Chapter 1
Importance of Site Disturbance on Erosion and Sediment Control

The major problem with erosion is the movement of soil off site and its subsequent impact on sedimentation on the receiving environment.

Introduction

Any discussion of erosion and sediment control has to consider the two basic components "erosion" and "sediment control". When land is disturbed at an earthworks site, the erosion rate increases with removal of ground cover, normally vegetative, which protects soils from erosion. The major problem with erosion is the movement of soil off site and its subsequent impact of sedimentation on the receiving environment.

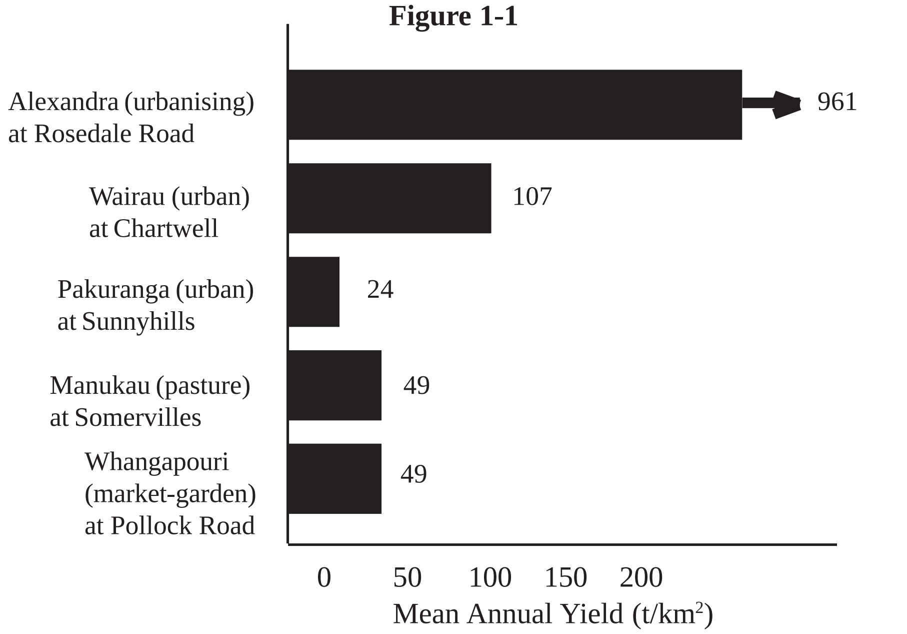
Erosion is a natural process and even land covered in native vegetation has erosion. Earthworking activities, however, dramatically increase erosion rates. Natural erosion is generally considered in geological terms (hundreds or thousands of years) whereas accelerated erosion from our activities is considered frequently on an annual basis.

When sediment loadings to receiving systems are increased, this fills drainage channels, especially along roads, and clogs culverts and storm drain systems. Domestic and public water supply reservoirs lose storage capacity, navigable channels must routinely be dredged, and filtering of water prior to usage can be expensive. Through a series of investigations, the ARC (Technical Publication 51 "Storm Sediment Yields from Basins with Various Landuses in Auckland Area) has provided some estimates for sediment loading versus land use as detailed in Figure 1.1. As can be seen, the urbanising catchment has significantly greater sediment yields than any other land use.

The high yield from the urbanising catchment stems from the considerable portion of its ground area that is bared for construction (for example - in the Alexandra Catchment approximately 28% at the time of the study). The yield from the sub-catchments undergoing 100% construction was estimated to be approximately 16,800 t/km^2/year, or hundreds of times the yield from undisturbed or stable areas of the catchment. A regional map detailing the individual catchments for which data is presented is shown in Figure 1-2.

The negative impact on aquatic organisms due to large influxes of sediment into streams or waterways is substantial. The initial effect is a drastic reduction in the number and density of benthos. Aquatic vegetation is often destroyed, either by burial or reduction of sunlight essential for growth. The reduction of sunlight from suspended sediment impairs primary production (the process by which sunlight is utilised by certain organisms to produce carbon and oxygen) and may reduce oxygen levels in the water, resulting from dying vegetation, to a point where aquatic life

Figure 1-1



ARC, Storm Sediment Yields from Basins with Various Landuses in Auckland Area, Technical Publication No. 51, November, 1994

cannot survive. Many species of fish, dependent on bottom dwelling organisms for food, and instream cover for refuge, are threatened by the damaged habitat. The habitat destruction associated with rapid sedimentation can severely impair the ability of coastal environments to support important intrinsic, recreational and commercial finfish and shellfish populations. Waterfowl, particularly migratory species, also utilise nearshore plant and shellfish communities as a food source. The reduction of waterfowl in recent years has been associated, in part, with habitat destruction from sedimentation derived from construction activity.

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The importance of the land urbanising process to downstream sediment loadings is dependent upon a number of different factors, each of which is important in its own right. These factors include:

