

Soil Stability in the Waikato Region 2007

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Table of contents

Acknowledgements	i
Executive summary	vii
1 Introduction	1
2 Methods	1
2.1 Background	1
2.2 Brief and specifications	2
2.3 Survey concepts and definitions	3
2.4 Description of survey methods	4
2.5 Technical conclusions	4
3 Report structure	4
3 Region wide results	5
3.1 Soil stability throughout the Waikato region, 2007	5
3.1.1 Stable surfaces	6
3.1.2 Erosion- prone surfaces	6
3.1.3 Eroded and eroding surfaces	6
3.1.4 Extensively disturbed surfaces	6
3.1.5 Unclassifiable surfaces	7
3.2 Soil disturbance throughout the Waikato region, 2007	7
3.2.1 Disturbance by land use	8
3.2.2 Disturbance by natural processes	8
3.2.3 Regional totals (land use related and natural processes)	9
3.2.4 Land uses in Waikato region	9
4 Horticulture and cropping	11
4.1 Overview	11
4.2 Soil stability	11
4.2.1 Stable surfaces	12
4.2.2 Erosion- prone surfaces	12
4.2.3 Eroded and eroding surfaces	12
4.2.4 Soil disturbance	12
4.2.5 Disturbance by land use	13
4.2.6 Disturbance by natural processes	13
4.2.7 Summary of disturbance	13
5 Dairy farms	14
5.1 Overview	14
5.2 Soil stability	14
5.2.1 Stable surfaces	14
5.2.2 Erosion- prone surfaces	14
5.2.3 Eroded and eroding surfaces	15
5.3 Soil disturbance	15
5.3.1 Disturbance by land use	16
5.3.2 Disturbance by natural processes	16
5.3.3 Summary of disturbance	16
6 Drystock farms	16
6.1 Overview	16
6.2 Soil stability	17
6.2.1 Stable surfaces	17
6.2.2 Erosion- prone surfaces	17
6.2.3 Eroded and eroding surfaces	17
6.3 Soil disturbance	18
6.3.1 Disturbance by land use	18
6.3.2 Disturbance by natural processes	19

6.3.3	Summary of disturbance	19
7	Forest plantations	19
7.1	Overview	19
7.2	Soil stability	20
7.2.1	Stable surfaces	20
7.2.2	Erosion- prone surfaces	20
7.2.3	Eroded and eroding surfaces	21
7.3	Soil disturbance	21
7.3.1	Disturbance by land use	22
7.3.2	Disturbance by natural processes	22
7.3.3	Summary of disturbance	22
8	Natural forest	22
8.1	Overview	22
8.2	Soil stability	23
8.2.1	Stable surfaces	23
8.2.2	Erosion- prone surfaces	23
8.2.3	Eroded and eroding surfaces	24
8.3	Soil disturbance	24
8.3.1	Disturbance by land use	25
8.3.2	Disturbance by natural processes	25
8.3.3	Summary of disturbance	25
9	Natural scrub	25
9.1	Overview	25
9.2	Soil stability	26
9.2.1	Stable surfaces	26
9.2.2	Erosion- prone surfaces	26
9.2.3	Eroded and eroding surfaces	26
9.3	Soil disturbance	27
9.3.1	Disturbance by land use	27
9.3.2	Disturbance by natural processes	28
9.3.3	Summary of disturbance	28
10	Exotic scrub	28
10.1	Overview	28
10.2	Soil stability	29
10.2.1	Stable surfaces	29
10.2.2	Erosion- prone surfaces	29
10.2.3	Eroded and eroding surfaces	29
10.3	Soil disturbance	30
10.3.1	Disturbance by land use	30
10.3.2	Disturbance by natural processes	31
10.3.3	Summary of disturbance	31
11	Tussock and mountain vegetation	31
11.1	Overview	31
11.2	Soil stability	32
11.2.1	Stable surfaces	32
11.2.2	Erosion- prone surfaces	32
11.2.3	Eroded and eroding surfaces	32
11.3	Soil disturbance	33
11.3.1	Disturbance by land use	33
11.3.2	Disturbance by natural processes	34
11.3.3	Summary of disturbance	34
12	Wetland and coastal vegetation	34
12.1	Overview	34
12.2	Soil stability	34
12.2.1	Stable surfaces	35
12.2.2	Erosion-prone surfaces	35

12.2.3	Eroded and eroding surfaces	35
12.3	Soil disturbance	36
12.3.1	Disturbance by land use	36
12.3.2	Disturbance by natural processes	37
12.3.3	Summary of disturbance	37
13	Summary	37
13.1	Soil stability, soil disturbance and bare soil region-wide	37
13.1.1	On stable and erosion- prone land	38
13.1.2	On eroded and eroding land	38
13.1.3	On extensively disturbed land	38
13.2	Soil disturbance region wide	39
13.3	Pressure on soil - impacts of land use	40
13.3.1	On land in rural use	40
13.3.2	On land in conservation use	41
13.3.3	On land in other use	41
13.4	Pressure on soil - impacts of natural processes	41
13.4.1	On land in rural use	42
13.4.2	On land in other use	42
References		43
Appendix 1: Data recording codes and procedures used for Environment Waikato's point sample 2009		44
Appendix 2	Technical conclusions	47

List of tables

Table 1:	Soil stability throughout the Waikato region, 2007	5
Table 2:	Soil disturbance throughout the Waikato region, 2007	7
Table 3:	Land uses in Waikato region 2007	9
Table 4:	Soil stability for horticulture and cropping in Waikato region, 2007	11
Table 5:	Soil disturbance amongst horticulture and cropping in Waikato region, 2007	12
Table 6:	Soil stability for dairy farms in the Waikato region, 2007	14
Table 7:	Soil disturbance on dairy farms in the Waikato region, 2007	15
Table 8:	Soil stability for drystock farms in Waikato region, 2007	17
Table 9:	Soil disturbance on drystock farms in the Waikato region 2007	18
Table 10:	Soil stability for forest plantations in Waikato region, 2007	20
Table 11:	Soil disturbance in forest plantations in Waikato region, 2007	21
Table 12:	Soil stability for natural forest in Waikato region, 2007	23
Table 13:	Soil disturbance in natural forest in the Waikato region 2007	24
Table 14:	Soil stability for natural scrub in the Waikato region 2007	26
Table 15:	Soil disturbance in natural scrub in Waikato region, 2007	27
Table 16:	Soil stability for exotic scrub in the Waikato region 2007	29
Table 17:	Soil disturbance in exotic scrub in Waikato region, 2007	30
Table 18:	Soil stability for tussock and mountain vegetation in Waikato region, 2007	32
Table 19:	Soil disturbance amongst tussock and mountain vegetation in Waikato region, 2007	33
Table 20:	Soil stability for wetlands and coastal vegetation in the Waikato region, 2007	34
Table 21:	Soil disturbance amongst wetland and coastal vegetation in Waikato region, 2007	36
Table 22:	Soil stability, disturbance and bare soil region wide	37
Table 23:	Soil disturbance and bare soil region-wide	39
Table 24:	Impacts of land use on soil	40
Table 25:	Impacts of natural processes on soil	41

Executive summary

This report summarises data and discusses results from a survey of soil stability (intactness and disturbance) undertaken for Environment Waikato (EW) in the year 2009. The survey has been carried out in accordance with the National Land Monitoring Forum's procedure for point sampling. A previous survey was conducted for the Waikato region in 2003. Both surveys have been undertaken primarily to provide information about soil stability (intactness and disturbance) for state of environment reporting.

The monitoring was defined by the boundaries of the area that EW has statutory responsibility for. Within this area, soil stability was assessed at 6122 sample points, distributed at 2 kilometre intervals on the map grid, using digital orthophotos taken for EW in 2007-08. Data recorded were land use, associated vegetation, soil stability, soil disturbance (if present), and area freshly disturbed (where present).

Soil stability

49.8% of the region's land surface was stable in 2007. 22.5% was erosion-prone but inactive. 16.8% was recently eroded or freshly eroding. 7.0% was extensively disturbed. 3.9% was unclassifiable (no aerial photographs).

49.4% of the region's land surface had intact soil (well-vegetated) in 2007. 23.0% had soil temporarily disturbed by land use. This percentage denotes that soil disturbed by land use is present on part (not all) of the surface area.

In 2007 9.3% of the region's land surface had soil recently disturbed by natural processes of erosion or deposition, but revegetating. 7.5% had soil freshly disturbed by natural processes. This percentage denotes that soil disturbed by natural processes is present on part (not all) of the surfaces' area.

In 2007 7.0% of the region's land surface had soil that was partially removed or absent due to extensive disturbance. This land included urban areas (1.0%) where much of the soil was covered by buildings and paved surfaces. It also included rural buildings and yards (2.5%) where some of the soil was covered. Finally it included shorelines and waterbodies (3.5%) where soil was either stripped or submerged.

Soil disturbance

In 2007 bare soil, sediment or rock exposed by all forms of disturbance amounted to 2.85% of the region's area.

On stable and erosion-prone land surfaces, land use related disturbance exposed bare soil by :

- farm or forest tracks (includes unsealed track surface) on 0.89% of the region's area,
- cultivation on 0.81%,
- harvest (includes forest harvest) on 0.15%,
- livestock grazing pressure on 0.08%,
- earthworks on 0.07%,
- rural roads (includes unsealed road surface) on 0.08%,
- drain excavation or cleaning on 0.03%.

On eroded and eroding land surfaces, natural disturbance exposed bare soil by:

- slope failures (landslides, debris avalanches, slumps and earthflows) on 0.10% of the region's area,
- surface erosion (sheetwash, sandblow, rockfall or outcrop) on 0.32%,
- riparian erosion and deposition (river and stream banks) on 0.06%,
- gullies (under-runners and open) on 0.05%,

On extensively disturbed land surfaces, land use related disturbance exposed bare soil, sediment and rock associated with :

- rural buildings and yards, quarries and mines on 0.14% of the region's area,
- urban earthworks etc. on 0.02%,

and natural disturbance exposed bare soil, sediment and rock associated with :

- shoreline processes on 0.05%.

Soil disturbance on land in rural use

62.2% of Waikato's land was under rural uses in 2007. They exposed bare soil on 2.02% of the region's area :

- Horticulture and cropping contributed 0.52%,
- Dairy pasture contributed 0.81%,
- Drystock pasture contributed 0.42%,
- Forest plantations contributed 0.27%.

On land under rural uses, natural processes of erosion and deposition exposed bare soil on an additional 0.22% of the region's area :

- <0.01% on land used for horticulture and cropping,
- 0.03% on land in dairy pasture,
- 0.17% on land in drystock pasture,
- 0.02% on land in forest plantations.

Soil disturbance on land in conservation use

26.9% of Waikato's land was under conservation uses in 2007. They exposed bare soil on 0.09% of the region's area :

- Natural forest contributed 0.01%,
- Natural scrub contributed 0.03%,
- Exotic scrub contributed 0.04%,
- Wetland and coastal vegetation contributed 0.01%,
- Tussock and mountain vegetation contributed <0.01%.

On land under conservation uses, natural processes of erosion and deposition exposed bare soil on an additional 0.31% of the region's area :

- 0.02% on land in natural forest,
- 0.03% on land in natural scrub,
- 0.02% on land in exotic scrub,
- 0.03% on land in wetland and coastal vegetation,
- 0.23% on land in tussock and mountain vegetation.

Soil disturbance on land in other use

7.0% of Waikato's land was under other uses (urban areas, rural buildings etc., shorelines or waterbodies) in 2007. Here land use-related activities exposed bare soil, sediment or rock on an additional 0.16% of the region's area :

- Rural buildings, yards, quarries and mines contributed 0.14%,
- Urban areas contributed 0.02%,
- Shorelines and waterbodies contributed <0.01%.

On land under other uses, natural processes of erosion and deposition exposed bare soil, sediment or rock on an additional 0.05% of the region's area :

- <0.01% amongst rural buildings etc.,
- <0.01% in urban areas,
- 0.04% along shorelines.

1 Introduction

This report summarises data and discusses results from a survey of soil stability (intactness and disturbance) undertaken for Environment Waikato (EW) in the year 2009. The survey has been carried out in accordance with the Land Monitoring Forum's (LMF) procedure for point sampling. A previous survey was conducted for the Waikato region in 2003, and is similar to surveys carried out in the Manawatu-Wanganui, Auckland, Gisborne, Wellington, Tasman and Bay of Plenty regions between 1997 and 2005.

This survey has been undertaken primarily to provide information about soil stability (intactness and disturbance) for state of environment reporting. Survey data are also expected to be useful for other purposes, such as providing detail about the region's land use and vegetation cover; assessing the extent of vegetative soil conservation measures; and as a source of facts and figures for the Council's policy documents and publications.

This document is the first of two reports:

- **Soil Stability in the Waikato Region 2007**
- Changes in Soil Stability in the Waikato Region from 2002 to 2007

2 Methods

2.1 Background

Key points about the background to this survey are :

- Councils have a statutory responsibility to collect information about state of the environment for their regions (Section 35, Resource Management Act).
- Much of the information collected in the past relates to water. Councils now see a need to collect more information about soil.
- Participation in the 500 Soils Programme is already supplying useful base-line information about soil quality i.e. changes in soil fertility, structure and biology under different land uses.
- However the 500 Soils Programme does not measure soil intactness or disturbance : how well a region's soil is being kept in place as a resource for farming, forestry and conservation; and how much is being disturbed through land use or lost through erosion.
- A soil intactness/disturbance monitoring programme should be technically sound, statistically robust, provide easily understandable data, within a short space of time, and at an acceptable cost.
- Techniques should be selected that meet each council's particular needs, but are also consistent with methods used by other regional councils.

The regional councils' Land Monitoring Forum (LMF) evaluated several pilot studies and prototype surveys carried out for its members between 1996 and 2003. Point sampling from aerial photography was found to be a suitable technique, and from 2004 to 2009 several region-wide surveys have been carried out using a standard format recommended by LMF. Survey procedure has been recently documented as Chapter Four of a Land Monitoring Manual for use by regional councils and their contractors.

One of the trials was undertaken for Environment Waikato in the year 2003, by Dr. D. Hicks of Ecological Research Associates. For that particular trial, EW requested point sampling of rural land from aerial photographs of the region taken in summer 2002-2003. The trial survey's methods, data analyses and findings were documented by Hicks (2003, 2005).

In 2009 EW commissioned Mr. A. B. Thompson of Thelton Environmental Ltd to undertake a new point sample from region-wide orthophotos (rectified aerial photographs) taken in 2007, and stored on the Council's geographic information system (GIS). Dr. Hicks designed the survey in June 2009, in conjunction with Mr. Thompson and the Council's soil scientist Dr. Reece Hill. One of the Council's GIS specialists, Mr. Dan Borman, set up a Geomedia procedure for Mr. Thompson to use on the GIS. Photo-interpretation was undertaken by Mr. Thompson in July-August 2009, followed by data analysis and draft report preparation in September-October. Dr. Hicks assisted Mr. Thompson throughout with procedural tests, quality control checks and report editing.

2.2 Brief and specifications

The specifications proposed for EW's survey were drafted in accordance with the LMF manual:

Objectives

The primary objective was to measure the stability of soil (intactness and disturbance) in the Waikato region and its change over time. This was to assist EW's preparation of reports about state of its environment. A secondary objective was to characterise soil disturbance using factors such as land use, vegetation cover, landform, and erosion type. This was to assist with addressing the issues of soil disturbance and accelerated soil erosion under current land uses. A third objective was to continue an established regional soil stability measurement programme which is technically sound, statistically robust, provides easily understandable data, within a short space of time, and can be carried out at an acceptable cost. This will assist with monitoring what effect natural events, land use changes, and remedial policies or measures are having on soil disturbance.

