slopes varying from 1 to 25%, with and without sediment control, and when located more than 20 metres from a watercourse.

TABLE 5 ESTIMATED SEDIMENT YIELD FROM DIFFERENT EARTHWORK SITES SHOWING THE EFFECTS OF SEDIMENT CONTROL AND PROXIMITY TO RECEIVING ENVIRONMENTS

Estimated Soil Yield - Tonnes/km^2/year															
Slope angle (%)	Bare Area 100m^2			Bare Area 200m^2			Bare Area 300m^2			Bare Area 400m^2			Bare Area 500m^2		
1	335[1]	100[2]	70[3]	410[1]	123[2]	86[3]	410[1]	123[2]	86[3]	410[1]	123[2]	86[3]	560[1]	167[2]	117[3]
2	520	156	109	595	167	117	595	179	125	670	202	141	860	257	180
5	1153	350	245	1450	424	297	1450	435	305	1600	480	336	2570	771	540
10	2900	780	546	3720	1080	756	3720	1116	781	4090	1227	859	6510	1953	1367
15	5470	1641	1149	7200	1899	1329	7200	2154	1508	7600	2299	1609	12200	3661	2563
20	8710	2613	1829	11200	3015	2111	11200	3349	2344	12200	3661	2563	19500	5838	4087
25	12600	3780	2646	16200	4470	3129	16200	4867	3408	17600	5291	3703	28100	8427	5899

[1] Estimated sediment yield from sites without sediment control
[2] Estimated sediment yield from sites with sediment control (70 % efficiency assumed)
[3] Estimated sediment yield from sites with 70 % efficient sediment control and more than 20 metres from a receiving environment (0.7 sediment delivery ratio)

Two hundred tonnes of sediment/km^2/year was assumed at the start of this section to approximate the level when a significant adverse effect may start to occur on the HGI. Table 5 indicates that the smallest earthwork site on the gentlest grade assessed in this study (100 m^2 area and 1% slope) would still generate more than this quantity of sediment in an average year without good sediment control (335 tonnes/km^2/year).

Sites up to 400 m^2 and 2 % slopes (with sediment control) are at or below the threshold level. Sites up to 500m^2 in area and on a 2 % slope also comply where they are more than 20 metres from a receiving environment.

A year of exposure has been assumed in the calculations. However most small earthwork sites are not bare for such long lengths of time. A more typical period for smaller sites might be an average of 1 month after which most of the site would have some sort of stabilised cover (such as gravelled access and work areas, floor foundations etc). An estimate of the potential sediment yield from these smaller sites when exposed for an average of 1 month is shown below in Table 6. The sediment yield data is still presented on a km^2 basis for comparative purposes. Sites greater than 500 m^2 in area have been assumed to be generally open for longer periods and therefore have not been included on the table.

TABLE 6 ESTIMATED SEDIMENT YIELDS WHEN SITES ARE EXPOSED FOR ONE MONTH ONLY

	Estimated Soil Yield* - Tonnes/km^2/1 month									
Slope angle (%)	Bare Area (100m^2)		Bare Area (200m^2)		Bare Area (300m^2)		Bare Area (400m^2)		Bare Area (500m^2)	
	< 20 m	>20 m	< 20 m	>20 m	< 20 m	>20 m	< 20 m	>20 m	< 20 m	>20 m
1	9	8	10	7	10	7	10	7	14	10
2	13	9	14	10	15	10	17	12	21	15
5	29	20	35	25	36	25	40	28	64	45
10	65	46	90	63	93	65	102	72	163	114
15	137	96	158	111	180	126	192	134	305	214
20	218	152	251	176	279	195	305	221	487	341
25	315	221	373	261	406	284	441	309	702	492

*Assumed 70 % efficient sediment control measures. 0.7 sediment delivery factor applied to sites more than 20 metres from a receiving environment.

Earlier in this section it has been assumed that an additional 50 tonnes/km^2/year is sufficient to result in an adverse effect on the identified environments (the difference between 150 and 200 tonnes/year). This 50 tonnes increases to about 60 tonnes when one month is taken from the natural yield (12.5 tonnes – from 150 tonnes/12 months). This is then about the point beyond which some sort of effect would start to result from the month of earthworks. Referring back to Table 6, the situations that would result in this level of sediment can be seen. The upper limit for each situation is shaded above.

Sites located away from receiving environments contribute lower levels of sediment as shown earlier in this report (e.g. Table 4). However, with reference to Table 6 and with regard to small sites open for relatively short periods, it does not appear as if proximity is a particularly sensitive parameter. This suggests that separate threshold levels are not required and that site location in relation to receiving environments may be appropriately considered as part of the assessment criteria.

6.4 Current Exemptions to the District Plan

A number of activities are currently exempt from control in the HGI District Plan under the wording of the earthworks definition and under Rule 6B.1.1.5 Roading. Exemptions under these two provisions are discussed below.

6.4.1 Definition of Earthworks

Under this current HGI plan, earthworks is defined as:

Earthworks means earthmoving operations carried out by any means for development purposes and includes:

i) quarrying;

ii) prospecting and exploration
iii) the disturbance of land surfaces by moving, removing, placing or replacing soil or earth; or by excavation, cutting or filling operations;
iv) contouring;
v) road, driveway and access construction.