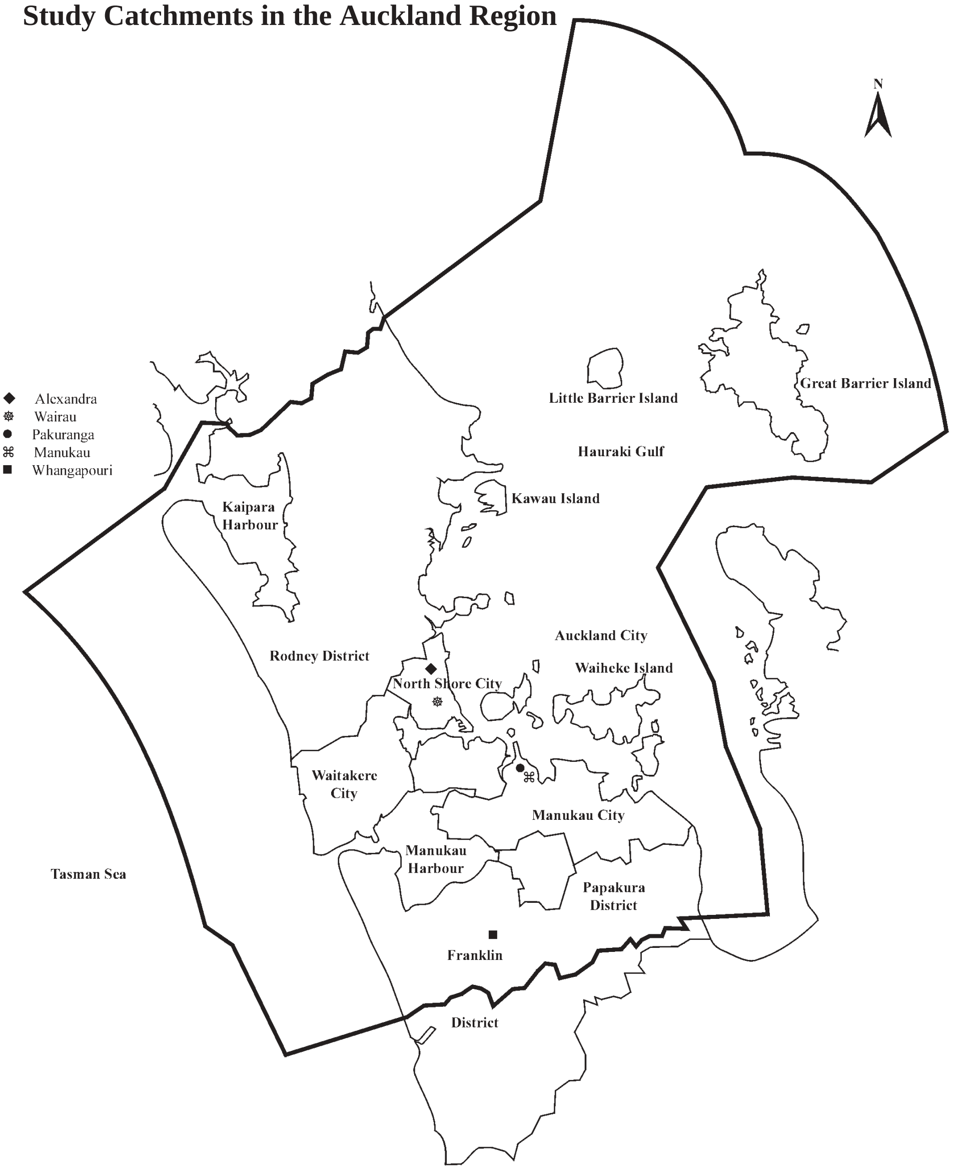
- Soil type,
- Area of disturbance,
- Slope angle and length,
- Vegetative Cover
- Vicinity of Receiving Environments
- Performance of Erosion and Sediment Control Practices
- Site development approach
- Rainfall (discussed in Chapter 2)

Each of these parameters will be discussed in more detail. Prior to the discussion of each of those items, it would be beneficial to place sedimentation in a historic perspective. This would allow us the ability to see if current rates of erosion are greater or less than historic levels.

Depositional History

Most of the information that could be found related to investigations that were done as part of the Upper Waitemata Harbour Catchment Study done by the Auckland Regional Water Board. There are generalised statements that can be made for the Region as a whole, but the major thrust of the investigation was for the Upper Har-

Figure 1-2
Study Catchments in the Auckland Region



bour.

Approximately 20,000 years ago the sea level stood 130 metres below its present level.

Approximately 20,000 years ago the sea level stood about 130 metres below its present level. The ancestral shoreline probably lay east of its present position and the Waitemata River extended from its headwaters near Rewiti and Waimauku to meet the sea near Great Barrier Island. It is generally accepted that from 15,000 to 20,000 years ago, there was a rapid rise in sea level (averaging 8 mm/year) until about 7,000 years ago when sea level was approximately 10 metres below its present level. Present levels were reached approximately 4,000 years ago.

The pollen show that when the Maori first came to the Waitemata in about 1420 AD, the forest areas were dominated by rimu, podocarp, rata, kauri, beech, and toatoa. The Maori settlers practised small scale burning of areas on the isthmus and upper harbour to obtain or cultivate food, a practice that would prevent forest regeneration and cause an increase in secondary growth such as bracken.

It was 1840 AD before Europeans undertook significant activity in the upper harbour areas, and 1841 AD when large blocks of land were purchased from the Maoris. Timber milling operations began as early as 1841 AD along with gum digging. The decimation of remaining forest by fire and timber haulage, the modification of stream banks to straighten flow paths to assist log transport, and pit digging associated with kauri gum exploitation would have resulted in increased erosion and sedimentation, at least until a new vegetation cover would become established. By 1870 farming became a significant activity in the Upper Waitemata Harbour catchment. This was much less harsh as a land use than the clearance of native forest. The catchment use changes brought about by European activity are reflected both in the pollen spectra of the sediments and perhaps in the four fold increase in sedimentation rate. The following Figure 1-2, details historic causes and rates of sedimentation.

Figure 1-2
Historic Causes and Rates of Sedimentation

Core Depth (metres)	Vegetation change	Cause of change	Average sedimentation rate
0.0	introduced pollen types appear	European settlement	3 mm/year
0.4			
	bracken becomes the dominant type	Maori settlement and forest clearance	0.8 mm/year
0.8			
0.9			
	catchment covered with forest		

The rates detailed in Figure 1-2 should be considered in the context of modern earth works activities. Again, investigations in the Lucas and Oteha stream have provided estimates that sedimentation rates to the estuary would approximate 10 mm/year if intensive development were carried out throughout the catchment.

Soil Type

Soil is a product of natural processes, including destructive and manufactured sources.

Soil is a product of natural processes, including destructive and manufactured sources. Weathering and microbial decay of organic residues are examples of destructive processes, whereas the formation of new minerals, such as certain clays, and the development of their layer patterns are manufactured. Soil is a habitat for plants and plants make a significant contribution to soil development. Soil characteristics vary widely from place to place. For example, soil is not very deep on steep slopes or sandier soils tend to originate from sandstone.