Monitoring area

The monitoring was defined by the boundaries of the area that Environment Waikato has statutory responsibility for. Within this area, soil stability was assessed at 6122 sample points, distributed at 2 kilometre intervals on the NZTM map grid. Although spatially regular, this sample design is random with respect to land use and other factors which are unrelated to the map grid. Sample points are the same as those used for a previous survey in 2003.

Sampling method

Monitoring was performed using digital orthophotos (rectified aerial photographs) taken for EW in 2007-08. Interpretation was by on-screen viewing through GIS software, with direct entry of data to a GIS-linked database. Viewing was carried out at a scale of 1:5000, zooming to larger scales to inspect detail at points when necessary, and to smaller scales to view points in the context of surrounding terrain. Data items related to the area delineated by a one hectare square centred on each sample point.

Data items

Data recorded in 2009 are land use, secondary vegetation, soil state, soil disturbance type, and area freshly disturbed. Items which have not changed since previous survey

(notably landform) were not re-recorded. Standard LMF codes were used when recording data.

Bare soil

Area freshly disturbed was measured by applying a 100 dot measuring grid to an area of 1 hectare at each point where bare soil is detected. Measurement was carried out at a viewing scale of 1:5,000. The measuring grid was applied to each point by means of a GIS layer.

Data storage

Sample point locations, one-hectare squares, and measuring grids were stored as Geomedia map layers. Sample point locations were cross-referenced to a Geomedia database, which contained their map grid references and raw data for all points. The database was exportable as an Excel spreadsheet.

Analysis procedure

The point analysis procedure involved spreadsheet sorts, followed by point counts and conversion of totals to percentages of regional area, and area in each land use. Cluster analysis of bare soil was carried out for aggregated points in each category (soil state and disturbance type as appropriate).

Photo-interpretation error

Photo-interpretation error was ascertained by randomly selecting 100 points and having them checked by an independent photo-interpreter, followed by field visits to points where information was in doubt.

Sample error

Standard statistical significance tests were applied to calculate confidence limits for sample results.

Reporting

A draft report was supplied to Environment Waikato prior to presentation of a final report. The final report is to include results and interpretation for soil stability (intactness and disturbance) in a format similar to recent reports for Environment Waikato, Greater Wellington Regional Council, Environment Bay of Plenty, and Auckland Regional Councils.

Additional investigations

Additional analyses and reports about vegetation associated with land uses, and extent/effect of vegetative soil conservation cover, can be prepared from the point sample. These may be required for the Waikato region as a whole, or for areas within the region (catchment management zones). Such reports will be supplied only if requested by EW, separately from the contract for region-wide point sampling and analysis/reporting of soil stability.

2.3 Survey concepts and definitions

Chapter Four of the LMF manual states some concepts that underpin the measurement of soil erosion for environmental reporting:

- Soil stability
- Soil intactness and disturbance
- Soil erosion and accumulation

LMF's standard report format interprets soil erosion or accumulation using the broader framework of soil stability, intactness and disturbance. Reports identify whether points are on stable or unstable landforms. They then show whether current vegetation cover (or its absence) indicates points as being intact, at risk of soil disturbance, or recently disturbed, or freshly disturbed. They also differentiate whether disturbance entails the shifting around of soil by land use, or its erosion and accumulation by natural processes.

Chapter Four defines these and other terms used in the reports e.g. stable and unstable, erosion-prone, eroded and eroding, extensively disturbed, land use-related disturbance, natural disturbance, intact soil, disturbed soil, vegetated soil, bare soil, rural land use, non-rural land use.

2.4 Description of survey methods

Chapter Four of the LMF manual describes a standard survey procedure, but also makes provision for variations in what is recorded and how it is analysed. The purpose of these variations is to meet Councils' particular needs.

EW's 2009 re-survey followed the standard procedure in almost all respects, so readers are referred to Chapter Four for a detailed description. Any variations were minor, and relate to locally applicable data recording codes (see list in Appendix 1).

2.5 Technical conclusions

Technical conclusions about the re-survey are given in Appendix 2 of this report. Technical conclusions about 2002-2007 comparisons are given in the second report (Thompson and Hicks 2009b).

3 Report structure

Initially this report will focus on region wide results that are presented as a series of key tables (Table 2.1, 2.2 and 2.3) in Section 4.

Table 2.1 summarises the stability of Waikato's soil in 2007, the year of aerial photographic survey. It is a regional overview which contains key items for state of environment reporting (SER), specifically:

- percentage of sample points which have stable surfaces (S),
- percentage of erosion-prone but inactive surfaces (U),
- percentage of recently eroded (R) and freshly eroding (E) surfaces,
- percentages disturbed by land use (on S and U surfaces), and
- percentages disturbed by natural processes (on R and E surfaces).

These percentages (with attached confidence limits) are from a region-wide sample of 6122 points, which is sufficiently large to calculate extent of intact and disturbed soil in hectares region-wide.

Due to rounding in the tables, calculated sub-totals and totals differ by 0.1% (point percentages) to 0.01% (area percentages) from the apparent sums of their components. Calculated sub-totals and totals are cited in the report text.

At points where soil disturbance has been recorded, not all the soil is bare. Cluster sampling has been used to measure areas and calculate percentages of bare soil on one-hectare squares around each sample point. In Table 2, the summed areas and percentages give region-wide measurements of:

- how much soil is bare due to different kinds of land use-related disturbance,

- how much soil is bare due to natural disturbance by various processes of erosion or deposition.

Table 2.3 contains summary data about land use on Waikato's soil in the year 2007, specifically:

- percentage of sample points in each of nine broad rural land uses (horticulture and cropping, dairy farms, drystock farms, forest plantation, natural forest, natural scrub, exotic scrub, wetland and coastal vegetation, tussock and mountain vegetation).
- percentage composition of vegetation cover, for sample points within each rural use, and
- percentage of sample points not in rural use (buildings and yards, urban areas, shorelines and water bodies, points unclassified or lacking aerial photo cover).

Following the region wide results, each land use listed in Table 2.3 will be reported in Section 5 under the headings of soil stability (Tables 2.4-2.20) and soil disturbance (Tables 2.5 to 2.21). They summarise to what extent Waikato's soil is intact or disturbed under various rural land uses, together with the land uses' respective contributions to bare soil, region-wide.

3 Region wide results

3.1 Soil stability throughout the Waikato region, 2007

Table 1: Soil stability throughout the Waikato region, 2007

	Points	Points as % of region ¹	95% c.i. ³	Bare soil as % of area ²	
Stable surfaces	3049	49.8	1.3		
S (i) with intact soil	2024	33.1			
S (ii) with soil disturbed by land use	1025	16.7	0.9	1.66	0.19
Erosion-prone surfaces	1379	22.5	1.0		
U (i) with intact soil	996	16.3	0.9		
U (ii) with soil disturbed by land use	383	6.3	0.6	0.46	0.07
Eroded (R) and eroding (E) surfaces	1024	16.7	0.9		
R (i) with re-vegetating soil	567	9.3	0.7		
E (ii) with soil disturbed by natural processes	457	7.5	0.7	0.53	0.11
Extensively disturbed surfaces	429	7.0	0.6		
Rural buildings and yards	151	2.5	0.4	0.14	0.06
Urban areas and urban-rural fringe	63	1.0	0.3	0.02	0.02
Water bodies and coastal features	215	3.5	0.5	0.05	0.03
Unclassifiable surfaces					
Points with no aerial photos	241	3.9	0.5	4	4
All surfaces in region total	6122	100.0	0.0	2.85	0.24
<p>Note 1: "% of sample" sub-totals/totals may differ by 0.1% due to rounding. Note 2: "% of area" sub-totals/totals may differ by 0.01% due to rounding. Note 3: confidence limits are not additive. Note 4: not measured in 2007.</p>					

The region's sample points are:

- 49.8% stable surfaces,
- 22.5% erosion-prone but inactive surfaces,
- 16.7% actively eroded and eroding surfaces,
- 7.0% extensively disturbed surfaces, and
- 3.9% unclassifiable (no aerial photographs).

3.1.1 Stable surfaces

Stable surfaces are protected floodplains, drained wetlands, elevated terraces, rolling downlands, parts of hill country and ranges that show no sign of past erosion, and old coastal dunes with weathered soils.

- 49.8% of the region's sample points have stable surfaces,
- two thirds of these stable sample points (33.1% of the region) have intact soil, currently well-vegetated, and
- a third of the stable sample points (16.7% of the region) have soil currently disturbed by land use. Bare soil within this category accounts for 1.66% of the region's area.

3.1.2 Erosion- prone surfaces

Erosion-prone surfaces are unprotected floodplains, undrained or semi-drained wetlands, drainage hollows through terraces and downlands, parts of hill country and ranges that show signs of past erosion but are currently not eroding, and intermediate-age coastal dunes that are fixed by vegetation.

- 22.5% of the region's sample points have erosion-prone surfaces that are currently inactive,
- three quarters of these erosion-prone sample points (16.3% of the region) have intact soil, currently well-vegetated, and
- a quarter of the erosion-prone sample points (6.3% of the region) have soil currently disturbed by land use. Bare soil within this category accounts for 0.46% of the region's area.

3.1.3 Eroded and eroding surfaces

Eroded and eroding surfaces are river and stream banks, wetland margins, under-runners or gullies through terraces and downlands, parts of hill country, ranges and mountains that are subject to mass movement erosion (slope failure), scour and deposition of sediment along valley bottoms, and young coastal dunes subject to sandblow.

- 16.7% of the region's sample points have recently active eroded surfaces and freshly active eroding surfaces,
- over half of these eroded and eroding sample points (9.3% of the region) have soil recently disturbed by natural erosion processes but revegetating, and
- under half of the eroded and eroding sample points (7.5% of the region) have soil freshly disturbed by natural erosion. Bare soil within this category accounts for 0.53% of the region's area.

3.1.4 Extensively disturbed surfaces

Extensively disturbed surfaces are areas of land where soil has been removed in whole or part, re-contoured, or covered by buildings, pavements or water.

- 7.0% of the region's sample points are extensively disturbed surfaces.

2.5% are rural land in non-agricultural use, where some of the soil is covered by buildings and yards; industrial premises and quarries; or roads, railways and airfields. Most of these points are vegetated or paved, but associated bare soil accounts for 0.14% of the region's area, much of it quarry or mine excavation, though some has other causes (construction earthworks, unsealed yards or tracks).

1.0% are land in urban use, where much of the soil is covered by buildings and paved surfaces. Some is still vegetated, particularly urban open spaces and residential gardens. The covered and vegetated areas now have little soil disturbance. Here, bare soil accounts for 0.02% of the region's area, mostly subdivision earthworks or new roading.

An additional 3.5% of the region's sample points are water bodies or coastal features, extensively disturbed by natural processes in the absence of any land use. Here bare ground accounts for 0.05% of the region's area, which comprises bare rock, soil sheetwash, landslides on cliffs; sandblows amongst dunes; sediment deposits along beaches, and tidal creeks.

3.1.5 Unclassifiable surfaces

A final 3.9% of the region's sample points are unclassifiable. These comprise points not covered by the 2007 aerial photography.

3.2 Soil disturbance throughout the Waikato region, 2007

Table 2: Soil disturbance throughout the Waikato region, 2007

	Points	Points as % of region ¹	95% c.i. ³	Bare soil as % of region ²	95% c.i. ³
By land use					
grazing pressure	146	2.4	0.4	0.08	0.02
cultivation	110	1.8	0.3	0.81	0.19
harvest	74	1.2	0.3	0.15	0.05
spraying	1	<0.1	<0.1	<0.01	<0.01
drains	46	0.8	0.2	0.03	0.01
tracks	925	15.1	0.9	0.89	0.07
earthworks	42	0.7	0.2	0.07	0.06
roads	64	1.0	0.3	0.08	0.02
rural land use sub-total	1408	23.0	1.1	2.12	0.20
rural buildings etc	151	2.5	0.4	0.14	0.06
urban areas etc.	63	1.0	0.3	0.02	0.02
Land use disturbance total	1622	26.5	1.1	2.27	0.21
By natural processes					
landslide	117	1.9	0.3	0.06	0.01
debris avalanche	34	0.6	0.2	0.03	0.02
slump or earthflow	14	0.2	0.1	0.01	<0.01
tunnel gully	44	0.7	0.2	0.02	0.01
gully	53	0.9	0.2	0.03	0.01
streambank scour	62	1.0	0.3	0.03	0.01
streambank deposit	29	0.5	0.2	0.03	0.01
sandblow	11	0.2	0.1	0.05	0.05
sheetwash	24	0.4	0.2	0.09	0.05
rockfall or bare rock	64	1.0	0.2	0.15	0.08
geothermal	4	0.1	0.1	0.02	0.03

natural processes sub-total	457	7.5	0.7	0.53	0.11
shorelines etc.	215	3.5	0.5	0.05	0.03
Natural disturbance total	672	11.0	0.8	0.57	0.12
undisturbed points	3587	58.6	1.2		
points with no photos in 2007	241	3.9	0.5		
Undisturbed etc. total	3831	62.6	1.2		
Total	6122	100.0	0.0	2.85	0.24
Note 1: "% of region" sub-totals/totals may differ by 0.1% due to rounding. Note 2: "bare soil as % of region" sub-totals/totals may differ by 0.01% due to rounding. Note 3: confidence limits are not additive. Note 4: not measured in 2007.					

3.2.1 Disturbance by land use

Land-use related disturbance is present on 26.5% of the region's land. Bare soil equates to 2.27% of the region's area.

- 23.0% of the region's land is currently disturbed by rural land use. This number corresponds with the sum of percentages for S (ii) and U (ii) from Table 2.1.
- Farm or forest tracks are the most widespread disturbance by land use, present on 15.1% of the region's land. Bare track surface equates to 0.89% of the region's area.
- Cultivation and harvest activities (includes forest harvest) are collectively present on 3.0% of the region's land, and responsible for bare soil on 0.81%, and 0.15% of the region's area respectively.
- Livestock grazing pressure is present on 2.4% of the region's land, and exposes bare soil on 0.08% of the region's area.
- Earthworks for farm buildings or forest harvest sites occupy 0.7% of the region's land, and account for bare soil on 0.07% of the region's area.
- Unsealed rural roads cross 1.0% of the region's land, and associated bare soil is 0.08% of the region's area.
- Drain excavation or cleaning is present at 0.8% of the region's land, and has bared soil on 0.03% of the region's area.
- Rural buildings etc. (yards and roads, quarries and mines) cover 2.5% of the region's land. Associated bare soil is 0.14% of the region's area.
- 1.0% of the region is in urban use. 0.02% of the region's area has bare soil due to disturbance associated with houses, commercial buildings, roads and open spaces.

3.2.2 Disturbance by natural processes

Disturbance by natural processes is present on 11.0% of the region's land and bare soil equates to 0.57% of the region's area.

- 7.5% of the region's land is currently disturbed by natural processes of erosion or deposition. This number corresponds with the percentage for E(ii) from Table 2.1.
- Slope failures are the most widespread disturbance by natural processes of erosion or deposition. Landslides and debris avalanches, slumps and earthflows, are

collectively present on 2.7% of the region's land. They cause bare soil on 0.10% of the region's area.

