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Towards a National Landslide Information Base for New Zealand

THOMAS GLADE AND MICHAEL CROZIER

ABSTRACT

Landslides constitute a problem as a natural hazard, as a factor in land development decisions, and as a major process in the depletion of New Zealand's soil resource. There are compelling social, economic, and legislative reasons for obtaining and accessing information on landslide activity. As a way of improving a currently weak information base, recommendations are given for establishing an information system appropriate to specific management functions.

ABOUT THE AUTHOR

Thomas Glade is a Ph.D student and Michael Crozier is an Associate Professor at the Research School of Earth Sciences, Department of Geography, Victoria University of Wellington, PO Box 600, Wellington.

INTRODUCTION

This paper aims to identify the main landslide issues for New Zealand and to demonstrate that, on rational, economic, and legislative grounds, sustainable management of New Zealand's natural and physical resources requires a good quality information base on landslides. It attempts to clarify the important management objectives, together with their appropriate information requirements. The existing information base is examined to identify problems and to provide suggestions for improving the collection and storage of data.

New Zealand's physical environment, land use history, and continued resource development combine to make the landslide phenomenon an important human concern in this country. Generally landslides are viewed as instantaneous events capable of producing catastrophic damage, destruction and death. However, low population density and initial habitation of favourable terrain has to date resulted in a low death toll. In contrast, Japan with many physical similarities to New Zealand, regularly has more than 90 people killed each year as a result of debris flows alone (Takahashi, 1981). Along with population growth, New Zealand can expect increasing costs

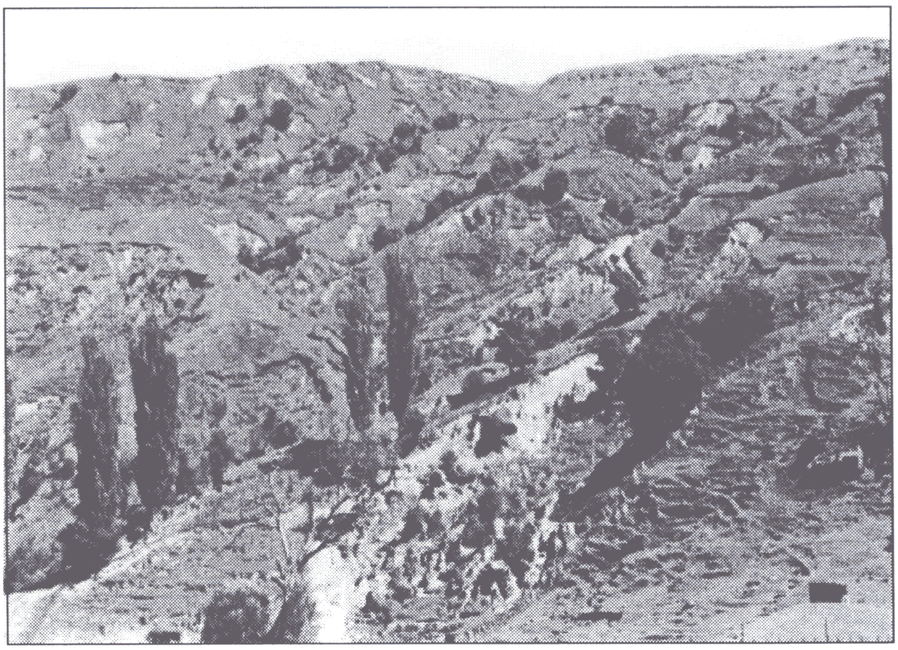

Figure 1: Landslide scars from Cyclone Bola (6-9 March 1988) illustrate soil erosion in northern Hawke's Bay.

from catastrophic landslide occurrence.

Many areas of New Zealand also suffer the chronic effects of slow landslide deformation, where buildings, roads and other communication links require costly on-going maintenance.

Increasingly, however, landslides are recognized as posing sufficient threat to affect decision making and costs of major development projects (Gillon *et al.*, 1991). Such concerns are not only driven by commercial considerations but also by legislative requirements to identify and reduce the adverse effects of development.

Figure 2: Landslide impact on productive soils, Wairarapa 1977.