The following shall not be included within the meaning of earthworks:
- *gardening for domestic purposes and horticulture;*
- *work carried out for effluent disposal systems or pile foundations for houses;*
- *utility trenching as specified in Rule 6B.1.3.6.*

In this report, it is recommended for the purpose of addressing sediment and erosion effects that the basis for earthwork thresholds be changed from a volume basis to one based on area and slope characteristics. In the interests of practicality it is suggested that all earthwork sites with a bare area of less than 50 m^2 be classified as permitted activities subject to standards. For earthwork sites greater than 50 m^2 in area, a threshold level of 400 m^2 and 5% slope has been suggested. Above this level, a resource consent should be required. No distinction on the type of earthwork activity has been made as to do so introduces inconsistency of application. It is noted however, that a change from a volume to surface area/slope criteria may allow more of the presently exempt activities identified in the above definition to comply with permitted activity criteria than might presently be the case (e.g. pile foundations, utility trenching etc). In addition, a permitted activity standard requiring all earthwork activities to employ erosion and sediment control measures is recommended in section 7.1.2.

Some earthwork situations however do give arise to different effects. An example is activities that expose topsoil only (such as most cultivation activities). The effects from topsoil are usually much less than from subsoil because the size of the soil aggregates are generally much larger and are retained more easily. In addition, it is noted in section 7.1.1 that land cultivation is subject to regional controls and that no controls should be implemented through the HGI District Plan. For both reasons, it is appropriate to retain the current exemption for gardening and horticulture cultivation.

6.4.2 Road Maintenance

Rule 6B.1.15 Roading exempts the use, maintenance and upgrading of existing formed roads from the controls of the Plan.

It would be expected that the extent of many road maintenance or upgrade activities would not exceed the proposed threshold for resource consent. However, road maintenance works are perceived to often involve steep banks and work in potentially concentrated flows of water, such as in roadside watertables. These imply that potentially significant sediment loadings may be generated. Deposition sites for waste soil can be a problem. These works are ongoing around the HGI.

It is appreciated that the nature of the works is often minor and quickly undertaken. There may also be emergency type works such as storm repair which require quick action. However, it is considered that such works can still be undertaken with sound erosion and sediment control principles. It is therefore suggested that a Road Maintenance Erosion and Sediment Control Plan

(Road Maintenance ESCP) may be an appropriate mechanism by which to address the erosion and sediment control implications of road maintenance and upgrade activities. It would be expected that this be a generic type document outlining a range of control practices and procedures that could be used in different circumstances. The Road Maintenance ESCP should address matters such as runoff control (both on and offsite), sediment control measures, stabilisation provisions, dumpsites etc. It is suggested that this Road Maintenance ESCP have a limited term to keep it focused (say, no more than five years), and be subject to review as required within this period. In letting contracts for maintenance of Council roads, the Council should ensure that contractors have made provision for erosion and sediment control. A list of known proposed works should be forwarded to the Council's enforcement staff on an annual basis.

A suggested alteration to the current wording of 6B1.1.5 could be:

C. The use, maintenance and upgrading of existing formed roads subject to compliance with an approved Road Maintenance Erosion and Sediment Control.

6.5 The Advantages and Disadvantages of Resource Consents

In Section 6.4.1, it is recommended that for earthworks sites greater than $50m^2$, the Council set a threshold of $400m^2$ area and 5% slope beyond which resource consents are required. However due to the costs to applicants in the resource consent process, it is likely that the Council will want to consider an alternative regime which places more reliance on permitted activity standards with a higher threshold for resource consents. This section will discuss the advantages and disadvantages of the resource consent process as compared with setting more rigorous permitted activity standards.

The erosion and sediment control measures on most small earthwork sites (less than one hectare) as discussed in this report are usually relatively simple measures such as silt fences or earthbunds. These are widely used around the region and there are plenty of technical guidelines and manuals from which to gain the necessary knowledge. The Council has its own fact sheets on these as well. In most cases therefore in-depth technical knowledge is not necessary to ensure effective implementation of the measures. Nor are these sorts of measures expensive to implement. Often, a few metres of properly installed and maintained silt fence may all be that is needed and this is both easily implemented and relatively inexpensive.

Sediment control on small earthwork sites should therefore be a relatively straightforward and cost effective exercise. However it is the **application** of the control measures that usually gives rise to most sediment-related problems from earthworks sites. Most earthwork sites differ in some way and these differences may necessitate some adjustment to site erosion and sediment control before the commencement of earthworks. Different control measures have different strengths and weaknesses and some are more suited to some sites than others. Adjustments may be necessary. As well as this, most earthwork sites are dynamic entities. Site conditions can change drastically and often very quickly through site development. Contours changes, runoff directions will be altered, and sediment control measures, that may have been appropriate at the start of a project, may not be so if/when conditions change. The sediment control implications of control measures that may now be inappropriate or ill positioned need to be addressed.

Even if changes are not required, ongoing maintenance of control measures is essential for the measures to be fully effective during earthworks. They need to be inspected to ensure that all site runoff continues to be directed to them, that they have not been breached and are still fully functional, that retained sediment is removed for full effectiveness etc. Monitoring, and if necessary, maintenance should be carried out during and after storm events, and for the entire period that the site is exposed to sediment generation. Experience has shown that in the absence of some sort of site auditing or monitoring system, maintenance of erosion and sediment control measures is, at best, often poorly done. On a regional scale, sediment control on earthwork sites around Auckland has evolved from no control, to education and encouragement through guidelines, and then to full regulatory control through resource consents. The Auckland Regional Council now has a highly organised monitoring system on the earthwork sites with regional consents to address the ongoing problem of poor sediment control application on site. This trend to greater control has been a direct result of poor application of sediment control on individual sites. Although the Auckland Regional Council has quite specific sediment-related standards for permitted activities (under the Auckland Regional Plan: Sediment Control), and has put quite a bit of effort into trying to improve awareness of these standards through public awareness initiatives, the results on small earthwork sites so far around the region appear inconsistent.