- Surface erosion, although not as widespread as slope failure, accounts for more bare soil. Sheetwash (0.4% of the region's land), rockfall or rock outcrops (1.0%), and sandblow (0.2%), collectively give rise to bare soil on 0.29% of the region's area.
- Riparian erosion and deposition are present on a similar percentage (1.5%) of the region's land, but deposits of sand, silt or gravel along watercourses together with bank scour and collapse, account for less bare soil, at just 0.06% of the region's area.
- Tunnel gullies (under-runners) and open gullies are comparable to riparian disturbance in both number of points and extent of bare soil (1.6% of the region's land and 0.05% of its area).
- Natural process disturbance associated with rural buildings etc. exposes bare soil on less than 0.01% of regional area.
- Natural process disturbance associated with urban areas etc. exposes bare soil on less than 0.01% of regional area
- Natural process disturbance associated with water bodies or shorelines exposes bare soil, sediment or rock on 0.05% of regional area.

3.2.3 Regional totals (land use related and natural processes)

58.6% of the region's land is currently free from soil disturbance.

Soil disturbance is present on 37.4% of land in Waikato. 26.5% is land use-related, while 11.0% is caused by natural processes of erosion or deposition. Bare soil amounts to 2.85% of the entire region's area, of which 2.27% is attributable to land use and 0.57% to natural processes.

Soil disturbance is unknown for 3.9% of the region's land which lacks aerial photo cover in 2007.

There is 95% confidence that sample percentages for soil intactness or disturbance are within 1.2% or better of the true regional figures. For bare soil, there is 95% confidence that sample percentages are within 0.24% or better.

3.2.4 Land uses in Waikato region

Summary land-use data are presented in this table as a background to discussions of soil stability under each land use.

Table 3: Land uses in Waikato region 2007

Land use	Composition	Points	Points as% of region ¹	95% c.i. ²
horticulture and cropping	vineyards incl. kiwifruit	4	<0.1	0.1
	orchards incl. avocado	8	0.1	0.1
	vegetable crops	18	0.3	0.1
	grain crops	62	1.0	0.3
	greenfeed crops	16	0.3	0.1
sub-total		108	1.8	0.3

Land use	Composition	Points	Points as% of region ¹	95% c.i. ²
Dairy	improved, hard-grazed	280	4.6	0.5
	improved, lax-grazed or spelled	1067	17.4	1.0
	improved, harvested	56	0.9	0.2
	sub-total	1403	22.9	1.1
Drystock	improved, hard-grazed	453	7.4	0.7
	improved, lax-grazed or spelled	923	15.1	0.9
	improved, harvested	17	0.3	0.1
	unimproved	151	2.5	0.4
	sub-total	1544	25.2	1.1
Forest plantations	open-canopy pines	173	2.8	0.4
	maturing pines	468	7.6	0.7
	harvested pines	84	1.4	0.3
	broadleaved trees	24	0.4	0.2
	sub-total	749	12.2	0.8
Natural forest	closed canopy	346	5.7	0.6
	with natural scrub	222	3.6	0.5
	with exotic grass, scrub or trees	58	0.9	0.2
	with other, principally houses	3	<0.1	0.1
	sub-total	629	10.3	0.8
Note 1: "% of region" sub-totals/totals may differ by 0.1% due to rounding. Note 2: confidence limits are not additive.				
Natural scrub	closed canopy	167	2.7	0.4
	with forest trees	298	4.9	0.5
	with exotic grass, scrub or trees	182	3.0	0.4
	with other, principally houses	6	0.1	0.1
	sub-total	653	10.7	0.8
Exotic scrub	closed canopy	29	0.5	0.2
	with natural scrub or forest trees	70	1.1	0.3
	with exotic grass or trees	82	1.3	0.3
	with other, principally houses	1	<0.1	<0.1
	sub-total	182	3.0	0.4
Tussock and mountain	tussock	20	0.3	0.1
	sub-alpine	58	0.9	0.2
	alpine	41	0.7	0.2
	bare rock	6	0.1	0.1
	sub-total	125	1.9	0.3
Wetland and coastal	wetland	52	0.8	0.2
	mangrove	1	<0.1	<0.1
	coastal grass and scrub	6	0.1	0.1

Land use	Composition	Points	Points as% of region ¹	95% c.i. ²
	sub-total	59	1.0	0.2
Other	rural buildings etc.	151	2.5	0.4
	urban areas etc.	63	1.0	0.3
	shorelines etc.	215	3.5	0.5
	unclassified points	0	-	-
	points with no photo cover	241	3.9	0.5
All region	total	6122	100	0.0

Note 1: "% of sample" sub-totals/totals may differ by 0.1% due to rounding.
Note 2: confidence limits are not additive.

4 Horticulture and cropping

4.1 Overview

1.8% of Waikato's sample points are currently under horticulture and cropping i.e. high-yielding food crops (Table 3). Less than 0.1% are grape vineyards or other vine crops (mainly kiwifruit), 0.1% fruit orchards, 0.3% vegetable crops, 1.0% grain crops (mainly maize), and 0.3% greenfeed crops (chou, turnips and similar). The table summarises soil stability for these uses collectively because they entail either seasonal cultivation of soil, or seasonal harvest of produce, or both.

4.2 Soil stability

Table 4: Soil stability for horticulture and cropping in Waikato region, 2007

	Points	Points as % of regional sample ¹	95% c.i. ³	Bare soil as % of regional area ²	95% c.i. ³
Stable surfaces (S)					
S (i) with intact soil	30	0.5	0.2		
S (ii) with soil disturbed by land use	65	1.1	0.3	0.48	0.15
sub-total	95	1.6	0.3		
Erosion-prone surfaces (U)					
U (i) with intact soil	3	<0.1	0.1		
U (ii) with soil disturbed by land use	8	0.1	0.1	0.04	0.03
sub-total	11	0.2	0.1		
Eroded (R) and eroding (E) surfaces					
R (i) with revegetating soil	1	<0.1	<0.1		
E (ii) with soil disturbed by natural processes	1	<0.1	<0.1	<0.01	<0.01
sub-total	2	<0.1	<0.1		
All surfaces in land use total	108	1.8	0.3	0.52	0.16

Note 1: "% of sample" sub-totals/totals may differ by 0.1% due to rounding.
Note 2: "% of area" sub-totals/totals may differ by 0.01% due to rounding.
Note 3: confidence limits are not additive.

4.2.1 Stable surfaces

Stable surfaces under horticulture and cropping are elevated terraces and rolling downlands, protected floodplains, or drained wetlands.

- 1.6% of the region's sample points are on stable surfaces under horticulture and cropping,
- 0.5% have intact soil, currently well-vegetated (maturing crop, or tree and vine cover), and
- 1.1% have soil currently disturbed by land use. Within this category, bare soil amounts to 0.48% of the sample's area.

4.2.2 Erosion- prone surfaces

The erosion-prone surfaces are drainage hollows on terraces and downlands, or unprotected floodplains, or semi-drained/undrained wetland remnants.

- 0.2% of the region's sample points are on erosion-prone surfaces under horticulture and cropping,
- Less than 0.1% have intact soil, currently well-vegetated, and
- 0.1% have soil currently disturbed by land use. Within this category, bare soil amounts to 0.04% of the sample's area.

4.2.3 Eroded and eroding surfaces

Eroded and eroding surfaces are where bank erosion or deposition occurs along the streams that run through terraces and downlands or across floodplains. Only two points were recorded.

- Less than 0.1% of the region's sample points are on eroded and eroding surfaces under horticulture and cropping,
- Less than 0.1% have soil recently disturbed by natural erosion processes, but revegetating, and
- Less than 0.1% have soil freshly disturbed. Within this category, bare soil amounts to less than 0.01% of the sample's area.

4.2.4 Soil disturbance

Table 5: Soil disturbance amongst horticulture and cropping in Waikato region, 2007

	Points	Points as % of regional sample ¹	95% c.i. ³	Bare soil as % of regional area ²	95% c.i. ³
By land use					
grazing pressure	0.0	0.0	0.0		
cultivation	45	0.7	0.2	0.48	0.15
harvest	2	<0.1	0.1	0.01	0.01
spraying	0	0.0	0.0		
drains	1	<0.1	<0.1	<0.01	<0.01
tracks	23	0.4	0.2	0.02	0.01
earthworks	0	0.0	0.0		
roads	2	<0.1	0.1	<0.01	<0.01
sub-total	73	1.2	0.3	0.52	0.16
By natural processes					
landslide	0	0.0	0.0		
debris avalanche	0	0.0	0.0		
slump or earthflow	0	0.0	0.0		
tunnel gully	0	0.0	0.0		

	Points	Points as % of regional sample ¹	95% c.i. ³	Bare soil as % of regional area ²	95% c.i. ³
gully	0	0.0	0.0		
streambank scour	0	0.0	0.0		
streambank deposit	1	<0.1	<0.1	<0.01	<0.01
sandblow	0	0.0	0.0		
sheetwash	0	0.0	0.0		
rockfall or bare rock	0	0.0	0.0		
sub-total	1	<0.1	<0.1	<0.01	<0.01
Other					
Undisturbed sub-total	34	0.6	0.2		
All in land use total	108	1.8	0.3	0.52	0.16
Note 1: "% of sample" sub-totals/totals may differ by 0.1% due to rounding. Note 2: "% of area" sub-totals/totals may differ by 0.01% due to rounding. Note 3: confidence limits are not additive.					

4.2.5 Disturbance by land use

Numbers in this section are obtained by adding the percentages for S (ii) and U (ii) from Table 4. When stable and erosion-prone surfaces are combined, 1.2% of Waikato's land is currently disturbed by horticulture and cropping. On most sites, growing crops, or fruit trees and vines with grass beneath, provide good ground cover. Nevertheless topsoil is exposed by:

- cultivation on 0.48% of the region's area,
- grazing pressure on 0.00%,
- harvest on 0.01%,
- spraying on 0.00%,
- drains on <0.01%,
- tracks on 0.02%,
- earthworks on 0.00%, and
- unsealed roads on <0.01%,

The above activities associated with horticulture and cropping land, collectively contribute 0.52% to the region's area of soil exposed by land use (2.27%, from Table 2).

4.2.6 Disturbance by natural processes

Numbers in this section correspond with the percentages for E (ii) in Table 4. Less than 0.1% of Waikato's land is disturbed by natural processes while under horticulture and cropping : the only disturbance currently recorded is streambank deposition. Exposed soil collectively amounts to less than 0.01%, so makes a minimal contribution to the region's area of soil bared by erosion (0.57%, from Table 2).

4.2.7 Summary of disturbance

Under horticulture and cropping, soil disturbance affects 1.2% of land in Waikato. 1.2% is land use-related, while <0.1% is caused by natural processes of erosion or deposition. Bare soil amounts to 0.52% of the entire region's area, of which almost all is attributable to land use and less than 0.01% to natural processes.

A further 0.6% of land in Waikato is under horticulture and cropping, and currently free from soil disturbance.

There is 95% confidence that sample percentages for soil disturbance are within 0.3% or better of the true regional figures. For bare soil, there is 95% confidence that sample percentages are within 0.16% or better.

5 Dairy farms

5.1 Overview

22.9% of Waikato's sample points are occupied by dairy farms (Table 3). They are entirely improved pasture. At the time of photography (mid to late summer 2007), 76% of dairy pasture (17.4% of the regional sample) had a dense grass cover (lax-grazed or spelled), 20% (2.5% of the regional sample) was hard-grazed or sparsely covered, while 4% (0.2% of the regional sample) was recently harvested for hay or silage.

5.2 Soil stability

Table 6: Soil stability for dairy farms in the Waikato region, 2007

	Points	Points as % of regional sample ¹	95% c.i. ³	Bare soil as % of regional area ²	95% c.i. ³
Stable surfaces (S)					
S (i) with intact soil	607	9.9	0.7		
S (ii) with soil disturbed by land use	542	8.9	0.7	0.73	0.10
sub-total	1149	18.8	1.0		
Erosion-prone surfaces (U)					
U (i) with intact soil	74	1.2	0.3		
U (ii) with soil disturbed by land use	68	1.1	0.3	0.08	0.03
sub-total	142	2.3	0.4		
Eroded (R) and eroding (E) surfaces					
R (i) with revegetating soil	61	1.0	0.2		
E (ii) with soil disturbed by natural processes	51	0.8	0.2	0.03	0.01
sub-total	112	1.8	0.3		
All surfaces in land use	1403	22.9	1.1	0.84	0.10
Note 1: "% of sample" sub-totals/totals may differ by 0.1% due to rounding. Note 2: "% of area" sub-totals/totals may differ by 0.01% due to rounding. Note 3: confidence limits are not additive.					

5.2.1 Stable surfaces

Stable surfaces in dairy pasture are protected floodplains, well-drained wetlands, elevated terraces or rolling downlands, and easy hill country footslopes.

- 18.8% of the region's sample points are on stable surfaces in dairy pasture,
- 9.9% have intact soil, currently well-vegetated, and
- 8.9% have soil currently disturbed by land use. Bare soil amounts to 0.73% of the sample's area.

5.2.2 Erosion-prone surfaces

The erosion-prone surfaces are unprotected floodplains, poorly-drained wetlands, drainage hollows on terraces and downlands, or unstable footslopes.

- 2.3% of the region's sample points are on erosion-prone surfaces in dairy pasture,

- 1.2% have intact soil, currently well-vegetated, and
- 1.1% have soil currently disturbed by land use. Here bare soil amounts to 0.08% of the sample's area.

5.2.3 Eroded and eroding surfaces

The eroded and eroding surfaces are sand erosion by wind, recorded at just one sample point at a coastal dairy farm; and bare rock outcrops recorded at eight points where dairy farms are on ash-mantled ignimbrite plateaux.

- 1.8% of the region's sample points are on eroded and eroding surfaces in dairy pasture,
- 1.0% have soil recently disturbed by natural erosion processes, but revegetating, and
- 0.8% have soil freshly disturbed, with bare soil amounting to 0.03% of the sample's area.

5.3 Soil disturbance

Table 7: Soil disturbance on dairy farms in the Waikato region, 2007

	Points	Points as % of sample ¹	95% c.i. ³	Bare soil as % of area ²	95% c.i. ³
By land use					
grazing pressure	47	0.8	0.2	0.03	0.01
cultivation	46	0.8	0.2	0.25	0.09
harvest	1	<0.1	<0.1	<0.01	<0.01
spraying	0	.00	0.0		
drains	38	0.6	0.2	0.02	0.01
tracks	448	7.3	0.7	0.48	0.05
earthworks	13	0.2	0.1	0.01	0.01
roads	17	0.3	0.1	0.02	0.01
sub-total	610	10.0	0.8	0.81	0.10
By natural processes					
landslide	9	0.1	0.1	<0.01	<0.01
debris avalanche	0	0.0	0.0		
slump or earthflow	2	<0.1	<0.1	<0.01	<0.01
tunnel gully	8	0.1	0.1	<0.01	<0.01
gully	8	0.1	0.1	<0.01	<0.01
streambank scour	10	0.2	0.1	<0.01	<0.01
streambank deposit	5	0.1	0.1	<0.01	<0.01
sandblow	1	<0.1	<0.1	<0.01	<0.01
sheetwash	0	0.0	0.0		
rockfall or bare rock	8	0.1	0.1	0.01	<0.01
sub-total	51	0.8	0.2	0.03	0.01
Other					
Undisturbed sub-t	742	12.1	0.8		
All in land use t	1403	22.9	1.1	0.84	0.10
Note 1: "% of sample" sub-totals/totals may differ by 0.1% due to rounding. Note 2: "% of area" sub-totals/totals may differ by 0.01% due to rounding. Note 3: confidence limits are not additive.					