If we dug a hole downward through the soil, the horizontal layers of various overlaying soils would be exposed. Such a view of the soil is called a profile and the individual layers are generally known as horizons. The character of soil can change significantly as the hole goes deeper. Every well-developed soil has its own distinctive profile characteristics as shown in the following picture. In judging a soil, its whole profile should be taken into consideration. The upper layers of a soil profile generally contain considerable amounts of organic matter and are darker in appearance. When looking at a soil profile, it should be recognised that the various layers are not always distinct and well defined. In fact, the transition from one to the other is often so gradual that the establishment of boundaries is rather difficult. Nevertheless, for any particular soil the various horizons are characteristic and greatly influence the growth of plants.

Example of a Soil Profile in the Albany Area

Soils in the Auckland region are variable depending on location. There are basic statements that can be made depending on location. North and west of the Waitemata Harbour are fairly consistent and uniform. South of the Harbour and east into the Hunuas has a much greater variation in soils. Regardless of where a site is being developed, site specific soils analysis should be accomplished to determine soils characteristics for that particular site.

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1 Waitakere City and the Waitakere Ranges

Predominant soils are illustrated by Waimatenui and Waitakere clays which are in the Northern brown granular clay and loam grouping. These soils are derived from andesitic rocks and volcanic ash and are formed under forest and an annual rainfall greater than 1260 mm. They are extensive on hilly land and rolling plateaus and are, or were, in mixed podocarp-kauri forest. They are clay soils with greyish brown to brown topsoils. Conversion from forest to grassland can cause serious sheet erosion. Shallow seated slip erosion is common in these soils.

2 West Harbour

Predominant soils are illustrated by Karaka and Weymouth, which are yellow brown loam. These soils occur around the Manukau and Waitemata Harbours. They are developed on sediments derived largely from volcanic ashes but in places partly from marine rocks. Being depositional soils, their erodibility is related to reduced slopes and is not as significant a problem as steeper slopes.

3 North Shore and the Rodney Area

North Shore soils are illustrated by Mata - Waikare and Waikare - Hukerenui soils which are classified as podzolised northern yellow-brown earths and podzols. North Shore soils also include Konoti - Taumata, and Marua - Rangiora which are classified in the northern yellow - brown earths. The soils are extensive on rolling and hilly lands and form mostly from strongly weathered sedimentary rocks. In both of these soil groupings the predominant native vegetation was kauri, rimu, and kamahi dominated vegetation. These soils are poorly drained.

In the yellow brown earths, replacement of forest by grassland has widened the moisture range of the soils and caused greater drying out of the surface. The consequent network of shrinkage cracks, and the weaker root bonds increases the rate of slip erosion of soils. Each of these slips tends to be followed by a succession of slips headward from the first one. The podzolised northern yellow-brown earths have a thick humus which protects the underlying mineral soil against erosion. The humus mat is a main source of plant nutrients, and it contains many tree roots. Any disturbance of the mat by removal of trees or earthworks exposes the soils, which can then be eroded rapidly. Slips and debris avalanches are natural phenomena and the rebuilding of soil with protective humus takes many years to occur.

4 <u>Soils adjacent to the West Coast</u>

These soils are illustrated by Red Hill-Horea soils which are classified as Northern yellow brown sands. These soils extend in an almost continuous strip along the western coast of North Auckland. They are formed on sand dune complexes with intervening plains. They require a dense vegetative cover to prevent wind erosion. Disturbance of the soil for earthworks can cause significant erosion from runoff.

5. <u>Central area around Pukekohe</u>

Predominant soils are described by Patumahoe-Onewhero and Hamilton-Naike soils which are classified as brown granular loams and clays and associated soils. They have been formed under broadleaved forest on undulating lands. The soils, developed under forest, are difficult to convert to grassland without serious sheet erosion. This difficulty applies particularly on hilly and steep lands where dense swards are slow to establish, and sheet and some slip erosion may remove large slices of topsoil. Wind erosion of topsoil occurs on some coastal lands. These tend to be well structured soils, different from clays, which fairly readily settle out in ponds.

6. <u>Hunuas area</u>

Predominant soils are described by Te Ranga-Marua, Rangiora-Opaheke, and Mata-Waihare which are classified as Northern yellow brown earths. These soils cover most of the ranges and hill country south of Auckland. On this land thin deposits of volcanic ash have been mostly eroded away and the soils are formed from weathered sedimentary or rhyolitic rocks. They were formed under mixed podocarp-kauri forests. Replacement of forest by grassland widens the moisture range of the soils and causes greater drying out of the surface. The consequent network of shrinkage cracks, and the weaker root bonds in the subsoil, increases the rate of slip erosion.

The most important physical property of a soil particle is it's size.

The most important physical property of a soil particle is it's size. The size of particles can be determined in a number of ways. The nominal diameter, as shown in Table 1-1 refers to the diameter of a sphere of the same volume as the particle, usually measured by the displaced volume of a submerged particle. The sieve diameter is the minimum length of the square sieve opening through which a particle will fall.

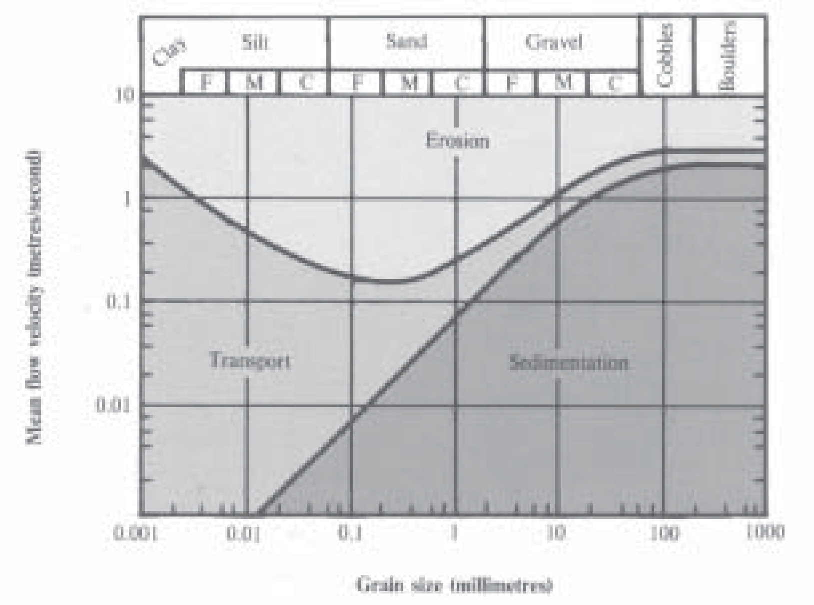
Sands and gravels are more erodible than silts and clays but silts and clays, once in suspension, are difficult to trap with sediment control practices.