Therefore, although sediment control measures may themselves be simple on most small sites; on-site application is often poor. Unless control measures are appropriate and well implemented and maintained, there is a high risk of potential failure and resultant sediment discharge. Poorly constructed or maintained measures may actually exacerbate problems; such as through concentrating runoff with the resultant heightened potential for scour. These effects are largely avoidable with good site management.

Section 6.3 of this report indicates that the smallest earthworks site on the gentlest grade assessed in this report (100 m^2 and 1% grade) has the potential to result in an adverse effect without appropriate and maintained sediment control measures. All earthwork sites should therefore implement and maintain sediment control measures to reduce the level of sediment leaving sites. Despite these controls however, the potential level of sediment discharged from earthwork sites will increase, as sites become steeper and/or larger. A point is reached when even properly installed and maintained sediment control measures will potentially not be sufficient to prevent adverse environmental effects from sediment runoff. Indications of these sediment levels have also been identified in section 6.3.

Proper and full implementation of control measures is therefore all-important. Some sort of control could be undertaken through focused standards for permitted activities or through resource consents. Permitted activity standards stipulate outcomes without necessarily specifying the actual manner of control. Because sediment occurs naturally, standards should be carefully worded to ensure that the end result is clearly defined and achievable (for instance requiring that no sediment is to leave a site or that a conspicuous change in visual clarity does not occur would be difficult to enforce because both of these events occur naturally every time it rains). Allowing more permitted activities means less Council involvement in determining the type of controls installed. Council's involvement for permitted activities would be restricted to education (including the provision of good practice guidelines), and monitoring rather than actually considering and approving an erosion and sediment control plan prior to an activity

commencing. However permitted activity standards are likely to be relatively ineffective unless a site auditing and enforcement programme is established by the Council.

Resource consents, on the other hand, allow for a greater involvement by the Council in determining how an activity may be controlled. More "hands-on" control of sediment can be achieved (recognising that most earthwork sites are different in some manner). However the resource consent approach also has disadvantages. Some of the advantages and disadvantages of resource consents from a sediment control perspective are outlined below in Table 7.

TABLE 7 RESOURCE CONSENTS – ADVANTAGES AND DISADVANTAGES FROM A SEDIMENT CONTROL PERSPECTIVE

Advantages	Disadvantages
Pre-Earthworks - Design Stage 1. The Council can have input into sediment control design before earthworks commence. Council can ensure that site circumstances are allowed for and potential problems recognised before works commence. Site awareness is heightened. 2. Council can assess and approve the appropriateness of proposed measures prior to the commencement of work. 3. The Council can ensure that control measures are tailored to a site through review of submitted documentation. Consent conditions can be imposed to control the effects of the activity. *Earthworks – Monitoring Stage* 4. There is a regulatory mechanism for the Council to undertake regular review of sediment control through site development. 5. The Council can recover from the applicant the costs incurred in approving, monitoring, and enforcing sediment control measures.	1. The consent procedure can be cumbersome and time consuming for applicants. Delays can be significant (this may be particularly irksome when a project is underway and changes to sediment control measures may be necessary). 2. Less than ideal vetting of applications can occur if processing staff are not sufficiently skilled to fully appreciate or evaluate different sites. Standards can vary between different processing staff. 3. Most sediment control problems are technical in nature and can usually be solved relatively easily. However the consent procedure can allow other matters (such as neighbourly disputes) to "piggy-back" and hijack an application. Use of the 'restricted' consent categories may address this problem. The Plan can specify that applications are non-notified and that assessment is restricted to specific criteria. 4. Costs to the applicant can be significant. This can extend to the preparation of application documentation as well as processing and monitoring costs.

In summary, effective sediment control on earthwork sites requires ongoing regard to the measures of control from the initial evaluation of a site before the commencement of earthworks through to the completion of the works. History suggests that this is unlikely to occur through

permitted activity standards unless the Council undertakes a rigorous auditing system including enforcement action where necessary. Using a permit-type system such as resource consents allows for a more hands-on approach from the Council that should result in better sediment control on individual earthwork sites. The main disadvantages of resource consents are seen in the process or in the implementation of the system.

A possible option for increasing site awareness and achieving better sediment control application with permitted activities could be to consider a combination of permitted activity standards with a registration programme for key development personnel such as builders, earthmovers etc. A registration programme is further discussed in section 7.2.3.

7.0 RECOMMENDATIONS

7.1 Statutory Recommendations

7.1.1 Extent of Controls

Elevated levels of sediment may arise from a number of disparate sources (such as earthworks, land cultivation, works in a watercourse etc). Some of these are the subject of specific controls by the Auckland Regional Council such as the Auckland Regional Plan: Sediment Control (which imposes controls on activities such as earthworks), and the ARC Proposed Air Land and Water Plan (which proposes controls over activities such as cultivation and works in a watercourse). The regional council may be a more appropriate body to deal with some of these issues.

Although some activities are beneath the threshold for regional consent, they may still have the potential to result in adverse effects (such as sediment from earthworks). Should control be required in such instances, then it is recommended that the council discuss this further with the ARC to achieve a consistent approach and avoid duplication. This may apply to land cultivation and waterway activities as well as to earthworks. At this stage, it is recommended that controls be implemented on specified land disturbing activities such earthworks but not on land cultivation, works in a watercourse or felling of vegetation. The Auckland Regional Council is proposing specific controls on the first two of these through the ARC Proposed Air Land and Water Plan and the statutory process is presently available for input. Vegetation removal controls have been removed from the Operative Auckland Regional Plan: Sediment Control, although permitted activity standards remain. It is suggested that a permitted activity standard requiring erosion and sediment control measures for earthworks should also extend to vegetation felling.