A much more insidious impact of landsliding in New Zealand has been the degradation of the hill country soil resource at an alarming rate (Figure 1). Productive hill country makes up 40 per cent of New Zealand land area and much of it has undergone several episodes of landslide activity (Harmsworth and Page, 1991; Hicks, 1995). Cumulatively, these have caused significant reduction of grassland productivity on up to 50 per cent of the landsurface in many localities (Trustrum *et al.*, 1984) as well as necessitating increased use of fertilisers, seed and additional management practices to compensate these soil losses (Trustrum *et al.*, 1990) (Figure 2).

Three other issues are generating concern over landslides. The first is the mounting evidence that development practices in New Zealand have increased the incidence of soil landslides in New Zealand; an important issue particularly in relation to the heightened awareness of environmental stewardship (Page *et al.*, 1994; Trustrum *et al.*, 1990). The second is the growing evidence from countries such as USA and Japan indicating that human measures can dramatically reduce the landslide risk (Schuster and Fleming, 1986; Oyagi, 1989). Third is the enshrinement of many of these concerns in resource management legislation (Clough and Hicks, 1992) and the consequent requirement to establish commensurate policy (King and Krausse, 1995).

To satisfy these concerns there is clearly a need for a wide range of information on landslides. The concerns encompass four areas of management, involving:

- Costs related to catastrophic failure, or on-going deformation of *existing elements*, including: information for risk analysis, hazard mitigation, insurance, compensation, maintenance and civil defence.
- Costs related to catastrophic failure, or on-going deformation of *proposed developments*, involving: information for project development, design, engineering measures and planning decisions.
- Degradation of the soil resource and downstream effects, involving information for sustainable management under the Resource Management Act (RMA).
- Adverse effects of human activity including information for obtaining consents and permits under RMA and Building Act (BA).

The first two areas of management can be approached to some extent by conventional hazard/risk analysis:

Hazard x Elements at Risk x Vulnerability = Total Risk

where in the case of landslides:

Hazard is the probability of occurrence of a given *magnitude* of failure, while *magnitude* refers to the nature of the process, including hazard characteristics such as velocity, volume, depth, duration, speed of onset, degree of displacement and degree of disruption,

Elements at Risk are people, property, livelihood and other values,

Vulnerability is the expected degree of loss for a given magnitude, and

Total Risk is the expected loss.

This methodology can also be used to assess 'potential risk' in areas where developments are proposed. This isdone by establishing the degree of hazard (which should be the first step in any assessment programme) and then relating it to realistic development scenarios (Crozier, 1993).

There are few reliable techniques available for assessing landslide hazard as defined and those available often require detailed geotechnical information on existing conditions. Because of the high cost involved they are generally only achievable at the site investigation level in cases where high risk is anticipated. Hazard is more commonly assessed by historically based, largely stochastic analysis of precedents. The accuracy with which hazard can be determined thus depends very greatly on the length, quality and nature of the information record. Probability of occurrence can be determined either directly from landslide record or indirectly by establishing the landslide triggering threshold of the initiating agent and analysing agent behaviour. In both approaches the minimum information requirements are a record of events including descriptions to characterise location, date, associated triggering conditions, causes, nature and length of warning, as well as landslide magnitude characteristics such as volume, material type and nature, and length of runout.

The main drawback of the precedent approach is the uncertainty associated with applying the findings to areas beyond where the precedence was established. For this reason or because there is insufficient record of

TABLE I
EXAMPLES OF DIRECT DAMAGE COSTS CAUSED BY LANDSLIDES

Region	*Event*	*Landslide damage in NZ$ M*
Torepatutahi (Reporoa), NZ[1]	1967	0.20
Eastern Whangarei, NZ[1]	1975	0.10
Kaikoura, NZ1,[3]	11.03.1975	0.20
Wairarapa, NZ[3]	July 1977	0.60
Tauranga/Te Puke, NZ[1]	1979	0.18
Clarence (Kaikoura), NZ[1]	1979	0.03
Abbotsford, Otago, NZ[4]	1979	9-13
Hawke's Bay and East Coast, NZ[5]	06.-09.03.1988	1.52
Manawatu-Wanganui, NZ[6]	22.-24.07.1992	0.78
Nationwide in NZ[7]	yearly average	30.00
Nationwide in Korea[8]	yearly average	17.07
Nationwide in Japan[9]	yearly cost 1973-84	243-743
San Francisco Bay, USA[10]	1968-69	82.41
Nationwide USA[11]	yearly average	1471.67