Table 1-1
Sediment Grade Scale

Class Name	size range mm		size range mm
Gravel		*Sand*	
very coarse	64-32	very coarse	2-1
coarse	32-16	coarse	1-0.5
medium	16-8	medium	0.5-0.25
fine	8-4	fine	0.25-0.125
very fine	4-2	very fine	0.125-0.062
Silt		*Clay*	
coarse	0.062-0.031	coarse	0.004-0.002
medium	0.031-0.016	medium	0.002-0.001
fine	0.016-0.008	fine	0.001-0.0005
very fine	0.008-0.004	very fine	0.0005-0.00024

Recognising the size of material on an earthworks site can increase the awareness of how easy or difficult it can be to remove sediment once it is in transport and assist in targeting appropriate erosion and sediment controls. The smaller the particle, the greater the length of time that it can stay in suspension. Sands and gravels are more erodible than silts and clays but silts and clays, once in suspension, are difficult to trap with sediment control practices. Limiting the extent of area being disturbed can significantly reduce downstream loadings of sediment. Figure 1-3 provides information on how particle size relates to erosion, transport, and sedimentation.

Figure 1-3
Grain Size Versus Velocity of Flow



Area of Disturbance

As would be expected, the greater the area of site disturbance, the greater the erosion potential. Removal of the vegetative cover, including vegetation and topsoil, increases surface runoff and erosion potential. Vegetation enhances evapotranspiration which tends to dry soils out between storm events. Vegetation also has a roughness associated with it which tends to accelerate or retard the flow of water across it. The following Table 1-2 provides information on the increased time that water takes to travel

Severe Rilling on a Slope

across various surfaces. The longer the travel time, the less the potential for erosion from that land surface.

Table 1-2

surface	roughness coefficient (n)	Travel times (hours)[1]
bare soil	0.011	.014
pasture	0.13	.093
grass (short)	0.15	.109
grass (taller)	0.24	.159
bush (light understory)	0.40	.24
bush (dense understory)	0.80	.447

[1] Assumed 50 m. length, 12% slope, and 83 mm of rainfall

As detailed in Table 1-3, at low levels of site disturbance (4-10% of the total site) median sediment loadings are predicted to increase about 4 fold over existing landuse sediment loadings. However, for maximum disturbance by earthworks (100%) the predicted increases in median loads range from about 40 to over 80 fold. (Mahurangi land use scenario modelling, ARC)

Site disturbance increases in areal extent show an increase of sediment loading of over 70 times that of pasture.

Another way to visualise the data generated through the Mahurangi Study is to show the data graphically in Figure 1-3. As can clearly be seen, site disturbance increases in areal extent show an increase of sediment loading of over 70 times that of pasture, which itself has an increased sediment loading of approximately 10 times that of native vegetation. Limiting the amount of area that can be opened at any one time can reduce sediment loading.

In conjunction with the areal extent of soil disturbance, the volume of material moved is also important. The exposure of subsoils originating from depths up to five metres by earthworks machinery over a very short period of time is thought to have the following effects:

- Sudden stress release created by the removal of soil overburden resulting in the loosening of surface soil grains and making them more readily available for detachment and transport by surface erosion processes,

- o Presence of soft, moist soils at the surface evidenced by low penetrometer values increasing soil potential erodibility,
- o The nature of the engineering works produces a soil surface with an extremely smooth, flat, and smeared surface, preventing surface ponding or infiltration, and therefore enhancing surface erosion processes, and
- o Exposure of deep subsoils exhibiting the absence of any plant residue or other organic matter which has been found to significantly reduce erosion rates.

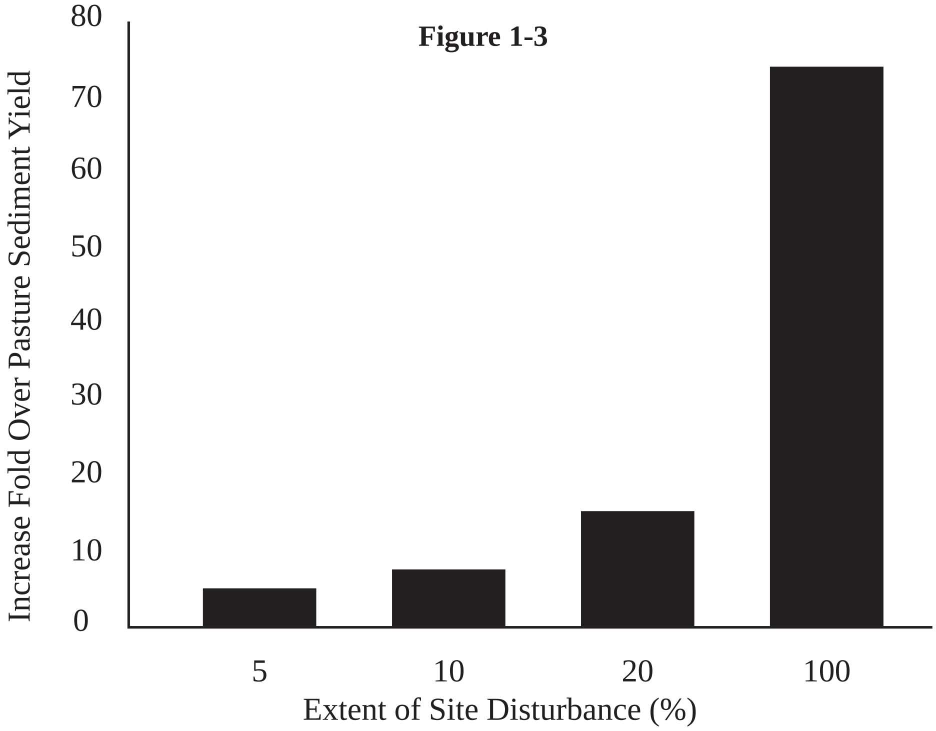
Table 1-3

Sediment Loadings from the Proposed Countryside Living Zone (Modelling sediment loadings to the Mahurangi Estuary, NIWA, 1997)