Recommendation 1

> Controls on land disturbing activities that could potentially duplicate regional controls should be discussed with the Regional Council. At this stage, it is recommended that controls only be implemented on earthworks.

A number of earthwork activities are presently exempt from control under the plan. These exemptions should be reviewed in relation to the recommended earthwork permitted activity levels.

Recommendation 2

The present exemptions of effluent disposal systems, pile foundations and utility trenching should be removed from the current earthworks definition. The definition would then read:

Earthworks means earthmoving operations carried out by any means for development purposes and includes:

i) quarrying;
ii) prospecting and exploration
iii) the disturbance of land surfaces by moving, removing, placing or replacing soil or earth; or by excavation, cutting or filling operations;
iv) contouring;
v) road, driveway and access construction.

The following shall not be included within the meaning of earthworks:
- *gardening for domestic purposes and horticulture.*

Recommendation 3

The current wording of 6B1.1.5 Roading should be modified to more specifically reflect the need for sediment control during the maintenance and upgrade of roads. It is suggested that a specific Erosion and Sediment Control Plan be prepared to address road maintenance and upgrade, and that earthworks be carried out in accordance with the approved Plan.

7.1.2 Permitted Activity Criteria

Recommendation 4

Earthworks on soils that drain to ground, such as on sand, should be exempt from regulatory control unless it is for reasons other than sediment control.
[Note: There may be good reasons to exert control in these situations e.g. for dune stability, but these should be for reasons other than sediment control].

Recommendation 5

Statutory control for earthworks should be based on a combination of site area and slope. Based on the assumptions and analysis of this report, permitted activity criteria can apply

to sites less than 400 m^2 in area and with slopes of less than 5%[1]. Proximity to receiving environments has not been determined to play any significant part in determining these limits (although it should be a factor included in the Assessment Criteria of the District Plan).

Slope has far more influence on sediment yield than does site area (section 4.4). In determining threshold criteria therefore site area is relatively benign. Relatively big changes in the area of a site will only have minor effects on site sediment yield (assuming a constant slope). However, there must be a point when the site area becomes so small that, despite the gradient of the slope, it is just not reasonable or practical to require a resource consent for the earthworks. Such sites, being so small, can also be stabilised within a very short time also with a corresponding reduction in risk. On the HGI there are not a large number of sites and their cumulative impacts are presumably minor.

In the interests of practicality therefore, it is suggested that consideration be given to exempting very small earthwork sites from the need for a consent. This should apply irrespective of slope. An area of 50 m^2 is suggested although variations around this level would not greatly affect this.

Recommendation 6

All earthwork activities, irrespective of slope angle, that will result in an exposed area of 50 m^2 or less should be exempt from earthwork controls.

Recommendation 7

Once exposed, earthwork sites contribute significantly more sediment than from a natural or stabilised state. Permitted activity standards should be framed to require all earthwork and vegetation clearance sites to implement and maintain sediment control measures while the soil is exposed.

7.1.3 Specific Erosion and Sediment Control Plans

On most small earthwork sites, erosion and sediment control measures can be simple, cheap and easily implemented (e.g. topsoil bunds, silt fences etc). For sites of low slope and minimal off site catchment it should be possible to achieve acceptable sediment control through techniques selected from a general "tool bag" of control procedures. Where a resource consent is required, the applicant would need to describe (either by means of text or with a basic site diagram) the general location of the control measures on the site. However standard construction techniques would be used and design calculations would not be needed. Various ways of promoting these control measures are suggested in section 7.2.2.

However, general procedures might not be so applicable on sites with high erosion potential. On these sites it is recommended that control measures should be more focused to ensure that

[1] Slope angle can be defined as the slope of the land surface measured by the nearest route from the bottom to the top of an area to be disturbed. It should have an accuracy no less than that achieved by a hand-held inclinometer or abney level.

control measures are appropriate and specific to the site. This can be achieved through site specific Erosion and Sediment Control Plans (ESCP) being provided to the Council. It would be one of the matters that the Council would exercise control/discretion over when processing an application for resource consent.

The suggested criteria for these site specific ESCPs are when sites are greater than 400 m^2 in area and where:

- The slope of the site is 15% or more in gradient; or
- The site has an above slope catchment of 2 hectares or more that can drain to/through the site.

Slope is selected as one of the criteria because of its influence on sediment yield. The 15% criterion is an arbitrary figure selected because sediment yields beyond this slope start to become very high (see Table 3 in section 6.2). The other factor (diversion of above site runoff) is suggested because concentrated flows through an earthworks site can generate very high sediment yields. The sediment yield data presented in this report has all been from sites assumed to be isolated from offsite runoff. Control over off site runoff is all important.

The suggested contents of an Erosion and Sediment Control Plan should include matters such as the following.