5.3.1 Disturbance by land use

Numbers in this section are obtained by adding the percentages for S(ii) and U(ii) from Table 6. When stable and erosion-prone surfaces are combined, 10.0% of Waikato's land is currently disturbed by dairy farming. The fairly high percentage is due to farm tracks (7.3%), grazing pressure (0.8%), seasonal cultivation (0.8%) for pasture renewal and summer green-feed, and drain clearance (0.6%). Other land use-related disturbances are minor. Not all the disturbed soil is bare, but where it is, the causes are:

- grazing pressure, exposing 0.03% of the region's soil,
- cultivation 0.25%,
- harvest <0.01%,
- drain clearance 0.02%,
- tracks 0.48%,
- earthworks 0.01%, and
- unsealed roads 0.02%.

These amount to 0.81% of the region's area, so dairy farming accounts for 36% of the region's land at risk of topsoil loss (2.27% region-wide, Table 2). However topsoil loss does not necessarily occur on all the exposed ground. A high proportion of tracks on dairy farms are surfaced with race rock or similar, and also away from streams - factors which reduce off-site soil loss. Likewise, a high proportion of soil bared by grazing pressure or seasonal cultivation is on flat land where any soil removed by runoff is likely to be trapped by adjacent dense pasture before reaching a watercourse.

5.3.2 Disturbance by natural processes

Numbers in this section correspond with the percentages for E (ii) in Table 6. Just 0.8% of land in Waikato is disturbed by natural processes occurring under dairy pasture. These are bank scour or deposits along watercourses, tunnel gullies or gullies in drainage hollows, and slumps or earthflows on unstable footslopes. Soil bared by natural disturbance is minor, equating to 0.03% of the region's bare ground, and so its contribution to region-wide soil erosion (0.57%, Table 2) is slight.

5.3.3 Summary of disturbance

Under dairy pasture, soil disturbance affects 10.8% of land in Waikato. 10.0% is land use-related, while 0.8% is caused by natural processes of erosion or deposition. Bare soil amounts to 0.84% of the entire region's area, of which 0.81% is attributable to land use and 0.03% to natural processes.

A further 12.1% of land in Waikato is under dairy pasture and currently free from soil disturbance.

There is 95% confidence that sample percentages for soil disturbance are within 1.1% or better of the true regional figures. For bare soil, there is 95% confidence that sample percentages are within 0.1% or better.

6 Drystock farms

6.1 Overview

25.3% of Waikato's sample points (Table 3) are presently drystock farms (beef cattle, deer, sheep, goats). At the time of photography (mid to late summer 2007), 60% of drystock pasture (15.1% of the regional sample) had a dense grass cover (lax-grazed or spelled), 30% (7.4% of the regional sample) was hard-grazed or sparsely covered, while 1% (0.3% of the regional sample) was recently harvested for hay or silage. The above were all improved pasture, and so the remaining 9% (2.5% of the regional sample) were unimproved pasture.

6.2 Soil stability

Table 8: Soil stability for drystock farms in Waikato region, 2007

	Points	Points as % of regional sample ¹	95% c.i. ³	Bare soil as % of regional area ²	95% c.i. ³
Stable surfaces (S)					
S (i) with intact soil	480	7.8	0.7		
S (ii) with soil disturbed by land use	264	4.3	0.5	0.26	0.06
sub-total	744	12.2	0.8		
Erosion-prone surfaces (U)					
U (i) with intact soil	230	3.8	0.5		
U (ii) with soil disturbed by land use	174	2.8	0.4	0.16	0.03
sub-total	404	6.6	0.6		
Eroded (R) and eroding (E) surfaces					
R (i) with revegetating soil	174	2.8	0.4		
E (ii) with soil disturbed by natural processes	226	3.7	0.5	0.17	0.05
sub-total	400	6.5	0.6		
All surfaces in land use	1548	25.3	1.1	0.59	0.08
Note 1: "% of sample" sub-totals/totals may differ by 0.1% due to rounding. Note 2: "% of area" sub-totals/totals may differ by 0.01% due to rounding. Note 3: confidence limits are not additive.					

6.2.1 Stable surfaces

Stable surfaces in drystock pasture are elevated terraces, rolling downlands, easy hillslopes, and old coastal dunes with weathered soils.

- 12.2% of the region's sample points are on stable surfaces in drystock pasture,
- 7.8% have intact soil, currently well-vegetated, and
- 4.3% have soil currently disturbed by land use. Bare soil amounts to 0.26% of the sample's area.

6.2.2 Erosion-prone surfaces

Erosion-prone surfaces are drainage hollows on terraces and downlands (including healed under-runners and gullies); moderate hill slopes showing traces of past slope failure, now completely revegetated; and young or intermediate-age coastal dunes fixed by pasture.

- 6.6% of the region's sample points are on erosion-prone surfaces in drystock pasture,
- 3.8% have intact soil, currently well-vegetated, and
- 2.8% have soil currently disturbed by land use. Here bare soil amounts to 0.16% of the sample's area.

6.2.3 Eroded and eroding surfaces

The eroded and eroding surfaces are landslides, slumps and earthflows on moderate hill country; under-runners and gullies there or in drainage hollows on terraces and downlands; and streambank scour or deposition along watercourses. Sandblow on sparsely vegetated dunes, sheetwash on sparsely vegetated hill country spurs or ridges, and rockfall or rock outcrops on inland bluffs and coastal cliffs, are also present.

- 6.5% of the region's sample points are on eroded and eroding surfaces in drystock pasture,
- 2.8% have soil recently disturbed by natural erosion processes, but revegetating, and
- 3.7% have soil freshly disturbed, with bare soil amounting to 0.17% of the sample's area.

6.3 Soil disturbance

Table 9: Soil disturbance on drystock farms in the Waikato region 2007

	Points	Points as % of regional sample ¹	95% c.i. ³	Bare soil as % of regional area ²	95% c.i. ³
By land use					
grazing pressure	96	1.6	0.3	0.06	0.01
cultivation	17	0.3	0.1	0.08	0.05
harvest	7	0.1	0.1	<0.01	<0.01
spraying	1	<0.1	<0.1	<0.01	<0.01
Drains	6	0.1	0.1	<0.01	<0.01
Tracks	280	4.6	0.5	0.22	0.03
earthworks	19	0.3	0.1	0.04	0.02
Roads	12	0.2	0.1	0.01	0.01
sub-total	438	7.2	0.6	0.42	0.06
By natural processes					
landslide	78	1.3	0.3	0.04	0.01
debris avalanche	0	0.0	0.0		
slump or earthflow	12	0.2	0.1	<0.01	<0.01
tunnel gully	32	0.5	0.2	0.02	0.01
Gully	35	0.6	0.2	0.02	0.01
streambank scour	19	0.3	0.1	0.01	<0.01
streambank deposit	8	0.1	0.1	0.01	0.01
sandblow	7	0.1	0.1	0.04	0.04
sheetwash	0	0.0	0.0		
rockfall or bare rock	35	0.6	0.2	0.03	0.02
sub-total	226	3.7	0.5	0.16	0.05
Other					
Undisturbed sub-	884	14.4	0.9		
All in land use	1548	25.3	1.1	0.59	0.08
Note 1: "% of sample" sub-totals/totals may differ by 0.1% due to rounding. Note 2: "% of area" sub-totals/totals may differ by 0.01% due to rounding. Note 3: confidence limits are not additive.					

6.3.1 Disturbance by land use

Numbers in this section are obtained by adding the percentages for S(ii) and U(ii) from Table 8. When stable and erosion-prone surfaces are combined, 7.2% of Waikato's land is currently disturbed by drystock farming. The percentage is less than that under dairy farming, however causes of topsoil disturbance are similar, with the principal

contributors being farm tracks (4.6%) and grazing pressure (1.6%). Other land-use-related disturbances are individually minor, though cumulatively amount to 1.0% of land. Topsoil is exposed by:

- grazing pressure on 0.06% of the region's area,
- cultivation on 0.08%,
- harvest on <0.01%,
- spraying on <0.01%,
- drains on <0.01%,
- tracks on 0.22%,
- earthworks on 0.04%, and
- unsealed roads on 0.01%.

Bare soil equates to 0.42% of the region's area, about 19% of the region's land at risk of topsoil loss (2.27%, Table 2). Most tracks on drystock farms are bare earth, many are on rolling to moderately steep ground, and some cross streams - factors which predispose towards off-site soil loss. On the other hand a high proportion of soil bared by grazing pressure or seasonal cultivation is on rolling to moderate slopes, where soil transported by runoff is more likely to be trapped by dense pasture downslope, than to enter watercourses.

6.3.2 Disturbance by natural processes

Numbers in this section correspond with the percentages for E(ii) in Table 8. 3.7% of land in Waikato is disturbed by natural processes occurring on land under drystock pasture. These are earthflows, slumps and large slope failures on moderate hillslopes; landslides on steep faces; tunnel gully or open gully erosion in drainage hollows; and streambank scour or deposition along watercourses. Soil actually bared on drystock farms is:

- by slope failures, 0.04% of the region's area,
- by gullies 0.04%,
- by streambank scour or deposit 0.02%, and
- by surface erosion 0.07%.

Soil bared by natural processes in drystock pasture equates to 0.16% of the region's area, and accounts for 31% of the region's soil erosion by natural processes (0.57%, Table 2).

6.3.3 Summary of disturbance

Under drystock pasture, soil disturbance affects 10.9% of land in Waikato. 7.2% is land use-related, while 3.7% is caused by natural processes of erosion or deposition. Bare soil amounts to 0.59% of the entire region's area, of which 0.42% is attributable to land use and 0.16% to natural processes.

A further 14.4% of land in Waikato is under drystock pasture and currently free from soil disturbance.

There is 95% confidence that sample percentages for soil disturbance are within 1.1% or better of the true regional figures. For bare soil, there is 95% confidence that sample percentages are within 0.08% or better.

7 Forest plantations

7.1 Overview

Forest plantations occupy 12.2% of Waikato's sample points (Table 3). 24% of plantations (2.8% of the regional sample) are young pines (prior to canopy closure), much of them second-rotation. 62% (7.6% of the regional sample) are maturing pines

(closed canopy). 11% (1.4% of the regional sample) are harvested pines, not yet re-planted. 3% (0.4% of the regional sample) are broadleaved plantations; mainly eucalypts.

7.2 Soil stability

Table 10: Soil stability for forest plantations in Waikato region, 2007

	Points	Points as % of regional sample ¹	95% c.i. ³	Bare soil as % of regional area ²	95% c.i. ³
Stable surfaces (S)					
S (i) with intact soil	319	5.2	0.6	0.16	0.04
S (ii) with soil disturbed by land use	120	2.0	0.3		
sub-total	439	7.2	0.6		
Erosion-prone surfaces (U)					
U (i) with intact soil	161	2.6	0.4	0.11	0.04
U (ii) with soil disturbed by land use	72	1.2	0.3		
sub-total	233	3.8	0.5		
Eroded (R) and eroding (E) surfaces					
R (i) with revegetating soil	47	0.8	0.2	0.02	0.01
E (ii) with soil disturbed by natural processes	30	0.5	0.2		
sub-total	77	1.3	0.3		
All surfaces in land use	749	12.2	0.8	0.29	0.06
Note 1: "% of sample" sub-totals/totals may differ by 0.1% due to rounding. Note 2: "% of area" sub-totals/totals may differ by 0.01% due to rounding. Note 3: confidence limits are not additive.					

7.2.1 Stable surfaces

Stable surfaces under forest plantation are elevated terraces, rolling downlands, easy hillslopes, and old coastal dunes with weathered soils.

- 7.2% of the region's sample points are on stable surfaces under forest plantations,
- 5.2% have intact soil, currently well-vegetated, and
- 2.0% have soil currently disturbed by land use. Bare soil amounts to 0.16% of the regional sample's area.

7.2.2 Erosion-prone surfaces

Erosion-prone surfaces are mostly moderate hillslopes or steep rangelands showing traces of past slope failure, now completely revegetated. Some also appear on coastal dunes of young to intermediate age, now stabilised by pine trees. A small proportion are stream banks, drainage hollows on terraces and downlands, or unstable footslopes.

- 3.8% of the region's sample points are on erosion-prone surfaces under forest plantations,
- 2.6% have intact soil, currently well-vegetated, and
- 1.2% have soil currently disturbed by land use. Here bare soil amounts to 0.11% of the sample's area.

7.2.3 Eroded and eroding surfaces

The eroded and eroding surfaces under forest plantation are streambank scour along watercourses; landslides or debris avalanches on hill faces and steep ranges; gully erosion in drainage hollows and incised steeper country; and rock outcrops on inland bluffs or ash-mantled ignimbrite plateaux.

- 1.3% of the region's sample points are on eroded and eroding surfaces under forest plantations,
- 0.8% have soil recently disturbed by natural erosion processes, but revegetating, and
- 0.5% have soil freshly disturbed, with bare soil amounting to 0.02% of the sample's area.

7.3 Soil disturbance

Table 11: Soil disturbance in forest plantations in Waikato region, 2007

	Points	Points as % of regional sample ¹	95% c.i. ³	Bare soil as % of regional area ²	95% c.i. ³
By land use					
grazing pressure	1	<0.1	<0.1	<0.01	<0.01
cultivation	1	<0.1	<0.1	<0.01	<0.01
harvest	60	1.0	0.2	0.13	0.05
spraying	0	0.0	0.0		
drains	1	<0.1	<0.1	<0.01	<0.01
tracks	103	1.7	0.3	0.11	0.03
earthworks	5	0.1	0.1	0.01	0.01
roads	21	0.3	0.1	0.03	0.01
sub-total	192	3.1	0.4	0.27	0.06
By natural processes					
landslide	7	0.1	0.1	<0.01	<0.01
debris avalanche	5	0.1	0.1	<0.01	<0.01
slump or earthflow	0	0.0	0.0		
tunnel gully	1	<0.1	0.0	<0.01	<0.01
gully	5	0.1	0.0	<0.01	<0.01
streambank scour	4	0.1	0.1	<0.01	<0.01
streambank deposit	0	0.0	0.0		
sandblow	0	0.0	0.0		
sheetwash	0	0.0	0.0		
rockfall or bare rock	8	0.1	0.1	0.01	<0.01
sub-total	30	0.5	0.2	0.02	0.01
Other					
Undisturbed sub-total	527	8.6	0.7		
All in land use total	749	12.2	0.8	0.29	0.06
Note 1: "% of sample" sub-totals/totals may differ by 0.1% due to rounding. Note 2: "% of area" sub-totals/totals may differ by 0.01% due to rounding. Note 3: confidence limits are not additive.					

7.3.1 Disturbance by land use

Numbers in this section are obtained by adding the percentages for S (ii) and U (ii) from Table 10. When stable and erosion-prone surfaces are combined, 3.1% of Waikato's land is currently disturbed, out of the 12.2% in forest plantations. 2.0% of land use-related disturbance is tracking or forest roads - this includes access tracks for planting and silviculture as well as roads for harvest. 0.1% is earthworks associated with forest harvest - landing stages and skid sites which are largely protected by slash. 1.0% is land where soil is exposed by harvest - concentrated along skidder tracks and hauler paths rather than disseminated throughout harvested compartments. Bare soil exposed to risk of topsoil loss by forestry is:

- by harvest, 0.13% of the region's area,
- by tracks and unsealed roads, 0.14%,
- by earthworks, 0.01%, and
- by miscellaneous disturbances, <0.01%.

These equate to 0.27% of the region's area, so amounts to 12% of the region's land at risk of topsoil loss (2.27%, Table 2). Much of the exposed soil is on upper slopes close to landing stages, where it is unlikely to move towards watercourses. Where it is on lower slopes, off-site soil loss may be mitigated by forest management practices on adjacent ground - metalling of tracks, over-sowing of grasses and legumes on harvest sites, and avoidance of planting or harvest near streams.