Proposed Countryside Living (Town)	Area (ha.)	Existing Sediment Loading (tonnes/yr)	CL(T) (tonnes/yr) 4% - 10%	CL(T) (tonnes/yr) 100%	Increase (tonnes/yr) 4% - 10%	Increase (tonnes/yr) 100%
A	77.5	294	522-2600	10027-45941	2-9	34-156
B	29.3	128	290-1394	4932-19465	2-11	39-152
C	57.7	176	344-2029	6833-39286	2-12	39-223
D	75.9	702	1097-3556	18990-61126	2-5	27-87
E	39.9	495	611-2769	9941-39883	1.2-6	20-81
F	124.5	272	1652-7224	15464-65350	6-27	57-240

CL(T) - Countryside Living (Town)
4% - 10% - 4% of steeper parts and 10% of the flat land will be urbanised
100% - 100% of catchment to be urbanised

Figure 1-3



(from Mahurangi Catchment Study)

All of the above factors promote the initiation and development of rill and sheetwash erosion processes. Therefore, to reduce the effects of these factors would significantly reduce on-site erosion rates. This would best be achieved by increasing the surface roughness component of soils by running large tracked machinery over exposed subsoil areas prior to rainfall events or following engineering activities each day.

Slope Angle and Length

There is much information relating the direct relationship that exists between sediment loading and slope. A reference guide exists to categorize slopes in a fairly simple context:

Slope
A 0 - 3^0 flat to gently undulating
B 4 - 7^0 undulating
C 8 - 15^0 rolling
D 16 -20^0 strongly rolling
E 21 -25^0 moderately steep
F 26 - 35^0 steep
G > 35^0 very steep

A simple way to relate the impact that slope has on sediment yield is to consider the Universal Soil Loss Equation. The Universal Soil Loss Equation (USLE) is a simple empirical formula that was developed approximately 30 years ago and derived from the theory of erosion processes. The general form of the equation is:

$$A = R \times K \times (L\ S) \times C \times P$$

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)

Both the length and the steepness of the land slope substantially affect the rate of soil erosion by water. The two effects have been evaluated separately in research and are represented in the soil loss equation by L and S, respectively. In field applications, however, considering the two as a single topographic factor, LS, is more convenient. Typical values for LS are shown in Table 1-4.

Both the length and the steepness of the land slope substantially affect the rate of soil erosion by water.

Table 1-4
Values of the Topographic Factor, LS, for Specific Combinations of Slope Length

Percent	Slope Length (metres)								
Slope	7.6	15	23	30	45	61	91	122	152
2	.133	.163	.185	.201	.227	.248	.280	.305	.326
5	.268	.379	.464	.536	.656	.758	.928	1.07	1.20
10	.685	.968	1.19	1.37	1.68	1.94	2.37	2.74	3.06
16	1.42	2.01	2.46	2.84	3.48	4.01	4.94	5.68	6.35

As can be seen from the table, the LS factor (and hence soil loss) increases with increasing slope and also with increasing slope length.

Table 1.5 shows, on a more local perspective, in the Auckland Region. Slope was considered as a component of the Mangemangeroa Catchment Study. That study was done for the ARC by NIWA specifically looking at sediment loading from a developing catchment..

Table 1.5
The Effect of Slope on Sediment Erosion Rate in the Mangemangeroa Catchment

Slope Class (ave. degree)	100% earthworks tonnes/km²/year low	medium	high	Pasture tonnes/km²/year median	Increase fold over pasture median
B (5.5^0)	57,300	122,000	264,000	660	185
C (11.5^0)	183,000	363,000	718,000	3,300	110
D (18^0)	311,000	641,000	>1,000,000	8,100	80
E (23^0)	422,000	816,000	>1,000,000	13,000	63

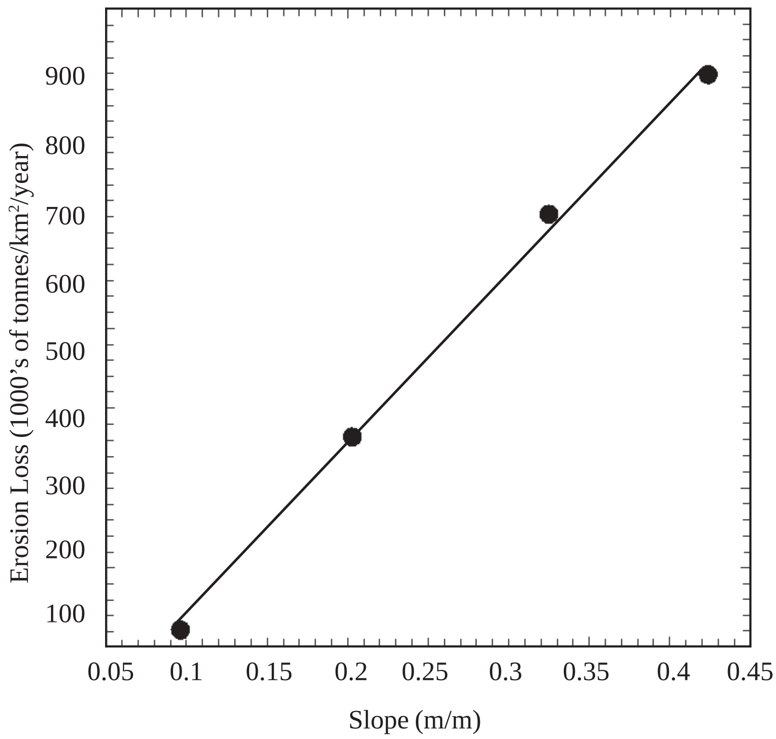
Steeper slopes contribute a disproportionate level of sediment for the same area disturbed

Figure 1-4 is a graphical presentation of the information related to slope and shows a clear relationship between slope and sediment loading. An important conclusion of the study is the finding, which is valid for the Auckland Region, that erosion rate triples as slope doubles. This makes the clear statement that steeper slopes contribute a disproportionate level of sediment for the same area disturbed.