A SITE DESCRIPTION

a) Description of the construction activity
b) Identification of the receiving environment
c) Area to be disturbed
d) Site map to include location of receiving environment, on site drainage patterns, typical slopes (contour plan preferably), area of soil disturbance, location of effluent field and service lines. and the location of erosion and sediment control measures

B EROSION AND SEDIMENT CONTROL MEASURES

e) Construction programme. This should detail how disturbance will be minimised and include any staging of earthworks and the timing. Installation of effluent systems, and services such as power and telephone should be detailed.
f) Above site runoff control. This should include details on design flow from the above catchment (calculations should be attached), proposed diversion measure(s), measures to control the erosion of the channels, and details on the nature of the outfall(s) (with measures to control outfall erosion if required).
g) Sediment control measures. Details required are type of measure, contributing catchment etc.
h) Site runoff control. This should include similar details to f) above, i.e. the proposed diversion system, calculations, etc.
i) Stabilised entranceway.
j) Stabilisation/removal of control measures. These should be detailed along with timing.
k) Any other matters such as location of topsoil and waste stockpiles, monitoring and maintenance details etc

l) Responsibility notification (who will be responsible for sediment control on site and contact details)

It is recommended that such a plan be prepared to the satisfaction of the Council prior to the commencement of site works. Ideally these plans should be prepared and approved prior to the granting of a resource consent. It is further suggested that only a registered earthworks contractor (see section 7.2.3 below), or representative with similar training, should prepare these plans.

Unfortunately, the person applying for the resource consent may not always know how a contractor will go about a task, and an ESCP approved as part of a resource consent application may not all be relevant when the works actually commence. Any changes that may be required could be accommodated through an appropriately worded condition of resource consent along with a pre-construction site meeting to further identify and work through the changes.

Recommendation 8

> An Erosion and Sediment Control Plan should be prepared for Council approval on earthwork sites of 400 m^2 or more that have slopes either greater than 15% or have a catchment of 2 hectares or more draining to or through the site.

7.2 Non Statutory Recommendations

7.2.1 Substantiation of HGI Natural Sediment Load

No sediment yield information has been found that applies specifically to the HGI. Although the information used has been taken from Auckland studies, it does not directly relate to the HGI. It is therefore recommended that a study into soil loads from a typical "natural catchment" be undertaken to more definitively address this issue. It is suggested that this should be carried out on Waiheke Island, not Great Barrier Island, because this is where pressure on both development and the environment is currently occurring. Should the same development intensity occur on Great Barrier Island, then the information should be directly transferable. Such a study could conceivably be a joint project between the Council and ARC.

A study such as this would be expected to involve measuring rainfall, flow and sediment through a series of storms. It should aim to estimate the magnitude of sediment yield from the representative catchment and determine the effects of individual storm, seasonal and annual variations. The procedure usually involves the use of automatic rain gauges to record rainfall intensity, a weir to measure flow, and an automatic sediment sampler to collect samples for later analysis of suspended sediment concentration. Such a project could operate for a year or more (obviously the longer the better for accuracy of information).

Recommendation 9

> That the Council investigates the possibility of a joint project with the Regional Council to more accurately determine background sediment yields in the Hauraki Gulf Islands.

7.2.2 General Education

Publicity material aimed to improve the erosion and sediment control understanding of developers, contractors, council personnel (including processing and compliance staff, relevant senior staff and management, and elected representatives), and the public is recommended. This educational programme could address a number of environmental matters, not only those that relate to sediment. Suggestions relating to sediment include:

- Update the sediment control brochures handed out with resource consents and building consents. These could include photographs or drawings indicating good and bad practice. The existing council diagrams could be modified as required here, and the ARC small site guideline might be helpful.
- Require a sign on site specifically addressing site environmental responsibilities. For instance it could say that an infringement notice will be issued if any soil, cement slurry or other building material is pumped, drained or otherwise disposed of to wetlands or any defined water channel, whether flowing or not.
- Prepare displays showing good and bad practice building practices and environmental control measures for display in service centres.
- Prepare some sample plans for different sites.

Recommendation 10

> Publicity material should be prepared and distributed to improve the erosion and sediment control understanding of the earthmoving industry, council staff and the public.

7.2.3 Registration Programme

There is apparently a relatively stable core of people such as developers, contractors and builders involved in development on the HGIs. Sediment control on the HGI usually involves quite small sites and simple control measures will often suffice. It is suggested that an upskilling programme be established by which to make these key people more environmentally accountable. This could be achieved through requiring at least one person on all construction sites to have attended a specific environmental training course. Contents of the programme could include the theory of erosion and sediment control, accepted practices, the effects of bad practices, preparation of Erosion and Sediment Control Plans, and compliance requirements. There should be regular (e.g. annual) reviews, and provision for removal of registration in the event of poor performance. The circumstances in which this would apply (e.g. after a certain number of infringement or abatement notices, enforcement action etc.) should be clearly defined. Site specific Erosion and Sediment Control Plans (see section 7.1.3) should only be accepted from registered personnel.

Such a programme could be organised by the council itself, in conjunction with the ARC sediment control programme, or through private consultants.

It is suggested that the basis for this system be worked out with representatives of the development industry e.g. with contractor and building industry representatives.

A successful registration programme may allow the threshold for a resource consent to be increased.

Recommendation 11

> It is recommended that a registration programme be established for the earthmoving industry. There should be provision for removal of the registration in the event of poor performance.

7.2.4 Compliance

Achieving compliance with environmental standards is not seen as a priority for most developments. This can be due to a variety of reasons such as environmental control measures not being core business, the requirements will cost both time and money, the expertise is not readily available, and because acceptable standards are either not known or are inconsistently applied. In many ways the smaller a site, the worse this situation seems to become.