Sources: 1. Stephens *et al.*, 1983; 2. Bell, 1976; 3. Hawley, 1980; Lambert *et al.*, 1984; 4. Blong and Eyles, 1989; 5. East Cape Catchment Board, 1988; Trotter, 1988; Eyles and Newsome, 1991; 6. Hicks *et al.*, 1993; 7. Hawley, 1984; 8. Yoon, 1991; 9. Oyagi, 1989; 10. Sidle *et al.*, 1985; 11. Schuster, 1978.

past activity, hazard assessments are sometimes based on theoretically determined causative factors rather than precedence. The outcome of this approach is the ranking of terrain susceptibility to landsliding (Crozier, 1995). For planning and management purposes, susceptibility assessments are greatly enhanced if they are augmented by information on magnitude and frequency of the anticipated landslides. The validation of landslide susceptibility mapping and its usefulness depends on the maintenance of appropriate records indicating the magnitude and frequency of on-going landslide activity and its relationship with terrain and triggering conditions.

Whereas risk to existing elements and proposed developments can be determined using the methodologies outlined, the remaining two areas of management concern identified require different methodologies but often similar basic information. In scientific terms, determining sustainability of the soil's productive capacity requires careful measurement and budgeting of soil loss and gain. In practice the ratio of soil loss to soil production (Trustrum *et al.*, 1990) is commonly so great that indices of depletion are sufficient to identify the rate of soil degradation. The information requirements for monitoring relate to the frequency, magnitude and areal extent of landslide erosion. Time sequence mapping, indicating age, depth, areal extent of landslides and sediment routing is the minimum required to achieve a measure of soil degradation.

Finally, determining the adverse effects of human activity can theoretically be approached by various forms of stability and sensitivity analysis. In most cases such analysis is too localized and too costly to be used as a general management tool. Thus the history of the effects of human activity is the main guide to management. It is, therefore, important that a record is established indicating the links between human activity and landslide occurrence. As with the other areas of management discussed, a number of basic information requirements can be identified which are common to all four areas of management.

THE ECONOMIC INCENTIVE

The economic consequences of landsliding can be partially assessed

Figure 3: Abotsford Landslide (1979), near Dunedin.
Source: Bill Brockie

by the amount of money individuals and organisations spend on the landslide problem. However, the real costs of landsliding are difficult to determine because only a few areas of expenditure on landslides are specifically indicated as landslides costs (Blong and Eyles, 1989). Besides direct landslide event damage (such as destruction of buildings), there are long-term costs consequential on landslide activity (such as on-going reduction in pasture production). In addition, there are indirect costs related to planning, preparedness, scientific investigations, engineering design and maintenance. Some examples of the cost of landsliding are provided in Table I - direct comparisons are difficult because of the different bases employed for assessing costs.

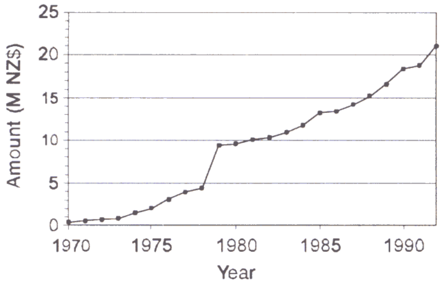

Figure 4: Cumulative amount of claims on the Earthquake Commission for landslip damage in the period 1971-1993 (1993 NZ$).
Source: New Zealand Earthquake Commission

The New Zealand Earthquake Commission (EQC) is one source of information on immediate event damage (Gordon, 1991). It deals with insurance claims on landslip damage and is therefore a starting point for assessing the minimum costs, resulting directly from a landslide event. For those holding property insurance, the EQC has been the compulsory insurer for the risks at war, earthquake and disaster since 1945. Landslip insurance was included in the act from 17 July 1970. Over the last 22 years the Earthquake Commission has paid landslip claims (damage to buildings) of about NZ$ 17 M with an average yearly cost of about NZ$ 0.77 M (Figure 3). Additionally for the land cover (damage to land), which was added to the insurance policies in 21 June 1984, the insurer has paid NZ$ 4.5 M overthe last eight years, together with the landslip claims, payments total over NZ$ 21 M for the last 22 years (Figure 4).