In addition, work has been done in numerous other areas which also clearly demon-

Figure 1-4

Predicted Effect of Slope on Erosion Loss



strate the linkage that slope has on sediment loading. A study done in the U.S. in the mid 1980's (Maryland Department of Natural Resources, Erosion and Sediment Control Practices, 1987) looked at a number of parameters which could effect the discharge of sediments off of an earthworks site. One component of the study was to specifically look at the benefits of temporary stabilisation as an erosion control tool. Figure 1-5 looks at various types of stabilisation techniques but also looks at the impact of slope on sediment loading. As can be seen from Figures 1-4 and 1-5, regardless of specific accuracies or consistency between figures, there is a clear trend that sediment loading increases with slope angle.

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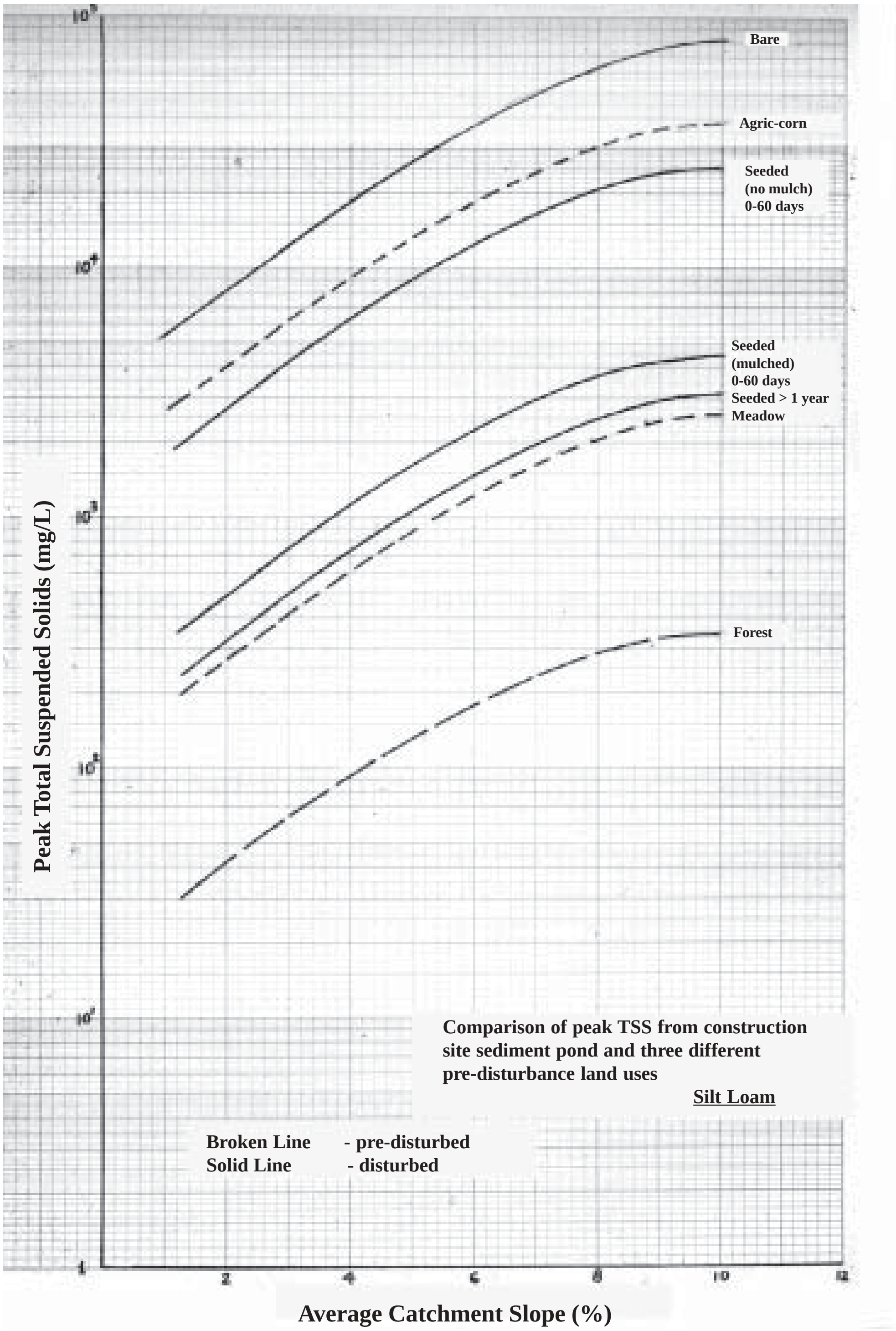
Figure 1-5
Relationship Between Vegetative Cover and Slope Versus Sediment Yield



Site disturbance may have profound impacts on vegetation, both existing and proposed. Invariably, once a site is disturbed the post-construction vegetation is a form of grass.

Vegetative Cover

Vegetation can be considered fairly easily if, once again, the Universal Soil Loss Equation is referred to. To repeat, the general form of the equation is:

$$A = R \times K \times (LS) \times C \times P$$

In the context of this section, the factors of importance are the "C" and "P" factors. The C factor is the ratio of soil loss under specified conditions to that of a bare site. When the soil is protected against erosion (forest or grass) then the C factor will reduce the soil loss estimate. C is 1.0 when the soil is bare.

The P factor relating to erosion control practice factor reflects the roughness of the earthworks surface. A factor of 1.0 is used to represent the native vegetation and grass situation. Representative C and P values are shown in Table 1.6.

Table 1.6
C and P Factors for USLE

Treatment	C Factor	P Factor
Bare soil		
compacted and smooth	1.0	1.3
track walked on contour	1.0	1.2
rough irregular surface	1.0	0.9
disked to 250 mm depth	1.0	0.8
Native Vegetation (undisturbed)	0.01	1.0
Pasture (undisturbed)	0.02	1.0
Temporary grass	0.1	1.0
Temporary cover crop	0.45	1.0

Lake Tutira provides a good case study to consider sedimentation rates. Lake sediments provide a long term record which records the cumulative effects of environmental change. Looking at Lake Tutira as an individual study, it was found that sedimentation rates under pasture are between 8-17 times that under forest and 5-6 times that under fern/scrub. At Lake Rotonuiaha, where the terrain is less steep, the increase in sedimentation rate from forest to pasture is approximately 6 times and from fern/scrub to pasture approximately 4 times. These sedimentation rates show a similar trend to those of several other studies.