Measures to address this could be:

- Require all sites with a resource consent to have a nominated person responsible for environmental controls. The person's name and phone number should be on the warning sign discussed above in bullet point two in section 7.2.2. This person could be the registered person as discussed above in section 7.2.3.
- Maintain a compliance system that demonstrates that erosion and sediment measures comply with that required by the Council (such as those promoted in 7.2.2, bullet point 1) or with those measures approved in the Erosion and Sediment Control Plan (section 7.1.3). This could be a self-regulating system (perhaps through the registration programme discussed above in section 7.2.3) with occasional "audits" by Council staff. Alternatively, a full monitoring system could be undertaken by the Council.
- Ensure all relevant council staff and elected representatives are aware of the issue. This would involve training such as through the registration system discussed above. Specific training may be required for compliance officers (how to assess Erosion and Sediment Control Plans, site monitoring procedures, administration of enforcement guidelines and procedures etc).
- More use could be made of instant fines, stop work and abatement notices as well as enforcement provisions. Criteria should be established against which to assess site conditions. For instance, a checklist for small earthwork sites was suggested in the report on the review of earthwork provisions of the Isthmus Section[2] of the district plan. A slightly modified version of this check sheet is appended as Appendix B (although this should be further modified to apply more specifically to the HGI). A series of photographs and drawings prepared for information purposes could also indicate the required standard of works. These photographs could be used as triggers for infringement notices etc.

[2] Review of Earthworks and Excavation Provisions: Isthmus Section, Auckland District Plan. Report prepared by Erosion Management Ltd for the Auckland City Council dated March 2001

Recommendation 12

Maintain a compliance system that demonstrates compliance with required erosion and sediment control measures. This system could extend to encompass all environmental responsibilities. A site could be self-monitoring (e.g. by the registered person on site) or by the Council. Occasional "audits" should be undertaken. The use of check sheets, definition of good and bad practices with specified penalties etc could be helpful.

7.3 Summary of Recommendations

Recommendation 1

Controls on land disturbing activities that could potentially duplicate regional controls should be discussed with the Regional Council. At this stage, it is recommended that controls only be implemented on earthworks.

Recommendation 2

The present exemptions of effluent disposal systems, pile foundations and utility trenching should be removed from the current earthworks definition. The definition would then read:

Earthworks means earthmoving operations carried out by any means for development purposes and includes:

i) quarrying;
ii) prospecting and exploration
iii) the disturbance of land surfaces by moving, removing, placing or replacing soil or earth; or by excavation, cutting or filling operations;
iv) contouring;
v) road, driveway and access construction.

The following shall not be included within the meaning of earthworks:

- *gardening for domestic purposes and horticulture.*

Recommendation 3

The current wording of 6B1.1.5 Roading should be modified to more specifically reflect the need for sediment control during the maintenance and upgrade of roads. It is suggested that a specific Erosion and Sediment Control Plan be prepared to address road maintenance and upgrade, and that earthworks be carried out in accordance with the approved Plan.

Recommendation 4

Earthworks on soils that drain to ground, such as on sand, should be exempt from regulatory control unless it is for reasons other than sediment control.

Recommendation 5

Statutory control for earthworks should be based on a combination of site area and slope. Based on the assumptions and analysis of this report, permitted activity criteria can apply to sites less than 400 m^2 in area and with slopes of less than 5%. Proximity to receiving environments has not been determined to play any significant part in determining these limits (although it should be a factor included in the Assessment Criteria of the District Plan).

Recommendation 6

All earthwork activities, irrespective of slope angle, that will result in an exposed area of 50 m^2 or less should be exempt from earthwork controls.

Recommendation 7

Once exposed, earthwork sites contribute significantly more sediment than from a natural or stabilised state. Permitted activity standards should be framed to require all earthwork and vegetation clearance sites to implement and maintain sediment control measures while the soil is exposed.

Recommendation 8

An Erosion and Sediment Control Plan should be prepared for Council approval for earthwork sites of 400 m^2 or more that have slopes either greater than 15% or have a catchment of 2 hectares or more draining to or through the site.

Recommendation 9

That the Council investigates the possibility of a joint project with the Regional Council to more accurately determine background sediment yields in the Hauraki Gulf Islands.

Recommendation 10

Publicity material should be prepared and distributed to improve the erosion and sediment control understanding of the earthmoving industry, council staff and the public.

Recommendation 11

It is recommended that a registration programme be established for the earthmoving industry. There should be provision for removal of the registration in the event of poor performance.

Recommendation 12

Maintain a compliance system that demonstrates compliance with required erosion and sediment control measures. This system could extend to encompass all environmental

responsibilities. A site could be self-monitoring (e.g. by the registered person on site) or by the Council. Occasional "audits" should be undertaken. The use of check sheets, definition of good and bad practices with specified penalties etc could be helpful.

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Soil and Water Conservation Society, Empire State Chapter: New York Guidelines for Erosion and Sediment Control. October 1991.

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APPENDIX A

ESTIMATIONS OF SOIL YIELD USING THE UNIVERSAL SOIL LOSS EQUATION FROM SMALL EARTHWORK SITES IN THE HAURAKI GULF ISLANDS

Assumptions

It is assumed that sites are approximately square for the purposes of these assessments and that runoff does not flow onto the sites from above. A silty clay soil type with textural classes of sand 7%, silt 46% and clay 47% is assumed. Sites are assumed to be bare, compacted, have zero organic matter and have a loose and irregular surface. The rainfall factor is calculated from ARC TP 108. A sediment delivery ratio factor has not been applied to the sediment yield assessment from each site (because the standard plot size used to derive LS values is 22.1 m in length and the small earthwork sites evaluated here are generally about this or less in length). Sediment control measures are assumed to be 70 % efficient in retaining sediment.