The EQC figures of payment per claim for landslip and land cover show a trend of increasing amounts per claim during the last twenty-two years (Figure 5). This may reflect the increasing value of assets or slowly increasing landslip damage caused by greater magnitude and/or frequency of events. However, these figures must be seen as representing minimum costs, because they give only the sum directly claimed from the Earthquake Commission insurance, and do not include real damage costs such as downstream effects, costs absorbed by the individual and by affected institutions; nor do they reflect long-term costs of pro-active measures, preparedness, and planning.

The cumulative economic loss to pasture production provides one example of the long-term effects of an erosional event. In the winter of 1977 an area of about 1400 km^2 of Wairarapa hill country was affected by landslides. The immediate loss of production was in total NZ$ 0.6 M. The estimation of the cumulative loss was NZ$ 5.6 M over the succeeding 14 years and NZ$ 9.35 M over the following 55 years, based on the assumption of oversewing the affected farmland and the necessity of fertiliser application (Hawley, 1980). Another example is the Cyclone 'Bola' occurring in 1988 in the Hawkes Bay and East Coast Region over a 12,000 km^2 area. This storm can be seen in economic terms as the worst natural disaster in New Zealand. In places, up to 50 per cent of the farmland slipped (Trotter, 1988). The total damage costs from landslips and flooding were in the order of NZ$ 100 M (East Cape Catchment Board, 1988). In an example from the Manawatu-Wanganui Region, Hicks *et al.* (1993) calculated the total damage caused by a rainstorm (22-24 July 1992) to 83 properties as NZ$ 4.5 M. The direct landslide damage component was estimated as NZ$ 0.79 M.

In an attempt to include all the factors affected by landslide occurrence and distribution through time and space, Hawley (1984) estimated an average yearly cost from urban landslides as NZ$ 3 M and rural landslides NZ$ 30 M for the whole of New Zealand.

Whereas some cost-estimates have been produced for individual events the real long-term costs need to take into account the history and recurrence intervals of damaging events. Hicks (1989) made an approximate analysis for the Waihora Valley, East Coast on the basis of an erosion-inducing rainfall occurring every 5.4 years. His analysis included not only the costs of direct storm damage but also the historical costs to individuals and organisations arising indirectly from recurring events.

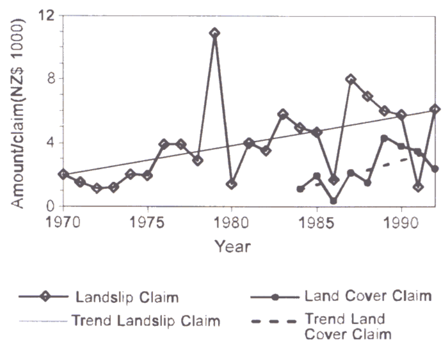

Figure 5: Amount per claim on the Earthquake Commission for landslip damage, expressed in 1993 NZ$.
Source: New Zealand Earthquake Commission

In assessing the economic influence of landsliding these direct costs must be augmented by the cost of taking proactive measures. One indication of this is the yearly expenditure by the Regional Councils throughout the country on soil conservation, erosion control, and land sustainability measures (Table II). The expenditure of all Regional Councils from 1990 to 1994 totals NZ$ 47 M of which only a part will relate specifically to landslide activity. This appears to be a substantial reduction compared to previous