7.3.2 Disturbance by natural processes

Numbers in this section correspond with the percentages for E(ii) in Table 10. A further 0.5% of land in Waikato is disturbed by natural processes occurring on land in forest plantations. Bare soil is caused by:

- slope failures on 0.01 % of the region's area,
- rock outcrops and rock-falls on 0.01%
- gully erosion on <0.01%, and
- streambank scour on <0.01%.

In forest plantations, natural erosion or deposition of soil amounts to 0.02% of the region's land; a small contribution to regional soil erosion by natural processes (0.57%, Table 2). Given the area in forest plantation (12.2% of the region), proportionately it is much less than might be expected and indicates the stabilising effect of tree roots in soil under maturing forest (8.0%) cf. harvested (1.4%) and replanted trees (2.8%).

7.3.3 Summary of disturbance

Under forest plantations, soil disturbance affects 3.6% of land in Waikato. 3.1% is land use-related, while 0.5% is caused by natural processes of erosion or deposition. Bare soil amounts to 0.29% of the entire region's area, of which 0.27% is attributable to land use and 0.02% to natural processes.

A further 8.6% of the Waikato's land is under forest plantations and currently free from soil disturbance.

There is 95% confidence that sample percentages for soil disturbance are within 0.8% or better of the true regional figures. For bare soil, there is 95% confidence that sample percentages are within 0.06% or better.

8 Natural forest

8.1 Overview

Natural forest is present at 10.3% of Waikato's sample points (Table 3). 5.7% are closed canopy forest. 3.6% are interspersed with woody scrub in canopy gaps due to

plant succession after natural disturbance (erosion or wind-throw during storms). 0.9% are natural forest with patches of grass, exotic scrub or exotic trees. These are areas adjacent to past or present farms. Less than 0.1% are natural forest with houses, either lifestyle blocks or urban-fringe.

8.2 Soil stability

Table 12: Soil stability for natural forest in Waikato region, 2007

	Points	Points as % of regional sample ¹	95% c.i. ³	Bare soil as % of regional area ²	95% c.i. ³
Stable surfaces (S)					
S (i) with intact soil	256	4.2	0.5		
S (ii) with soil disturbed by land use	7	0.1	0.1	0.01	<0.01
sub-total	263	4.3	0.5		
Erosion-prone surfaces (U)					
U (i) with intact soil	221	3.6	0.5		
U (ii) with soil disturbed by land use	12	0.2	0.1	0.01	<0.01
sub-total	233	3.8	0.5		
Eroded (R) and eroding (E) surfaces					
R (i) with revegetating soil	106	1.7	0.3		
E (ii) with soil disturbed by natural processes	28	0.5	0.2	0.02	0.01
sub-total	134	2.2	0.4		
All surfaces in land use total	630	10.3	0.8	0.03	0.01
Note 1: "% of sample" sub-totals/totals may differ by 0.1% due to rounding. Note 2: "% of area" sub-totals/totals may differ by 0.01% due to rounding. Note 3: confidence limits are not additive.					

8.2.1 Stable surfaces

Stable surfaces in natural forest are moderate hillslopes, or spurs and ridges in the ranges; apart from a small proportion where forest remains on footslopes, terraces or downlands.

- 4.3% of the region's sample points are on stable surfaces under natural forest,
- 4.2% have intact soil, currently well-vegetated, and
- 0.1% have soil currently disturbed by land use. Bare soil amounts to 0.01% of the sample's area.

8.2.2 Erosion-prone surfaces

Erosion-prone surfaces are moderate hillslopes showing traces of past slope failure (now completely revegetated), or steep slopes in the ranges with similar evidence. A small proportion are forest remnants adjacent to watercourses that run through footslopes, terraces or downlands.

- 3.8% of the region's sample points are on erosion-prone surfaces under natural forest,
- 3.6% have intact soil, currently well-vegetated, and
- 0.2% have soil currently disturbed by land use. Here bare soil amounts to 0.01% of the sample's area.

8.2.3 Eroded and eroding surfaces

The eroded and eroding surfaces are landslides and debris avalanches in the hill country and ranges; and streambank scour or deposition along watercourses.

- 2.2% of the region's sample points are on eroded and eroding surfaces under natural forest,
- 1.7% have soil recently disturbed by natural erosion processes, but revegetating, and
- 0.5% have soil freshly disturbed, with bare soil amounting to 0.02% of the sample's area.

8.3 Soil disturbance

Table 13: Soil disturbance in natural forest in the Waikato region 2007

	Points	Points as % of regional sample	95% c.i. ³	Bare soil as % of regional area ²	95% c.i. ³
By land use					
grazing pressure	0	0.0	0.0		
cultivation	0	0.0	0.0		
harvest	0	0.0	0.0		
spraying	0	0.0	0.0		
drains	0	0.0	0.0		
tracks	15	0.2	0.1	0.01	0.01
earthworks	1	<0.1	<0.1	<0.01	<0.01
roads	3	<0.1	<0.1	<0.01	<0.01
sub-total	19	0.3	0.1	0.01	0.01
By natural processes					
landslide	5	0.1	0.1	<0.01	<0.01
debris avalanche	10	0.2	0.1	0.01	<0.01
slump or earthflow	0	0.0	0.0		
tunnel gully	0	0.0	0.0		
gully	0	0.0	0.0		
streambank scour	10	0.2	0.1	<0.01	<0.01
streambank deposit	3	<0.1	0.1	<0.01	<0.01
sandblow	0	0.0	0.0		
sheetwash	0	0.0	0.0		
rockfall or bare rock	0	0.0	0.0		
sub-total	28	0.5	0.2	0.02	0.01
Other					
Undisturbed sub-total	583	9.5	0.7		
All in land use total	630	10.3	0.8	0.03	0.01
Note 1: "% of sample" sub-totals/totals may differ by 0.1% due to rounding. Note 2: "% of area" sub-totals/totals may differ by 0.01% due to rounding. Note 3: confidence limits are not additive.					

8.3.1 Disturbance by land use

Numbers in this section are obtained by adding the percentages for S(ii) and U(ii) from Table 12. When stable and erosion-prone surfaces are combined, just 0.3% of Waikato's land is currently disturbed by land use-related activities within natural forest. These are almost entirely access tracks or unsealed rural roads (earthwork disturbance was recorded at just one sample point). Equating to 0.01% of the region's bare soil, their contribution to land at risk of topsoil loss (2.27%, Table 2) is negligible.

8.3.2 Disturbance by natural processes

Numbers in this section correspond with the percentages for E(ii) in Table 12. 0.5% of land in Waikato is disturbed by erosion or deposition within natural forest. Bare soil on disturbed surfaces is limited to and attributable to:

- slope failures on 0.01% of the region's area,
- stream scour and deposit on 0.01%,

These causes of disturbance amount to 0.02% of the region's area, a very small contribution (3.6%) towards the region's total soil bared by erosion or deposition (0.57%, Table 2). Although the region's remaining forest is mainly on hill country or steep ranges subject to high rainfall, for the most part it is underlain by stable geology.

8.3.3 Summary of disturbance

Under natural forest, soil disturbance affects 0.8% of land in Waikato. 0.3% is land use-related, while 0.5% is caused by natural processes of erosion or deposition. Bare soil amounts to 0.03% of the entire region's area, of which 0.01% is attributable to land use and 0.02% to natural processes.

9.5% of land in the Waikato is under natural forest, and currently free from soil disturbance.

There is 95% confidence that sample percentages for soil disturbance are within 0.8% or better of the true regional figures. For bare soil, there is 95% confidence that sample percentages are within 0.03% or better.

9 Natural scrub

9.1 Overview

Natural scrub is present at 12.6% of Waikato's sample points (Table 3). 2.7% are closed canopy scrub. 4.9% are scrub with emerging forest trees; such areas include forest long since cut-over, and long-abandoned farms. 3.0% are scrub with grass, exotic scrub or exotic trees in canopy gaps; these are areas of recently abandoned or lightly grazed pasture. 0.1% is scrub with houses; either lifestyle blocks or homes on the urban fringe.

9.2 Soil stability

Table 14: Soil stability for natural scrub in the Waikato region 2007

	Points	Points as % of regional sample ¹	95% c.i. ³	Bare soil as % of regional area ²	95% c.i. ³
Stable surfaces (S)					
S (i) with intact soil	232	3.8	0.5		
S (ii) with soil disturbed by land use	18	0.3	0.1	0.02	0.01
sub-total	250	4.1	0.5		
Erosion-prone surfaces (U)					
U (i) with intact soil	210	3.4	0.5		
U (ii) with soil disturbed by land use	22	0.4	0.1	0.02	0.01
sub-total	232	3.8	0.5		
Eroded (R) and eroding (E) surfaces					
R (i) with revegetating soil	125	2.0	0.4		
E (ii) with soil disturbed by natural processes	46	0.8	0.2	0.03	0.01
sub-total	171	2.8	0.4		
All surfaces in land use total	653	10.7	0.8	0.06	0.01
Note 1: "% of sample" sub-totals/totals may differ by 0.1% due to rounding. Note 2: "% of area" sub-totals/totals may differ by 0.01% due to rounding. Note 3: confidence limits are not additive.					

9.2.1 Stable surfaces

Stable surfaces in natural scrub are moderate hillslopes, or spurs and ridges in the ranges; apart from a small proportion where scrub remains on footslopes, terraces or downlands.

- 4.1% of the region's sample points are on stable surfaces in natural scrub,
- 3.8% have intact soil, currently well-vegetated, and
- 0.3% have soil currently disturbed by land use. Bare soil amounts to 0.02% of the sample's area.

9.2.2 Erosion-prone surfaces

Erosion-prone surfaces are moderate hillslopes showing traces of past slope failure (now completely revegetated), or steep slopes in the ranges with similar evidence. A small proportion are scrub remnants adjacent to watercourses that run through footslopes, terraces or downlands.

- 3.8% of the region's sample points are on erosion-prone surfaces in natural scrub,
- 3.4% have intact soil, currently well-vegetated, and
- 0.4% have soil currently disturbed by land use. Here bare soil amounts to 0.02% of the sample's area.

9.2.3 Eroded and eroding surfaces

The eroded and eroding surfaces are landslides and gullies on hill country; debris avalanches in the ranges; streambank scour or deposition along watercourses; and rock outcrops on inland bluffs.

- 2.8% of the region's sample points are on eroded and eroding surfaces in natural scrub,
- 2.0% have soil recently disturbed by natural erosion processes, but revegetating, and

- 0.8% have soil freshly disturbed, with bare soil amounting to 0.03% of the sample's area.

9.3 Soil disturbance

Table 15: Soil disturbance in natural scrub in Waikato region, 2007

	Points	Points as % of regional sample ¹	95% c.i. ³	Bare soil as % of regional area ²	95% c.i. ³
By land use					
grazing pressure	1	<0.1	<0.1	<0.01	<0.01
cultivation	0	0.0	0.0		
harvest	0	0.0	0.0		
spraying	0	0.0	0.0		
drains	0	0.0	0.0		
tracks	31	0.5	0.2	0.02	0.01
earthworks	1	<0.1	<0.1	<0.01	<0.01
roads	7	0.1	0.1	0.01	0.01
sub-total	40	0.7	0.2	0.03	0.01
By natural processes					
landslide	13	0.2	0.1	0.01	<0.01
debris avalanche	12	0.2	0.1	0.01	<0.01
slump or earthflow	0	0.0	0.0		
tunnel gully	0	0.0	0.0		
gully	3	<0.1	0.1	<0.01	<0.01
streambank scour	9	0.1	0.1	<0.01	<0.01
streambank deposit	6	0.1	0.1	<0.01	<0.01
sandblow	0	0.0	0.0		
sheetwash	0	0.0	0.0		
rockfall or bare rock	3	<0.1	0.1	<0.01	<0.01
sub-total	46	0.8	0.2	0.03	0.01
Other					
Undisturbed sub-total	567	9.3	0.7		
All in land use total	653	10.7	0.8	0.06	0.01
Note 1: "% of sample" sub-totals/totals may differ by 0.1% due to rounding. Note 2: "% of area" sub-totals/totals may differ by 0.01% due to rounding. Note 3: confidence limits are not additive.					

9.3.1 Disturbance by land use

Numbers in this section are obtained by adding the percentages for S(ii) and U(ii) from Table 14. When stable and erosion-prone surfaces are combined, 0.7% of Waikato's land is currently disturbed by land use-related activities within natural scrub. Most disturbance is access tracks or rural roads remaining within areas formerly harvested for timber or formerly farmed. Grazing pressure was recorded at 1 point, as was earthworks. Equating to 0.03% bare soil by area, land use-related disturbance in natural scrub makes a larger contribution to the region's soil at risk of topsoil loss (2.27%, Table 2) than is the case in natural forest. Components of the bare soil are:

- tracks at 0.02% of the region's area,

- unsealed roads at 0.01%,
- earthworks at <0.01%, and
- grazing pressure at <0.01%.

9.3.2 Disturbance by natural processes

Numbers in this section correspond with the percentages for E (ii) in Table 14. 0.8% of land is disturbed by erosion or deposition within natural scrub, and bare soil on disturbed surfaces is due to:

- slope failures on 0.02% of the region's area,
- gullies on <0.01%
- stream scour and deposit on 0.01%, and
- bare rock on <0.01%.

These equate to 0.03% of the region's area; 5.4% of soil exposed by natural erosion region-wide (0.57%, Table 2).

9.3.3 Summary of disturbance

Under natural scrub, soil disturbance affects 1.5% of land in the Waikato. 0.7% is land use-related, while 0.8% is caused by natural processes of erosion or deposition. Bare soil amounts to 0.06% of the entire region's area, of which 0.03% is attributable to land use and 0.03% to natural processes.

9.3% of land in the Waikato is in natural scrub, and currently free from soil disturbance.

There is 95% confidence that sample percentages for soil disturbance are within 0.8% or better of the true regional figures. For bare soil, there is 95% confidence that sample percentages are within 0.01% or better.

10 Exotic scrub

10.1 Overview

Exotic scrub occupies 3.0% of Waikato's sample points (Table 3). 0.5% are closed-canopy stands; typically blackberry, broom or gorse, although other species e.g. tobacco weed, brush wattle, pampas, are locally present. 1.1% are mature exotic scrub stands intermingled with native scrub which successively replaces it. Another 1.4% contain remnant pasture or exotic trees, on abandoned or reverting farmland. Less than 0.1% are scrub in association with houses on farms or lifestyle blocks.

10.2 Soil stability

Table 16: Soil stability for exotic scrub in the Waikato region 2007

	Points	Points as % of regional sample ¹	95% c.i. ³	Bare soil as % of regional area ²	95% c.i. ³
Stable surfaces (S)					
S (i) with intact soil	60	1.0	0.2		
S (ii) with soil disturbed by land use	9	0.1	0.1	0.01	0.01
sub-total	69	1.1	0.3		
Erosion-prone surfaces (U)					
U (i) with intact soil	45	0.7	0.2		
U (ii) with soil disturbed by land use	24	0.4	0.2	0.03	0.03
sub-total	69	1.1	0.3		
Eroded (R) and eroding (E) surfaces					
R (i) with revegetating soil	24	0.4	0.2		
E (ii) with soil disturbed by natural processes	22	0.4	0.1	0.02	0.01
sub-total	46	0.8	0.2		
All surfaces in land use	184	3.0	0.4	0.07	0.03
Note 1: "% of sample" sub-totals/totals may differ by 0.1% due to rounding. Note 2: "% of area" sub-totals/totals may differ by 0.01% due to rounding. Note 3: confidence limits are not additive.					

10.2.1 Stable surfaces

Stable surfaces in exotic scrub range from infertile soils on terraces, downlands or footslopes, through spurs and ridges in hill country, to shallow soils on steep but stable faces in the ranges.