1 ESTIMATED SOIL YIELD FROM A 1OO M^2 EARTHWORK SITE

(assumed 10 metre length)

	USLE Parameters					Estimated Soil Yield	
Slope angle (%)	R	K	LS	C	P	Estimated sediment generated (Tonnes/ ha/year)	Estimated sediment yield (Tonnes/ km^2/year)
1	78	0.53	0.09	1.0	0.9	3.35	100
2	78	0.53	0.14	1.0	0.9	5.2	156
5	78	0.53	0.31	1.0	0.9	11.53	350
10	78	0.53	0.78	1.0	0.9	29	780
15	78	0.53	1.47	1.0	0.9	54.7	1641
20	78	0.53	2.34	1.0	0.9	87.1	2613
25	78	0.53	3.38	1.0	0.9	126	3780

2. ESTIMATED SOIL YIELD FROM A 200 M^2 EARTHWORK SITE
(assumed 15 metre length)

	USLE Parameters					Estimated Soil Yield	
Slope angle (%)	R	K	LS	C	P	Estimated sediment generated (Tonnes/ ha/year)	Estimated sediment yield (Tonnes/ km^2/year)
1	78	0.53	0.11	1.0	0.9	4.1	123
2	78	0.53	0.15	1.0	0.9	5.6	167
5	78	0.53	0.38	1.0	0.9	14.14	424
10	78	0.53	0.97	1.0	0.9	36	1080
15	78	0.53	1.7	1.0	0.9	63.3	1899
20	78	0.53	2.7	1.0	0.9	100.5	3015
25	78	0.53	4.0	1.0	0.9	149	4470

3 ESTIMATED SOIL YIELD FROM A 300M^2 EARTHWORK SITE
(assumed 17 metre length)

	USLE Parameters					Estimated Soil Yield	
Slope angle (%)	R	K	LS	C	P	Estimated sediment generated (Tonnes/ ha/year)	Estimated sediment yield (Tonnes/ km^2/year)
1	78	0.53	0.11	1.0	0.9	4.1	123
2	78	0.53	0.16	1.0	0.9	5.95	179
5	78	0.53	0.39	1.0	0.9	14.5	435
10	78	0.53	1.0	1.0	0.9	37.2	1116
15	78	0.53	1.93	1.0	0.9	72	2154
20	78	0.53	3.0	1.0	0.9	112	3349
25	78	0.53	4.36	1.0	0.9	162	4867

4 ESTIMATED SOIL YIELD FROM A 400M^2 EARTHWORK SITE

(assumed 20 metre length)

	USLE Parameters					Estimated Soil Yield	
Slope angle (%)	R	K	LS	C	P	Estimated sediment generated (Tonnes/ ha/year)	Estimated sediment yield (Tonnes/ km^2/year)
1	78	0.53	0.11	1.0	0.9	4.1	123
2	78	0.53	0.18	1.0	0.9	6.7	202
5	78	0.53	0.43	1.0	0.9	16.0	480
10	78	0.53	1.1	1.0	0.9	40.9	1227
15	78	0.53	2.06	1.0	0.9	76	2299
20	78	0.53	3.28	1.0	0.9	122	3661
25	78	0.53	4.74	1.0	0.9	176	5291

5 ESTIMATED SOIL YIELD FROM A 500M^2 EARTHWORK SITE

(assumed 25 metre length)

	USLE Parameters					Estimated Soil Yield	
Slope angle (%)	R	K	LS	C	P	Estimated sediment generated (Tonnes/ ha/year)	Estimated sediment yield (Tonnes/ km^2/year)
1	78	0.53	0.15	1.0	0.9	5.6	167
2	78	0.53	0.23	1.0	0.9	8.6	257
5	78	0.53	0.69	1.0	0.9	25.7	771
10	78	0.53	1.75	1.0	0.9	65.1	1953
15	78	0.53	3.28	1.0	0.9	122	3661
20	78	0.53	5.23	1.0	0.9	195	5838
25	78	0.53	7.55	1.0	0.9	281	8427

6 ESTIMATED SOIL YIELD FROM A 2,500M^2 EARTHWORK SITE
(assumed 50 metre length)

	USLE Parameters					Estimated Soil Yield	
Slope angle (%)	R	K	LS	C	P	Estimated sediment generated (Tonnes/ ha/year)	Estimated sediment yield (Tonnes/ km^2/year)
1	78	0.53	0.17	1.0	0.9	6.3	190
2	78	0.53	0.26	1.0	0.9	9.7	290
5	78	0.53	0.84	1.0	0.9	31	938
10	78	0.53	2.15	1.0	0.9	80	2400
15	78	0.53	4.02	1.0	0.9	150	4487
20	78	0.53	6.4	1.0	0.9	238	7143
25	78	0.53	9.25	1.0	0.9	344	10324

7 SUMMARY OF ESTIMATED SOIL YIELDS FROM SITES OF DIFFERENT SIZES WITHOUT SEDIMENT CONTROL

	Estimated Soil Yield - Tonnes/km^2/year					
Slope angle (%)	Bare Area (100 m^2)	Bare Area (200 m^2)	Bare Area (300 m^2)	Bare Area (400 m^2)	Bare Area (500 m^2)	Bare Area (2500 m^2)
1	335	410	410	410	560	630
2	520	595	595	670	860	970
5	1153	1450	1450	1600	2570	3100
10	2900	3720	3720	4090	6510	8000
15	5470	7200	7200	7600	12200	15000
20	8710	11200	11200	12200	19500	23800
25	12600	16200	16200	17600	28100	34400