Site disturbance may have profound impacts on vegetation, both existing and proposed. Invariably, once a site is disturbed the post-construction vegetation is a form of grass. There are advantages to grass and there are disadvantages just as there are advantages and disadvantages of other types of plants. The following is a brief discussion of various vegetative forms.

<u>Grasses, both annual and perennial</u>

Many annual grasses, including cereals, have good erosion control benefits. They are quick to germinate, and provide the fastest initial growth ground cover. They have a fibrous root mat which can extend into the ground up to 150 mm, which provides good soil surface coverage. They are readily available commercially at a relatively low cost. Their disadvantages relate to the need to replant with perennial grasses if permanent stabilisation is required in addition to the shallow root depth. Annual grasses also tend to die off during the summer months.

Perennial grasses, other than aggressive species such as kikuyu, grow slower than annual grasses and require more moisture and topsoil (for nutrients). With the variable nature of Auckland weather, they may require irrigation during dry periods. Application of mulching or hydroseeding techniques however, can establish a ground cover to provide short term protection from raindrop or sheet erosion until grass establishment. The seedlings do not compete well with annual grasses so establishment of a ground cover may necessitate use of herbicides to reduce competition with annual grasses. Perennial grasses have the same disadvantage as annual grasses with respect to slope protection.

Grasses are not good at providing stream channel erosion protection. The shallow root system has no channel armouring function.

Several other disadvantages of grasses relates to those in close proximity to streams. Grasses are not good at providing stream channel erosion protection. The shallow root system has no channel armouring function. In addition, the short height of grasses provides no shading for stream channels with potential thermal impacts adversely impacting on water quality. In a related area, grasses provide little benefit from a habitat standpoint.

Shrubs

Shrubs are less effective than grasses at short term erosion control due to the spacing of the plants themselves and the slower rate of growth. Their root depth is approximately the same as grasses root depth. The shallow nature of New Zealand soils ensures that roots are shallow in depth also as the humus enriched upper horizon is the primary source of nutrients. They can provide long term erosion control in addition to providing habitat for local wildlife. Shrubs are longer lived than grasses and can (depending on the species) exist in shaded or partially shaded areas.

In terms of initial site disturbance and revegetation, shrubs have limited benefit for protecting bare soils from erosion. On the other hand, leaving a portion of a site undisturbed where existing shrubs exist can provide good erosion protection of soils.

Trees

Trees of the Auckland region have three predominant rooting patterns.

- Tap-rooted species, where the tap-root remains dominant but laterals and pegs may also be well developed. (kauri)
- Plate-rooted species, where most of the root system consists of shallow spreading laterals, the tap-root is superseded and peg roots are usually weakly developed. (rimu)
- Heart rooted species where a number of major roots descend steeply from the base of the bole. (tarairi)

For the most part New Zealand trees are shallow rooted which probably reflects dependence on nutrient cycling through litter fall. However, it may be that deeply descending roots function disproportionately to their mass in bringing up water and nutrients from lower horizons. Root depth from mature trees can extend more than three metres into the ground. (Wardle, Peter, Vegetation of New Zealand, Cambridge University Press, 1991)

From an erosion control standpoint, trees are not good for initial site stabilisation. Their benefits are more long term by providing leaf canopy interception of rainfall, organic litter to cover the ground surface, stream channel erosion control benefits resulting from greater root depth for channel armouring, and habitat for wildlife. The overall benefits of trees will be discussed in Chapter 3. An interesting fact, similar to information provided under grasses related to slope slippage, also compares sedimentation rates. Sedimentation rates from Lake Tutira shows that while conversion of forest to pasture resulted in an approximately 8-17 times increase, the Lake Waikaremoana rate has decreased by nearly 50% since 1911 under a continuous indigenous forest cover.

Vicinity of Receiving Environments

The proximity of the receiving environment has a profound impact on sediment delivery. Soil washing from a disturbed slope may be deposited before it reaches a stream or water body. The likelihood of sediment reaching receiving environments depends on the delivery mechanism (overland flow or enclosed storm drain), the slope of the overland flow path (steep or flat), the length of flow, the vegetative cover of the overland flow path, and finally, the storm event itself (storm characterisation is discussed in Chapter 2).

A receiving environment can include the following:

- streams (perennial and ephemeral),
- estuaries and inlets,
- open coastal waters,
- aquifers,
- lakes, and
- wetlands

The vicinity of the disturbed area to any of these receiving environments and the delivery mechanism of the sediment determine the magnitude of the impact. Having enclosed storm drains on site, when functional, could allow for almost 100% delivery to the receiving environment. A common term for discussing how much sediment enters a receiving environment is “sediment delivery ratio”. Eroded soils often move a short distance before a decrease in runoff velocity, caused by a slope break or dense vegetative cover, causes their deposition. The ratio of sediment delivered at a given location in the receiving environment to the gross erosion from the catchment area above that location is the sediment delivery ratio. The delivery ratio may vary substantially for any given size of drainage area. Other important factors include soil texture, relief, type of erosion, sediment transport system, and areas of deposition within the catchment. Fine soil texture, high channel density, and high stream gradients generally indicate delivery ratios that are above average for the catchment-area size.

Anything that reduces runoff velocity reduces its capacity to transport sediment.

With a typical field size area, the delivery ratio can closely approach 1.0 if the runoff drains directly into a lake or stream system with no intervening obstructions or flattening of the land slope. On the other hand a substantial width of forest litter or dense vegetation below the eroding area may cause deposition of essentially all the sediment except the clay material. Anything that reduces runoff velocity (such as reduction in gradient, physical obstructions, vegetation, and ponded water) reduces its capacity to transport sediment. When the sediment loading exceeds the transport capacity of the runoff, deposition occurs.