- 1.1% of the region's sample points are on stable surfaces in exotic scrub,
- 1.0% have intact soil, currently well-vegetated, and
- 0.1% have soil currently disturbed by land use. Bare soil amounts to 0.01% of the sample's area.

10.2.2 Erosion- prone surfaces

The unstable surfaces are drainage hollows through terraces, downlands or footslopes, and moderate hillslopes or steep ranges showing traces of past slope failure, now completely revegetated.

- 1.1% of the region's sample points are on erosion-prone surfaces in exotic scrub,
- 0.7% have intact soil, currently well-vegetated, and
- 0.4% have soil currently disturbed by land use. Here bare soil amounts to 0.03% of the sample's area.

10.2.3 Eroded and eroding surfaces

The eroded and eroding surfaces are where mass movement, gully or surface erosion occurs on any of the unstable landforms listed above, and the scars are colonised by exotic scrub.

- 0.8% of the region's sample points are on eroded and eroding surfaces in exotic scrub,
- 0.4% have soil recently disturbed by natural erosion processes, but revegetating, and

- 0.4% have soil freshly disturbed, with bare soil amounting to 0.02% of the sample's area.

10.3 Soil disturbance

Table 17: Soil disturbance in exotic scrub in Waikato region, 2007

	Points	Points as % of regional sample ¹	95% c.i. ³	Bare soil as % of regional area ²	95% c.i. ³
By land use					
grazing pressure	1	<0.1	<0.1	<0.01	<0.01
cultivation	0	0.0	0.0		
harvest	4	0.1	0.1	0.01	0.01
spraying	0	0.0	0.0		
Drains	0	0.0	0.0		
Tracks	23	0.4	0.2	0.02	0.01
earthworks	3	<0.1	0.1	0.01	0.02
Roads	2	<0.1	<0.1	<0.01	<0.01
sub-total	33	0.5	0.2	0.04	0.03
By natural processes					
landslide	4	0.1	0.1	<0.01	<0.01
debris avalanche	3	<0.1	0.1	<0.01	<0.01
slump or earthflow	0	0.0	0.0		
tunnel gully	0	0.0	0.0		
Gully	1	<0.1	<0.1	<0.01	<0.01
streambank scour	4	0.1	0.1	<0.01	<0.01
streambank deposit	4	0.1	0.1	<0.01	<0.01
sandblow	1	<0.1	<0.1	<0.01	0.01
sheetwash	0	0.0	0.0		
rockfall or bare rock	2	<0.1	<0.1	<0.01	<0.01
geothermal	3	<0.1	0.1	<0.01	0.01
sub-total	22	0.4	0.1	0.02	0.01
Other					
undisturbed sub-total	129	2.1	0.4		
All in land use total	184	3.0	0.4	0.07	0.03
Note 1: "% of sample" sub-totals/totals may differ by 0.1% due to rounding. Note 2: "% of area" sub-totals/totals may differ by 0.01% due to rounding. Note 3: confidence limits are not additive.					

10.3.1 Disturbance by land use

Numbers in this section are obtained by adding the percentages for S(ii) and U(ii) from Table 16. When stable and erosion-prone surfaces are combined, 0.5% of Waikato's land is currently disturbed by land use-related activities within exotic scrub. As with natural scrub, most disturbance is access tracks remaining within areas formerly farmed. The balance is scrub clearance, earthworks associated with house-building, and bare soil associated with grazing pressure (observed at one sample point). Bare soil due to land use disturbance equates to 0.04% of the region's bare soil, which

presents a small contribution (2%) to the region's exposed soil at risk of topsoil loss (2.27%, Table 2).

10.3.2 Disturbance by natural processes

Numbers in this section correspond with the percentages for E(ii) in Table 16. 0.5% of land in Waikato is disturbed by erosion or deposition within exotic scrub. Bare soil on disturbed surfaces is due to:

- slope failures on 0.01% of the region's area,
- gullies on <0.01%,
- streambank scour and deposition on 0.01%,
- sandblow on <0.01%,
- bare rock on <0.01%, and
- geothermal activity on <0.01%

These add to 0.02% of the region's area and present a small contribution (3.6%) to the region's total soil bared by natural disturbance (0.57%, Table 2). Exotic scrub's contribution is surprisingly low, given that it colonises abandoned or unstable sites following unsuccessful attempts at use, or after frequent natural disturbance. Such a low figure may be attributed to the very small area currently in exotic scrub (3.0% of the Waikato region).

10.3.3 Summary of disturbance

Under exotic scrub, soil disturbance affects 0.9% of land in Waikato. 0.5% is land use-related, while 0.4% is caused by natural processes of erosion or deposition. Bare soil amounts to 0.07% of the entire region's area, of which slightly over 0.04% is attributable to land use, and slightly over 0.02% to natural processes (the remaining 0.01% is rounding error).

2.1% of land in the Waikato is occupied by exotic scrub and currently free from soil disturbance.

There is 95% confidence that sample percentages for soil disturbance are within 0.4% or better of the true regional figures. For bare soil, there is 95% confidence that sample percentages are within 0.03% or better.

11 Tussock and mountain vegetation

11.1 Overview

Tussock and mountain vegetation occupy 2.0% of Waikato's sample points (Table 3). It comprises tussock on elevated plateaux, sub-alpine scrub (including exotic heather), alpine tussock and herb-field, and bare rock on mountain flanks and summits.

11.2 Soil stability

Table 18: Soil stability for tussock and mountain vegetation in Waikato region, 2007

	Points	Points as % of regional sample ¹	95% c.i. ³	Bare soil as % of regional area ²	95% c.i. ³
Stable surfaces (S)					
S (i) with intact soil	37	0.6	0.2		
S (ii) with soil disturbed by land use	0	0.0	0.0		
sub-total	37	0.6	0.2		
Erosion-prone surfaces (U)					
U (i) with intact soil	6	0.1	0.1		
U (ii) with soil disturbed by land use	1	<0.1	<0.1	<0.01	<0.01
sub-total	7	0.1	0.1		
Eroded (R) and eroding (E) surfaces					
R (i) with revegetating soil	28	0.5	0.2		
E (ii) with soil disturbed by natural processes	53	0.9	0.2	0.23	0.10
sub-total	81	1.3	0.3		
All surfaces in land use total	125	2.0	0.4	0.23	0.10
Note 1: "% of sample" sub-totals/totals may differ by 0.1% due to rounding. Note 2: "% of area" sub-totals/totals may differ by 0.01% due to rounding. Note 3: confidence limits are not additive.					

11.2.1 Stable surfaces

Stable surfaces in the mountains are generally confined to lower slopes, spurs and ridges.

- 0.6% of the region's sample points are stable surfaces on mountains,
- 0.6% have intact soil, currently well-vegetated, and
- 0.0% have soil currently disturbed by land use, so there is no bare soil measured here.

11.2.2 Erosion-prone surfaces

Erosion-prone surfaces in the mountains are steep upper slopes and inactive gullies.

- 0.1% of the region's sample points are erosion-prone surfaces on mountains,
- 0.1% have intact soil, currently well-vegetated.
- <0.1% (one sample point) has soil disturbed by land use (plantation forestry), with bare soil less than 0.01% of regional sample area.

11.2.3 Eroded and eroding surfaces

Eroded and eroding surfaces are mass movement scars on upper slopes, active gullies or streams, unvegetated or re-vegetating scree slopes, and old or fresh rock-falls on bluffs.

- 1.3% of the region's sample points are eroded and eroding surface on mountains,
- 0.5% are areas of surface and sub-surface erosion which are re-vegetating,
- 0.9% are freshly disturbed, with bare soil or rock amounting to 0.23% of the regional sample's area.

11.3 Soil disturbance

Table 19 Soil disturbance amongst tussock and mountain vegetation in Waikato region, 2007

	Points	Points as % of regional sample ¹	95% c.i. ³	Bare soil as % of regional area ²	95% c.i. ³
By land use					
grazing pressure	0	0.0	0.0		
cultivation	0	0.0	0.0		
harvest	0	0.0	0.0		
spraying	0	0.0	0.0		
drains	0	0.0	0.0		
tracks	1	<0.1	<0.1	<0.01	<0.01
earthworks	0	0.0	0.0		
roads	0	0.0	0.0		
sub-total	1	<0.1	<0.1	<0.01	<0.01
By natural processes					
landslide	1	<0.1	<0.1	<0.01	<0.01
debris avalanche	4	<0.1	0.1	0.01	0.01
slump or earthflow	0	0.0	0.0		
tunnel gully	3	<0.1	0.1	<0.01	<0.01
gully	1	<0.1	<0.1	<0.01	<0.01
streambank scour	6	0.1	0.1	<0.01	<0.01
streambank deposit	2	<0.1	<0.1	<0.01	0.01
sandblow	0	0.0	0.0		
sheetwash	24	0.4	0.2	0.09	0.05
rockfall or bare rock	11	0.1	0.1	0.10	0.07
geothermal	1	0.0	0.0	0.02	0.03
sub-total	53	0.9	0.2	0.23	0.10
Other					
undisturbed sub-total	71	1.2	0.3		
All in land use total	125	2.0	0.4	0.23	0.10
Note 1: "% of sample" sub-totals/totals may differ by 0.1% due to rounding. Note 2: "% of area" sub-totals/totals may differ by 0.01% due to rounding. Note 3: confidence limits are not additive.					

11.3.1 Disturbance by land use

Numbers in this section are obtained by adding the percentages for S(ii) and U(ii) from Table 18. When stable and erosion-prone surfaces are combined, less than 0.1% (one single point) of Waikato's land is currently disturbed by land use-related activities on mountains. This is due to the unproductive, isolated and steep nature of the land, generally precluding land use. Nonetheless, plantation forestry borders these areas, which accounts for a single point representing a vehicle track.

11.3.2 Disturbance by natural processes

Numbers in this section correspond with the percentages for E(ii) in Table 18. Only 1.0% of Waikato's land is disturbed by natural erosion or deposition in mountains. However bare soil and rock are extensive and caused by:

- slope failures, exposing 0.01% of the region's area,
- tunnel gullies and gullies, <0.01%
- streambank scour or deposition, <0.01%
- sheetwash, 0.09%
- bare rock, 0.10%
- geothermal disturbance, 0.02%

These add to 0.23%, which contributes a substantial 38% to the region's area of bare soil due to natural disturbance (0.59%, Table 2). Proportionately it is very high relative to the small area of mountains (2.0% of the region).

11.3.3 Summary of disturbance

Soil disturbance amongst tussock and mountain vegetation affects 0.9% of land in Waikato. A negligible amount of this is land-use-related and so almost all the 0.9% is due to natural disturbance. Bare soil or rock in the mountains amounts to 0.23% of the entire region's area.

Another 1.2% of land in the Waikato is occupied by mountain vegetation and is currently free from soil disturbance.

There is 95% confidence that sample percentages for soil disturbance are within 0.3% or better of the true regional figures. For bare soil, there is 95% confidence that sample percentages are within 0.10% or better.

12 Wetland and coastal vegetation

12.1 Overview

Wetland and coastal vegetation occupies 1.0% of Waikato's sample points (Table 3). The components are freshwater wetland (0.8%), mangrove and saltmarsh (<0.1%), and coastal grass and scrub (0.1%).

12.2 Soil stability

Table 20: Soil stability for wetlands and coastal vegetation in the Waikato region, 2007

	Points	Points as % of regional sample ¹	95% c.i. ³	Bare soil as % of regional area ²	95% c.i. ³
Stable surfaces (S)					
S (i) with intact soil	3	<0.1	0.1		
S (ii) with soil disturbed by land use	0	0.0	0.0	0.00	0.00
sub-total	3	<0.1	<0.1		
Erosion-prone surfaces (U)					
U (i) with intact soil	47	0.8	0.2		
U (ii) with soil disturbed by land use	2	<0.1	<0.1	0.01	0.01
sub-total	49	0.8	0.2		
Eroded (R) and eroding (E)					

surfaces					
R (i) with revegetating soil	3	<0.1	0.1		
E (ii) with soil disturbed by natural processes	4	0.1	0.1	0.03	0.04
sub-total	7	0.1	0.1		
All surfaces in land use total	59	1.0	0.2	0.03	0.04
Note 1: "% of sample" sub-totals/totals may differ by 0.1% due to rounding. Note 2: "% of area" sub-totals/totals may differ by 0.01% due to rounding. Note 3: confidence limits are not additive.					

12.2.1 Stable surfaces

Stable surfaces in wetland and coastal vegetation are confined to drained wetlands that have been under productive use for some time.

- <0.1% of the region's sample points are on stable surfaces on wetlands,
- <0.1% have intact soil, currently well-vegetated, and
- 0.0% have soil currently disturbed by land use, so there is no bare soil measured here.

12.2.2 Erosion-prone surfaces

The erosion-prone surfaces are mostly undrained or semi-drained swamps (on floodplains and coastal flats) but also include intact or partly reclaimed mangrove swamps (in estuaries), perched wetlands on terraces and downlands, and vegetated young sand dunes or coastal cliffs.

- 0.8% of the region's sample points are on erosion-prone surfaces under wetland or coastal vegetation,
- 0.8% have intact soil, currently well-vegetated, and
- <0.1% have soil disturbed by land-use-related activities, with exposed soil amounting to 0.01% of the region's area.

12.2.3 Eroded and eroding surfaces

Eroded and eroding surfaces comprise active sand blows and rockfalls on coastal cliffs, plus banks of watercourses flowing through wetlands or tidal creeks.

0.1% of the region's sample points are on eroded and eroding surfaces under wetland and coastal vegetation,

- <0.1% have soil recently disturbed by natural erosion processes but revegetating, and
- another 0.1% have soil freshly disturbed, with bare soil amounting to 0.03% of the regional sample's area.

12.3 Soil disturbance

Table 21: Soil disturbance amongst wetland and coastal vegetation in Waikato region, 2007

	Points	Points as % of regional sample ¹	95% c.i. ³	Bare soil as % of regional area ²	95% c.i. ³
By land use					
grazing pressure	0	0.0	0.0		
cultivation	1	<0.1	<0.1	0.01	0.01
harvest	0	0.0	0.0		
spraying	0	0.0	0.0		
drains	0	0.0	0.0		
tracks	1	<0.1	<0.1	<0.01	<0.01
earthworks	0	0.0	0.0		
roads	0	0.0	0.0		
sub-total	2	<0.1	<0.1	0.01	0.01
By natural processes					
landslide	0	0.0	0.0		
debris avalanche	0	0.0	0.0		
slump or earthflow	0	0.0	0.0		
tunnel gully	0	0.0	0.0		
gully	0	0.0	0.0		
streambank scour	0	0.0	0.0		
streambank deposit	0	0.0	0.0		
sandblow	4	0.1	0.1	0.03	0.04
sheetwash	0	0.0	0.0		
rockfall or bare rock	0	0.0	0.0		
sub-total	4	0.1	0.1	0.03	0.04
Other					
undisturbed sub-total	53	0.9	0.2		
All in land use total	59	1.0	0.2	0.03	0.04
Note 1: "% of sample" sub-totals/totals may differ by 0.1% due to rounding. Note 2: "% of area" sub-totals/totals may differ by 0.01% due to rounding. Note 3: confidence limits are not additive.					

12.3.1 Disturbance by land use

Numbers in this section are obtained by adding the percentages for S (ii) and U (ii) from Table 20. When stable and erosion-prone surfaces are combined, <0.1% of Waikato's land is currently disturbed by land use-related activities within wetland and coastal vegetation. Exposed soil is 0.01% of the region's area, a negligible contribution to the total bared by land use (2.27% region-wide, Table 2); and is accounted for by:

- cultivation at 0.01% (1 sample point), and
- tracks at <0.01% (1 sample point).