8 SUMMARY OF ESTIMATED SOIL YIELDS FROM SITES OF DIFFERENT SIZES WITH SEDIMENT CONTROL

	Estimated Soil Yield - Tonnes/km^2/year					
Slope angle (%)	Bare Area (100 m^2)	Bare Area (200 m^2)	Bare Area (300 m^2)	Bare Area (400 m^2)	Bare Area (500 m^2)	Bare Area (2500 m^2)
1	100	123	123	123	167	190
2	156	167	179	202	257	290
5	350	424	435	480	771	938
10	780	1080	1116	1227	1953	2400
15	1641	1899	2154	2299	3661	4487
20	2613	3015	3349	3661	5838	7143
25	3780	4470	4867	5291	8427	10324

It has been assumed that all sediment on site has been treated by sediment retention measures that are 70 % efficient. These measures normally concentrate flows for treatment purposes. If an earthworks site is close to a specified reference point e.g. a wetland or waterbody, then further retention of sediment in the concentrated flow from the treatment measure would be expected to be slight. In the table below, it is assumed that there will be effectively no additional retention of sediment from sites that are within 20 metres of a receiving environment. For sites that are further away, a sediment delivery ratio of 0.7 has been assumed (i.e. 70 % of the generated sediment will flow through to the reference point). This is a reflection of the relative steepness of the HGI topography. Table 9 indicates the relative sediment yield to receiving environments that are within 20 metres of an earthworks site compared to that from more distant sites.

9. ESTIMATED SEDIMENT YIELDS FROM DIFFERENT EARTHWORK SITES SHOWING PROXIMITY TO RECEIVING ENVIRONMENTS

	Estimated Soil Yield - Tonnes/km^2/year											
Slope angle (%)	Bare Area (100m^2)		Bare Area (200m^2)		Bare Area (300m^2)		Bare Area (400m^2)		Bare Area (500m^2)		Bare Area (2500 m^2)	
	< 20 m	>20 m	< 20 m	>20 m	< 20 m	>20 m	< 20 m	>20 m	< 20 m	>20 m	< 20 m	>20 m
1	100	70	123	86	123	86	123	86	167	117	190	133
2	156	109	167	117	179	125	202	141	257	180	290	203
5	350	245	424	297	435	305	480	336	771	540	938	657
10	780	546	1080	756	1116	781	1227	859	1953	1367	2400	1680
15	1641	1149	1899	1329	2154	1508	2299	1609	3661	2563	4487	3141
20	2613	1829	3015	2111	3349	2344	3661	2563	5838	4087	7143	5000
25	3780	2646	4470	3129	4867	3408	5291	3703	8427	5899	10324	7227

10 ESTIMATED SEDIMENT YIELDS FROM DIFFERENT SITES SHOWING THE EFFECTS OF SEDIMENT CONTROL AND PROXIMITY TO RECEIVING ENVIRONMENTS

Estimated Soil Yield - Tonnes/km^2/year*															
Slope angle (%)	**Bare Area 100m^2**			**Bare Area 200m^2**			**Bare Area 300m^2**			**Bare Area 400m^2**			**Bare Area 500m^2**		
1	335[1]	100[2]	70[3]	410[1]	123[2]	86[3]	410[1]	123[2]	86[3]	410[1]	123[2]	86[3]	560[1]	167[2]	117[3]
2	520	156	109	595	167	117	595	179	125	670	202	141	860	257	180
5	1153	350	245	1450	424	297	1450	435	305	1600	480	336	2570	771	540
10	2900	780	546	3720	1080	756	3720	1116	781	4090	1227	859	6510	1953	1367
15	5470	1641	1149	7200	1899	1329	7200	2154	1508	7600	2299	1609	12200	3661	2563
20	8710	2613	1829	11200	3015	2111	11200	3349	2344	12200	3661	2563	19500	5838	4087
25	12600	3780	2646	16200	4470	3129	16200	4867	3408	17600	5291	3703	28100	8427	5899

[1] Estimated sediment yield from sites without sediment control

[2] Estimated sediment yield from sites with 70 % efficient sediment control

[3] Estimated sediment yield from sites with 70 % sediment control and more than 20 metres from receiving environment

APPENDIX B

SEDIMENT CONTROL CHECK SHEET

AUCKLAND CITY COUNCIL
Building Site - Silt Control Check Sheet

Site Address		**File Ref**	
Builder/Developer			
Stage of Construction		**Drains to Ground**	**Yes** **No**
Est'd Area	**Level?**	**Fall ….. 2m….. 4m ….. >5m**	
Date of Inspection / /		**Name of Inspector**	

Description	**Condition**		**Remarks**
a) Above site drainage controls	**Yes**	**No**	
b) Silt fence	**Yes**	**No**	
Fabric buried 200 mm?			
Stakes spaced at 2 m intervals?			
Constructed along contour?			
Subject to concentrated flows?			
c) Stabilised Entrance	**Yes**	**No**	Approx. dim. (m * m)
Material used? Average Size?			
Est.d thickness of entrance?			
Graded to silt fence?			
Geotextile used?			
d) Down pipe connected?	**Yes**	**No**	
e) Stockpiles?	**Yes**	**No**	
Upslope drainage controls?			
Silt fence at toe?			
Surface covered?			
f) Other items			
Any areas of special risk?			
Do any items a) to e) above need repair or cleaning out?			
Any evidence of drainage or silt to street/offsite?			
g) Comments?			
Diagram of Site			