Performance of Traditional Erosion and Sediment Control Practices in Terms of Sediment Retention and Sediment Yield

Erosion Control

Temporary stabilisation

As shown in figure 1-, sediment reductions by temporary straw mulching, when placed directly on disturbed land can reduce sediment discharge from that land approximately 90%. This effectiveness only applies for sheet flow conditions. If concentrated flow crosses a disturbed area, the straw mulching will not limit concentrated flow erosion. In those areas other forms of erosion control are necessary.

Sediment reductions by temporary straw mulching, when placed directly on disturbed land can reduce sediment discharge from that land approximately 90%

Erosion control blankets in areas of concentrated flow

Erosion control blankets are usually either synthetic or organic fibers held together with plastic netting. While they can be effective, their performance varies. Some general trends are that organic materials tend to be the most effective and that thicker materials are generally superior. These materials can be expensive. Their performance, when used correctly, are around 90% for erosion reduction.

Check dams

The purpose of check dams is to reduce flow velocities in areas of concentrated flow to the point where erosion of the channel boundaries does not occur. They are not designed to remove sediment once it is in the water column but rather to prevent scour of channel boundaries until vegetative stabilisation has occurred.

Sediment Control

There are two basic functions of traditional sediment control practices 1) to reduce sediment loads leaving a construction site once they have entered the water column, and 2) to convey water through and off site without increasing erosion potential of site soils. Sediment control approaches include a number of specific practices and a few of the more common practices are discussed here.

Silt fence

Silt fences are widely used throughout the Auckland region, and they are often abused. They perform well under some conditions and are not prohibitive in cost to use. They are often used inappropriately in areas having too large a catchment size or in areas where concentrated flow occurs. While considered generally as a filtering mechanism, their primary function is to pond water behind them to allow for settling of sediments, thus effectiveness relates to detention time. The effectiveness of silt fences, through studies, ranges from 36% to 90% for sediment loading reduction. A common conclusion of the studies is that their effectiveness decreases with increasing slope, primarily due to reduced ponding volumes behind the fence.

Sediment retention ponds

Sediment retention ponds are faced with the daunting responsibility of intercepting large volumes of stormwater runoff having massive sediment loading and having significant trapping of the entrained sediments while allowing the stormwater

Silt Fence Installation on the ALPURT Motorway Project

inflows to be released. From the initial discussion on sediment loading, 168 tonnes of sediment can be delivered per year to the pond from each disturbed hectare draining to it. Studies in the U.S. have documented much higher erosion rates from disturbed land with normal ranges being 492 tonnes/hectare. The Auckland rate of erosion is based on one study and the results could be considerably higher if a similar analysis was done elsewhere in the region. Regardless of the annual amount generated, sediment retention ponds have to do a difficult job in a very dynamic environment.

In terms of performance, the expectations are very site specific with primary variables being slope and soil conditions.

In terms of performance, the expectations are very site specific with primary variables being slope and soil conditions. Looking at studies where inflow and outflow monitoring was conducted, performance has been varied considerably, even for the same pond during different storms. Performance results (recognising that

Typical Sediment Pond with a Decant System different areas have different soils, slopes, rainfall, and design criteria) demonstrate reductions in sediment loadings from 40% - 98% as a result of sediment retention pond performance. A study in the Auckland region (Winter, R., Balks, M., Moon, V., Sediment Yield During Earthworks & Efficiency of a Sediment Retention Pond, 1998) documented performance of a sediment retention pond in the Albany area at approximately 90% effectiveness at trapping suspended material. It is expected, in the Auckland region, that sediment retention ponds would function at 70% - 90% effectiveness based on ARC design guidance.

Site Development Approach

How a site is developed also can have a profound impact on sediment loading. The ARC has a set of recommendations called “The 10 Commandments”, some of which are very appropriate to reinforce here with respect to site development approaches.

<u>Fit land development to land sensitivity</u>

Some parts of a site should never have earthworks undertaken and some others need really careful working. Avoid areas that are wet (streams, wetlands, springs), have steep or fragile soils, or are conservation sites or features. Bear in mind the *minimum earthworks strategy* - ideally, only clear areas required for structures or for access.

<u>Stage construction</u>

Carrying out bulk earthworks over the whole site maximises the time and area that soil is exposed and prone to erosion. “Construction Staging” where the site has earthworks undertaken in small units over time with progressive revegetation, limits erosion.

Careful planning is needed. Temporary stockpiles, access and utility service installation all need to be planned.

<u>Protect steep slopes</u>

Existing steep slopes should be avoided. If clearing is absolutely necessary, runoff from above the site can be diverted away from the exposed slope to stop gullies forming. If they are worked and stabilisation is required, traditional vegetative covers like topsoiling and seeding may not be enough.

<u>Protect watercourses</u>

Existing streams, watercourses and proposed drainage patterns need to be mapped. Clearing is not permitted adjacent to a watercourse unless the works have been approved by the ARC. Where undertaken, work that crosses or disturbs the watercourse needs careful planning.

<u>Stabilise exposed areas rapidly</u>

The ultimate erosion and sediment control objective is to fully stabilise soils with vegetation after each stage and at specific milestones within stages. Methods are site specific and can range from conventional sowing through to straw mulching. Mulching is the most effective instant protection.

The ultimate erosion and sediment control objective is to fully stabilise soils with vegetation after each stage and at specific milestones within stages.

<u>Install perimeter controls</u>

Perimeter controls above the site keep clean runoff out of the worked area - a critical factor for effective erosion control. Perimeter controls can also retain or direct sediment laden runoff within the site. Common perimeter controls are diversion drains, silt fences, and earth bunds.

<u>Employ detention devices</u>

Along with erosion control measures, sediment retention structures are needed to capture runoff so sediment generated on site can settle out. The fine grained nature of Auckland soils means sediment retention ponds are often not highly effective. Ensure the other control measures used are appropriate for the project and adequately protect the receiving environment.

The above discusses the individual factors which influence sediment loading from an earthworks site. All of the factors are of importance when developing a site and consideration of all factors needs to be undertaken. This is discussed in Chapter 4.

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