12.3.2 Disturbance by natural processes

Numbers in this section correspond with the percentages for E (ii) in Table 20. 0.1% of Waikato's land is disturbed by natural erosion or deposition within wetlands and coastal areas. Bare soil associated with these areas amounts to 0.03% of the region's area and is confined to:

- Wind erosion of young sand dunes, at 0.03%.

This is a measureable contribution (5.5%) to the region's area of bare soil due to natural disturbance (total 0.57%, Table 2). Proportionately it is quite high relative to the area of land in wetland and coastal vegetation (1.0% of the region).

12.3.3 Summary of disturbance

In wetlands and coastal vegetation, soil disturbance affects 0.1% of land in the Waikato region. The majority of disturbance is by natural means (sandblow), however a small amount is land use-related; a mix of cultivation and access tracks in partly drained wetlands. Bare soil (or bare sand) amounts to 0.03% of the region's area.

Another 0.9% of land in the Waikato is occupied by wetland or coastal vegetation and is currently free from soil disturbance.

There is 95% confidence that sample percentages for soil disturbance are within 0.2% or better of the true regional figures. For bare soil, there is 95% confidence that sample percentages are within 0.04% or better.

13 Summary

This section summarises key points from the preceding results. The conclusions are for Waikato's soil in 2007, the year of new aerial photographic coverage. They are based on a sample of one-hectare areas at 6122 points, taken from the coverage at two kilometre spacing throughout the region. The sample represents true regional figures to +/- 1.3% or better for point data, and +/- 0.24% or better for bare soil.

13.1 Soil stability, soil disturbance and bare soil region-wide

Table 22: Soil stability, disturbance and bare soil region wide

		Points as % of sample ¹	Bare soil as % of area ²
Stable	Intact	33.1	
	disturbed by land use	16.7	1.66
Erosion-prone	Intact	16.3	
	disturbed by land use	6.3	0.46
Eroded and eroding	revegetating	9.3	
	freshly disturbed by natural processes	7.5	0.53
Extensively disturbed	shorelines etc.	3.5	0.05
	rural buildings etc.	2.5	0.14
	urban areas etc.	1.0	0.02
Other	no photos or unclassified	3.9	Not measureable
Totals	as % of region	100.0	2.85

Note 1: "% of sample" sub-totals/totals may differ by 0.1% due to rounding.

13.1.1 On stable and erosion-prone land

49.4% of land in the Waikato region has intact soil. Of this:
33.1% is on stable land that shows no signs of past erosion and is currently well-vegetated. Such land includes drained wetlands, protected floodplains, elevated terraces, and rolling downlands, together with footslopes spurs or ridges in the hill country and ranges, and

- 16.3% is on erosion-prone land that is currently inactive and well-vegetated. This land includes hill faces or steep faces with healed erosion scars; inactive gullies, drainage hollows or watercourses that run through footslopes, downlands, and terraces; flood-prone river flats, undrained wetlands and stabilised sand dunes. Here vegetation cover - whether crops, pasture, plantations, scrub or forest - is at present sufficiently dense to protect soil against disturbance.

23.0% of the region's land has soil currently disturbed by rural land use. Of this:

- 16.7% is on stable land. 1.66% has bare soil, and
- 6.3% is on erosion-prone land. 0.46% has bare soil.

13.1.2 On eroded and eroding land

- 16.7% of Waikato's land has eroded or eroding soil - soil that has recently been, or still is, on the move. This land includes hill faces and steep faces with revegetating or fresh mass movement scars (debris avalanches, slips, slumps and earthflows); footslopes, downlands and terraces that have gullies of all types (under-runners, open gullies, gullied debris flow deposits), or scour and deposition along streambanks; areas within coastal dunes where sand is blown away or accumulates; sheetwash of soil on ridges, spurs or coastal cliffs; rockfalls or rock outcrops where soil is absent from cliffs, bluffs, gorges, ignimbrite flows and mountain slopes. Of this:
 - 9.3% is eroded - it has been disturbed in recent years but is now revegetating, and
 - the other 7.5% is eroding - it is freshly disturbed by natural processes of erosion and deposition. 0.53% has bare soil.

13.1.3 On extensively disturbed land

On another 3.5% of the region's land which is shorelines and water bodies, soil is exposed or absent. This area includes lakes, notably Lake Taupo; large river principally the Waikato and Waihou; coastal cliffs, beaches, tidal creeks, and estuarine sandflats or mudflats. Here bare soil, rock or sediment exposed by fresh erosion or deposition amounts to 0.05% of the region's area.

2.5% of the region is partly covered by rural buildings and yards, industrial sites in rural areas, or quarries and mines. Bare soil associated with these features is 0.14% of the region's area.

A final 1.0% of the region's soil is covered by urban uses - residential buildings and gardens, commercial buildings and yards, urban roads, railways and airfields, open spaces with planted or retained vegetation. Associated bare soil has been measured at 0.02% of the region's area.

13.2 Soil disturbance region wide

Table 23: Soil disturbance and bare soil region-wide

Disturbance cause :	Disturbance type :	Points as % of sample¹	Bare soil as % of area²
Land use	grazing pressure	2.4	0.08
	cultivation	1.8	0.81
	harvest	1.2	0.15
	spraying	<0.1	<0.01
	drains	0.8	0.03
	tracks	15.1	0.89
	earthworks	0.7	0.07
	rural roads	1.0	0.08
	rural buildings etc	2.5	0.14
	urban areas etc.	1.0	0.02
	Land use sub total		26.5
Natural processes	landslide	1.9	0.06
	debris avalanche	0.6	0.03
	slump or earthflow	0.2	0.01
	tunnel gully	0.7	0.02
	gully	0.9	0.03
	streambank scour	1.0	0.03
	streambank deposit	0.5	0.03
	sandblow	0.2	0.05
	sheetwash	0.4	0.09
	rockfall or rock outcrop	1.0	0.15
	geothermal	0.1	0.02
	shorelines etc.	3.5	0.05
	Natural processes sub total		11.0
Totals	as % of region	37.5	2.85
<small>Note 1: "% of sample" sub-totals/totals may differ by 0.1% due to rounding. Note 2: "% of area" sub-totals/totals may differ by 0.01% due to rounding.</small>			

37.5% of the region's land has fresh soil disturbance. This comprises 26.5% land use related disturbance and 11.0% disturbance by natural processes.

- The main land use-related disturbance is by farm tracks and logging roads (present on 15.1% of Waikato's land), together with unsealed roads passing through land in rural use (1.0%). Grazing pressure in pasture is the next most extensive (2.4%). Collectively, cultivation, harvest and spraying of cropland and pasture affect 3.0% of land. Drain or pond excavation and earthworks contribute an equal amount of disturbance to the region, present at 0.8% and 0.7% of land respectively.
- Bare soil within these disturbed areas amounts to 2.11% of the region's land; of which 2.03% is attributed to rural land use and 0.08% to rural roads.
- On extensively disturbed surfaces, another 0.16% of the region's land is bared by land use related disturbance. Most of this (0.14%) is attributable to activities associated with rural buildings and a small amount (0.02%) is associated with urban areas.

- The main natural disturbance is by slope failure (mass movement) scars, which are collectively present on 2.7% of land. Surface erosion processes (sandblow, sheetwash, rockfall, rock outcrops) are on 1.7%. Sediment deposition and bank scour along watercourses are next most extensive, together on 1.5%. Various forms of gully erosion are collectively present on 0.6%.
- This fresh natural disturbance amounts to 0.57% of the region's area; of which 0.30% is bare soil amongst rural land uses; and 0.27% is bare rock, sand or silica.
- On extensively disturbed surfaces 0.05% of the region's land is bared by fresh natural disturbance, mainly in association with shorelines.

13.3 Pressure on soil - impacts of land use

Table 24: Impacts of land use on soil

	Impacts of Land Use on Soil			
	Area in use % of region	Area of land disturbed by use as % of region ¹	Bare soil within disturbed area as % of region ² as % of land in use	
Rural uses:				
Horticulture and cropping	1.8	1.2	0.52	29.20
Dairy pasture	22.9	10.0	0.81	3.54
Drystock pasture	25.3	7.2	0.42	1.65
Forest plantation	12.2	3.1	0.27	2.23
sub-total	62.2	21.5	2.02	3.25
Conservation uses:				
Natural forest	10.3	0.3	0.01	0.13
Natural scrub	10.7	0.7	0.03	0.29
Exotic scrub	3.0	0.5	0.04	1.48
Wetland and coastal	1.0	<0.1	0.01	0.56
Tussock and mountain	2.0	<0.1	<0.01	0.02
sub-total	26.9	1.5	0.09	0.33
Other:				
Rural buildings etc.	2.5	0.8	0.14	5.60
Urban areas etc.	1.0	0.2	0.02	2.32
Shorelines etc.	3.5	<0.1	<0.01	0.07
sub-total	7.0	0.9	0.16	2.31
No photos	3.9	Not measurable	Not measurable	
Regional total	100.0	23.9	2.27	2.27

Note 1: "% of sample" sub-totals/totals may differ by 0.1% due to rounding.
Note 2: "% of area" sub-totals/totals may differ by 0.01% due to rounding.

13.3.1 On land in rural use

62.2% of land in Waikato is currently in rural uses, and 21.5% of the land is disturbed by those uses.

- They have exposed 2.02% of the region's soil. All land uses contribute: orchards and cropland (cultivation and harvest), dairy farms (tracks, races and cultivation), drystock pasture (grazing pressure, cultivation and tracks), forestry (harvest and logging tracks).

- As a percentage of land in each use, bare soil falls from 29.20% amongst horticulture and cropping, through 3.54% in dairy pasture and 2.23% in forest plantations, to 1.65% in drystock pasture.

13.3.2 On land in conservation use

26.9% of the region's land is in conservation uses, and 1.5% is disturbed by activities associated with those uses.

- They have exposed 0.09% of the region's soil. The bulk is in natural and exotic scrub (unsealed roads, access tracks, earthworks and scrub clearance).
- As a percentage of land in each use, bare soil rises from 0.02% in tussock and mountain vegetation, through 0.13% in natural forest, 0.29% in natural scrub, 0.56% in wetland and coastal vegetation, to 1.48% in exotic scrub (mainly access tracks).

13.3.3 On land in other use

2.5% of Waikato's land has been extensively disturbed by erection of rural buildings and yards, industrial sites, quarries and mines, or rural roads. 0.8% is currently disturbed. Here an additional 0.14% of the region's soil is exposed to topsoil loss, mainly by unsealed yards, tracks and earthworks.

1.0% of the region's land has been extensively disturbed by urbanisation, though just 0.2% has current disturbance. Here 0.02% of the region's soil is exposed to topsoil loss, mainly by housing subdivision and road construction.

13.4 Pressure on soil - impacts of natural processes

Table 25 Impacts of natural processes on soil

	Impacts of Natural Processes on Soil			
	Area in use % of region	Area of land disturbed by erosion as % of region ¹	Bare soil within disturbed area	
			as % of region ²	as % of land in use
Rural uses:				
Horticulture and cropping	1.8	<0.1	<0.01	0.04
Dairy pasture	22.9	0.8	0.03	0.12
Drystock pasture	25.3	3.7	0.16	0.64
Forest plantation	12.2	0.5	0.02	0.14
sub-total	62.2	5.0	0.21	0.33
Conservation uses:				
Natural forest	10.3	0.5	0.02	0.17
Natural scrub	10.7	0.8	0.03	0.26
Exotic scrub	3.0	0.4	0.02	0.70
Wetland and coastal	1.0	0.1	0.03	2.95
Tussock and mountain	2.0	0.9	0.23	11.25
sub-total	26.9	2.7	0.32	1.21
Other:				
Rural buildings etc.	2.5	<0.1	<0.01	0.10
Urban areas etc.	1.0	<0.1	<0.01	0.02

Shorelines etc.	3.5	0.3	0.04	1.24
sub-total	7.0	0.3	0.05	0.69
No photos or unclassified	3.9	Not measurable	Not measurable	
Total	100.0	7.5	0.57	0.57
Note 1: "% of sample" sub-totals/totals may differ by 0.1% due to rounding. Note 2: "% of area" sub-totals/totals may differ by 0.01% due to rounding.				

13.4.1 On land in rural use

5.0% of land in Waikato is freshly disturbed by natural processes of erosion or deposition amongst rural land uses.

- Here these processes have exposed 0.22% of the region's subsoil. Most of the fresh disturbance is in drystock pasture (mass movement, gullyng, streambank scour and deposition, sandblow, rock outcrops; though there is also measureable disturbance in dairy pasture (gullyng, streambank scour and deposition, rock outcrops); and forest plantations (mass movement, gullyng, rock outcrops).
- As a percentage of land in each use, bare subsoil rises from 0.04% amongst horticulture and cropping, through 0.12% in dairy pasture and 0.14% in forest plantations, to 0.68% in drystock pasture. This higher amount under drystock pasture is attributable to a greater incidence of mass movement and sandblow.

On land in conservation use

2.7% of the region's land is freshly disturbed by natural processes on land in conservation use.

- Here erosion or deposition has exposed 0.31% of the region's soil. Half is bare surfaces in mountains (sheetwash, scree, rockfall). The rest is evenly distributed amongst other conservation uses though the causes vary; from forest (mass movement and streambank scour or deposition); through natural and exotic scrub (gullyng, streambank scour or deposition, rock outcrops, geothermal disturbance); to wetland and coastal vegetation (sandblow).
- As a percentage of land in each use, bare soil rises from 0.26% and 0.28% in natural scrub and natural forest respectively, to 0.70% in exotic scrub. Amongst wetland and coastal vegetation, bare soil elevates to 2.95% on account of coastal sand erosion by wind. Bare soil peaks at 11.25% in mountains due to extensive sheetwash, scree slopes and rock bluffs.

13.4.2 On land in other use

Disturbance by natural processes is currently slight amongst rural buildings and within urban areas; exposing less than 0.01% of the region's soil in each case (0.10% of the land under rural buildings etc. and 0.02% of the urbanised land). Along shorelines and water bodies, 0.04% of the region's soil is currently exposed by natural processes (1.24% of the land in this category).

References

- Burton AS, Taylor A, Hicks DL 2009. Assessing soil stability. In: Land and soil monitoring : a guide for SoE and regional council reporting. Hamilton, Land Management Forum. pp. 89-116
- Hicks DL 2004. Soil intactness assessment of the Waikato Region : 2003. Environment Waikato Technical Report 2003/14. Hamilton, Waikato Regional Council (Environment Waikato)
- Hicks DL 2005. Soil disturbance by land use and natural processes in the Waikato. In: Hicks DL 2004. Soil intactness assessment of the Waikato Region : 2003. Environment Waikato Technical Report 2003/14. Hamilton, Waikato Regional Council (Environment Waikato) pp. 67-77
- Thompson AB, Hicks DL 2009. Changes in soil stability in the Waikato Region from 2002 to 2007. Environment Waikato Technical Report 2009/30. Hamilton, Waikato Regional Council (Environment Waikato)

Appendix 1: Data recording codes and procedures used for Environment Waikato's point sample 2009

Point number

A unique reference number for each sample point, from 1 to 6122 was automatically assigned by the GIS program Geomedia. However because this number may change if the attribute table is re-opened in a different workspace, a locked identification number was assigned by an EW GIS specialist to each point, enabling their re-location during data sorts and analyses.

Grid reference

This survey re-located the same points as in 2003. Their grid references had been stored as 8-digit eastings and northings, derived by applying a NZTM (New Zealand Transverse Mercator) map-grid layer over the aerial photograph GIS layer, and selecting points spaced two kilometres apart at map grid intersections.

Soil stability

The four soil stability codes outlined in Chapter 4 of the LMF Manual were used to analyse soil stability. These are:

- s stable surfaces (vegetated)
- u erosion-prone unstable surfaces (inactive, vegetated)
- r eroded unstable surfaces (recently disturbed, revegetating)
- e eroding unstable surfaces (freshly disturbed, bare)

Nature of disturbance

Standard codes defined in Chapter 4 of the LMF Manual were used to record the nature of disturbance. These are:

Topsoil :

- c exposed by cultivation
- x exposed by harvest
- y exposed by spraying
- z exposed by grazing
- t exposed by farm or forest track (not sealed)
- r exposed by road (not sealed)
- d exposed by drain excavation, cleaning or tile drainage
- e exposed by earthworks

The 'r' code is additional to codes outlined in the LMF manual, in order to differentiate between farm tracks and public roads.

Subsoil :

- l landslide or slip
- u slump or flow
- a debris avalanche
- p tunnel (under-runner)
- g open gully

'Large slope failure' and 'large gully' codes (ll and lg respectively) as outlined in the LMF manual, have not been recorded in this survey, consistent with the 2002 survey.

Other :

bs streambank scour
bd streambank deposition
w wind erosion or deposition of sand
s sheetwash
br rockfall or rock outcrops
ge geothermal

The code 'ge' (geothermal) has been added, consistent with the 2002 survey.

Percentage bare ground

Percentage bare ground was recorded by the procedure recommended in the LMF Manual i.e. using a 10 x 10 grid of dots superimposed as a GIS layer on a one hectare area around each ortho-photo sample point.

Land use

The LMF manual provides a base-set of codes for recording land use. These same codes have been used in this survey, except that:

- orchards and vineyards (o) has been differentiated into 4 separate codes, - orchards (miscellaneous) 'o', avocado orchards 'oa', grape vineyards 'ov', and kiwifruit vineyards 'ok'. In the 2002 survey, only the 'o' code was used for orchards and vineyards.
- the code 'gf' has been used in this survey to differentiate green-feed crops from grain crops ('g')
- 'sf' (ground-fern) and 'sa' (sub-alpine scrub) have been differentiated from natural scrub (s),
- 'mg' (saline wetland vegetation) has been differentiated from coastal scrub and grass (m).

The other LMF codes for recording non-vegetated land use have been used, with the addition of 'bs' (bare sand), 'br' (bare rock). Urban areas (u) have been differentiated into 'ui' (industrial/commercial buildings and yards), 'uh' (houses and associated gardens), and 'uo' (parks and reserves). Also 'bg' (indoor agriculture) has been differentiated into 'bh' (glasshouses/shadehouses) and 'ba' (poultry barns, pig sheds etc).

Associated vegetation

The same codes as above have been used for recording secondary vegetation, using the annotations provided in the LMF manual.

Landform

The landform codes in the LMF manual have been used in this survey, with the following exceptions:

- a code for plateaux (dp) has been used instead of downland (d) for a few points on broad undulating ridges within hill country or steeplands,
- the code 'a' denoting river or stream has been differentiated into 'la' (large river – alluvial), 'sa' (small river or stream – alluvial), 'lr' (large river – rock channel) and 'sr' (small river or stream – rock channel),
- a code for drains (dr) has been added.

Data analysis

Data storage

Sample point locations were stored as Geomedia metadata. These are cross-referenced to a screen display (shapefile) which shows their locations relative to region-wide orthophotos and map layers e.g. topographic; and a database (attribute table) which contains data recorded for all points. It is duplicated in an Excel spreadsheet which enables data sorting.

Sorts and point counts

An initial data sort was carried out in the Excel spreadsheet, to check for consistency in use of codes, and correct where necessary. Subsidiary spreadsheets were created region-wide and for each land use e.g. dairy pasture. These were repeatedly sorted to count points in each category of interest i.e. soil stability, nature of disturbance.

Statistical analysis

Formulae were inserted into each spreadsheet, enabling calculation of percentages and error margins for each category of interest.

Data presentation

Sort, point count and statistical analysis results for particular topics were stored as four series of summary spreadsheets (1A to 11A for soil stability in 2007, 1B to 11B for soil disturbance in 2007, 1C to 11C for 2002-2007 changes in stability, 1D to 11D for 2002-2007 changes in disturbance).

Each report's tables were sourced from these spreadsheets.

Graphs of summary data were not included in the reports. Instead, electronic versions of the summary spreadsheets were supplied to EW. These enable EW staff to generate customised graphs, as and when needed for internal use or external publication.

Reports

Two reports were supplied. Each was drafted to a standard format consistent with LMF Guidelines, then modified after review by Dr. Reece Hill (EW's soil scientist). They are:

- * Soil Stability in the Waikato Region 2007
- * Changes in Soil Stability and Disturbance from 2002 to 2007

The first report is the essential document that EW needs to have, as a source of information that could be presented in its regional state-of-environment report. The second report compares 2007 results with 2002 results for the Waikato region. These comparisons are likely to be a useful basis for observations about change in soil stability, intactness and disturbance between 2002 and 2007.

Appendix 2 Technical conclusions

Survey procedure

Preliminary up-grade of 2007 point sample

Most data items from EW's previous survey equate to standard items in the post-2003 survey format adopted by LMF. However three differences are that some data storage formats and codes have altered due to post-2003 standardisation; land use-related soil disturbance is now recorded in greater detail (5 categories subdivided into 8); and amount of fresh disturbance is now measured for a 1 hectare area (centred on each sample point). For entirely compatible change detection i.e. types and amounts of fresh erosion, the following up-grades have been carried out :

- * Re-locate freshly disturbed points (613 out of 6122) on EW's 2002 orthophoto cover; re-classify land use-related soil disturbance into post-2003 LMF categories; re-measure all soil disturbance to post-2003 NMLF standard,
- * Convert 2002 point sample codes to standard LMF format,

Soil disturbance measurement up-grade took 5 days (done as a separate contract in 2005), and code conversion took 1 day (0.5 days GIS staff, 0.5 days contractor time).

Photo-interpretation

The procedure for interpreting orthophotos - on-screen viewing through GIS software, with direct entry of data to a GIS-linked database - proved very satisfactory due to high quality of the orthophoto coverage, and good standard of the Geomedia procedure set up on EW's GIS by Dan Borman. Setting up the procedure took 0.5 day of his time and 1.5 days of the contractor's time (parameter setting and procedure test).

Photo-interpretation, at 22 days for 6122 points, was done at an average rate of 278 points a day by the principal contractor (ABT) with advice from the sub-contractor (DLH) on 2 days.

Data analysis

Point counts were obtained by importing data into Excel. The master spreadsheet was repeatedly sorted for desired combinations of data. This process enabled any errors in recording codes to be detected in the course of sorts. These were corrected in the master spreadsheet. Corrected data was then copied into working spreadsheets that were formatted to calculate totals, percentages and error margins. Sorts and checks took 2 days. Obtaining totals, percentages and error margins from the working spreadsheets took :

- 3 days for 2007 soil stability,
- 3 days for 2007 soil disturbance,
- 4 days for 2002-2007 changes

Data analysis remains intensive, as the procedure is interactive rather than automatic. For instance, to calculate bare soil percentages and confidence intervals for all types of disturbance within a land use, requires 33 iterations of the "sort and calculate" procedure within the relevant spreadsheet.

Analysis of 2007 data proved straight-forward, except for 241 points that have no orthophoto cover. This represents 3.9% of the region (+- 0.5 at 95% confidence).

These omissions precluded region-wide comparison of all 6122 points. Rather than attempt "cut-down" comparisons of change at 5881 points which were recorded at both dates, all comparisons were expressed as percentages of 6122. This has the effect that all numbers in region-wide tables for 2007 are under-estimates. One way to adjust for this, would be to scale up by 3.9% (241/6122). For instance, total bare soil due to fresh disturbance of all types would rise from 2.80% to 2.91% of the region's area. However rises are small enough to be contained within the error margins for each category (for example +/-0.19% in 2002 and +/-0.24% in 2007), so there seems little point in applying a scaling factor, particularly as the effect on comparisons for each land use is less. For instance, 2002 records for the 241 missing points indicate that just 41 were dairy pasture at that date. Unless there were a great deal of fresh disturbance in 2007 at those particular points, their addition would have minimal effect on 2002-2007 change in soil disturbance (0.84% of the region's area, at 661 out of 1403 points in dairy pasture).

Photo-interpretation check

Generating random points for checking took 1 hour (GIS staff). Independent on-screen checks took 1 day (2 days' contractor time). This enabled field checks to be cut down to 20 points where there was doubt about interpretation. Printing screen-dumps of these plus a map showing their location relative to roads took a further 2 hours (GIS staff). Field checking the cut-down points took 2 days. Analysis of check results took an additional 0.5 day.

This procedure was based on the one adopted for Marlborough District Council's point sample check in August 2009. It has proven a quick alternative to driving past random points within viewing distance of public roads (which took 6 days for the 2003 EW field checks), or the expense of hiring an aircraft or helicopter. Results are discussed later in this report.

Report preparation

Report preparation (42 summary tables plus accompanying text) took :

	Draft	Final
Report 1	6 days	4 days
Report 2	6 days	3.5 days

i.e. a total 16 days. This includes approximately 2 half-days discussing drafts with EW's soil scientist Dr. Reece Hill. Report-writing remains a time-consuming part of the survey; particularly any alteration of summary tables (which entails re-running a calculation spreadsheet for the relevant table).

Overall, the survey took Mr. Thompson and Dr. Hicks 59 days, compared with the quoted time of 57 days. Draft reports were delivered somewhat after EW's deadline (30 September), and final reports delivered by early January 2010.

Photo-interpretation accuracy

This section presents results of field checks at 100 randomly selected points. They indicate reliability of photo-interpreted data stored for 6122 points in the sample.

Land use

Correct at 92 points. Photo-interpretation errors are :

- * sparse or emergent grain crop recorded as sparse dairy pasture (1 point),
- * unimproved pasture recorded as exotic scrub (1 point),
- * sparse drystock pasture recorded as harvested drystock pasture (1 point),
- * drystock pasture recorded as sparse drystock pasture (1 point),
- * plantation forest recorded as emergent plantation forest (1 point),
- * coastal vegetation recorded as exotic scrub (1 point)
- * sparse drystock pasture recorded as drystock pasture (1 point),
- * native scrub recorded as exotic scrub – the two intermingled but native dominant (1 point)

Associated secondary vegetation

Correct at 84 points. Photo-interpretation errors are :

- * 7 points where secondary vegetation was omitted (natural forest, wetland, exotic scrub, natural scrub, exotic tress, and dry-stock pasture),
- * 3 points where the suffix (pattern of vegetation) changed (exotic shelterbelt to hedgerow, harvested dairy pasture to sparse dairy pasture, and exotic trees to sparse/emergent exotic trees),
- * 6 points where secondary vegetation has been incorrectly recorded (indoor agricultural building instead of house, sparse exotic scrub instead of unimproved pasture, sparse exotic trees instead of sparse natural trees, natural scrub instead of exotic tree shelterbelt, exotic scrub instead of natural scrub, sparse natural scrub instead of sparse natural trees).

Landforms

Correct at 96 points. Photo-interpretation errors are :

- * hill-slope recorded as steep-land (1 point).
- * steep-land recorded as hil-lslope (1 point).
- * small rock channel recorded as small alluvial channel (1 point).
- * small alluvial channel recorded as small rock channel (1 point).

Soil stability

Correct at 91 points. Photo-interpretation errors are :

- * re-vegetating surfaces recorded as stable (2 points),
- * unstable surfaces recorded as re-vegetating (2 points),
- * unstable surface recorded as stable (2 points).
- * eroding surface recorded as unstable (1 point).
- * re-vegetating surface recorded as eroding (1 point).
- * stable surface recorded as unstable (1 point).

Disturbance type

Correct at 91 points. Photo-interpretation errors are :

- * nil where tracks were previously recorded (2 points)
- * track recorded as unsealed road (1 point)
- * gully erosion recorded as tunnel gully (1 point)
- * bare ground from grazing pressure previously not recorded (1 point)
- * nil where stream-bank deposition was recorded (1 point)
- * stream-bank deposition previously not recorded (2 points)

- * stream-bank scour recorded as gully (1 point)

Bare soil

Percentage of soil bare is correctly recorded at 71 points. Photo-interpretation errors are :

- * bare soil measured but under-recorded (9 points)
- * bare soil measured but over-recorded (6 points)
- * bare soil present but not measured (9 points)
- * re-vegetating ground misinterpreted as bare soil (5 points)

Overall comments on photo-interpretation accuracy

Accuracy is over 90% except for secondary vegetation (84%) and bare soil (71%). With these exceptions, accuracy is at least as good as, and in some instances better than, other point sample surveys recently carried out for regional councils' state of environment monitoring, which are typically in the 85% to 95% range.

The secondary vegetation error-rate, at 16%, comprises 7% genuine omission errors and 9% minor changes. This error rate is of little consequence in determining the degree of soil stability and disturbance in the region, but will be of greater interest in any subsequent analysis of the effect of vegetative conservation cover on soil stability.

The error-rate in the recording of bare soil is higher than in the previous survey. Of the 29% errors, 15% were under or over-recording (usually slight) and 14% were genuine errors, being failure to record something that was there, or recording something that wasn't. This error rate is higher than expected.

The low error for landform codes contrasts with previous surveys which have had a high error rate (11-20%). The reason is that orthophotos cannot be viewed stereoscopically when interpreting them on a computer screen. Subtle changes in relief - where downlands are close to footslopes, terrace edges and stream floodways - are hard to detect. During re-survey of EW's points, the original 2003 landform codes were re-examined with reference to a 20 metre contour overlay and changed where necessary. This considerably improved their accuracy.

Few types of error were repeated more than once in the course of a hundred points. This being the case, it is unlikely that they will cause problems for any future analysis or re-survey of the point sample. There was no need to attempt to correct data for errors which affect accuracy by one percent - indeed it would be impossible to make consistent corrections without visiting every sample point.

Changes subsequent to photography are not a problem. The sample is intended to provide a snapshot of the region in 2007, the year of photography. There was no need to attempt to adjust data for subsequent changes, which should be detected by re-survey in a future year.

Representativeness of results

Statistical error analysis was carried out for all tables in the survey reports, to ascertain how closely sample data match the region's soil stability, soil disturbance and bare soil percentages.

Soil stability and disturbance

For soil stability and disturbance region-wide there is 95% confidence that 2007 point sample data are representative of true figures to $\pm 1.2\%$ or better (Table 2.1) For soil stability by land use there is also 95% confidence that point sample data are representative of true figures to $\pm 1.2\%$ or better (Tables 2.2 to 2.10).

Bare soil

For bare soil region-wide there is 95% confidence that 2007 cluster measurements around sample points represent true figures to $\pm 0.24\%$ or better (Table 2.1). For bare soil by land use there is 95% confidence that cluster measurements represent true figures to $\pm 0.16\%$ or better (Tables 2.2 to 2.10).

Extraction of regional sub-sets

Data for 6122 points region-wide were stored in the Council's GIS for future use. From a statistical viewpoint, it is safe to conduct sub-regional analyses of soil stability and bare soil for local authority districts, large territorial areas, catchments, or sub-catchment management zones where number of points exceeds 100. Error margins will generally be less than 1%.

The point sample has been designed to provide statistical data for the Waikato region as a whole. It is sufficiently large, that it can also provide valid data for reasonably large subdivisions within it. However, to attempt a data analysis for soil stability / bare soil in an area of land any smaller than 100 km², or for land use / vegetation cover in an area smaller than 500km², would be pushing the sample beyond the purpose for which it is intended.

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