TABLE II
EXPENDITURE ON SOIL CONSERVATION, EROSION CONTROL AND LAND SUSTAINABILITY OF TERRITORIAL AUTHORITIES

Regional and District[1] Councils	*Susceptibility as % of region[2]*	*Previous Programme][3] Actual Programme*	*Expenditure (in thousand NZ$)* 90/91	91/92	92/93	93/94	94/95[4]	95/96[4]	96/97[4]	97/98[4]
Auckland	2 / 32	Env. Management (Soil Resources)	*5	*5	180	158	169	169	169	*6
Bay of Plenty	<1 / 21	Soil Conservation Works	241	312	218	236	*6	*6	*6	*6
Canterbury	1 / 14	Soil Conservation Works	361	100	114	120	118	*6	*6	*6
		Land Resource Monitoring	43	36	134	128	194	240	*6	*6
		Land Resource Investigations	32	24	*6	*6	131	130	*6	*6
Gisborne(1)	41 / 68	Soil Conservation	1,455	1,917	885	541	813	730	740	*6
		Soil Conservation Forestry	2,033	2,706	3,192	*6	*6	*6	*6	
Hawke's Bay	17 / 45	[Soil Conservation] Sustainable Land Management	[1,029]	[228]	331	393	837	703	751	759
		Hazard Management (Landslip)	/	/	/	0	39	0	0	0
Manawatu-Wanganui	20 / 39	Soil Conservation	543	3,100	1,578	702	651	788	*6	*6
Marlborough(1)		Marlborough Forestry Corporation	/	/	*5	*5	*5	*5	*5	*5
Nelson-Marlborough	<1 / 27	Land Management	1,537	103	*7	*7	*7	*7	*7	*7
Nelson(1)		Forestry	/	/	*5	*6	*6	*6	*6	*6
Northland	10 / 32	Soil Conservation Services	81	48	*6	385	*6	*6	*6	*6
		Sustainable Land Management	93	198	*6	479	164	48	*6	*6
Otago	1 / 16	[Land Management] Land Sustainability	[857]	1,526	1,053	1,146	388	535	550	550
Southland	<1 / 7	[Soil Conservation] Land Sustainability	[128]	[1,020]	[115]	[114]	116	123	*6	*6
Taranaki	5 / 24	[Soil Conservation] Land Management and River Control	[2,778]	746	1,021	/	/	/	/	/
		Land Management	/	/	/	386	389	396	*6	*6
Tasman(1)		Riverworks (Soil Conservation)	/	/	*5	*5	107	105	*6	*6
Waikato	4 / 21	[Soil Conservation] Land Management	[2,473]	[2,201]	[2,036]	[1,729]	1,330	*5	*6	*6
Wellington	28 / 36	[Land Resource] Soil Conservation	[915]	166	489	352	1,370	1,459	1,419	1,436
West Coast	0 / 4	River Control and Drainage Scheme	*5	*5	*5	*5	*5	*5	*6	*6
Total expenditure per Council's financial year (July-June)			12,556	13,748	10,815	10,027	6,775	5,374	3,539	2,553

Sources: Regional Councils and District Councils Annual Reports and Plans

Notes:
(1) City and District Councils with partly regional authority responsibilities;
(2) Susceptibility of landsliding (per cent deep mass movement / per cent shallow mass movement) as a percentage of the agricultural land covered by the Regional Council. Susceptibility is defined by various erosion processes indicated by erosion scars, either active or healed. Derived from MWD's Land Resource Inventory (Source: Clough and Hicks, 1992);
(3) Square brackets refer to pre-existing programmes and their expenditure;
(4) Estimated expenditure by Regional Councils Annual Plans;
(5) Not specified in the Annual Report/Plan;
(6) Data not available;

expenditure committed to these purposes, even assuming that the resources for Table II are incomplete. For example, in the period 1979 to 1989 the Waikato Catchment Board spent NZ$ 25 M specifically on soil conservation works (Waikato Catchment Board, 1989).

Many examples of the high economic impact of landslides can be found for overseas countries such as

TABLE III
TYPES OF INFORMATION CURRENTLY AVAILABLE FOR LANDSLIDE PROBLEMS[1]

Articles in newspapers and scientific journals

Official and/or internal reports from governmental agencies (DSIR's Soil Bureau, MWD's Water and Soil Division), departments, ministries or institutes

- Information extracted from the New Zealand Land Resource Inventory compiled by Department of Survey and Land Information
- Reports of Institute of Geological and Nuclear Sciences including a national landslide inventory of earthquake triggered landslides
- Reports of the Earthquake Commission
- Files of the Regional and District Councils, including reports of engineering consultants*
- Information from the regional branches of the Department of Conservation*

Reports and theses from universities

Landslide information held by the national transport authorities (Transit New Zealand with its branches and New Zealand Rail Ltd.)*

Note:
1 All sources have coverage at national, regional and site scales except for items denoted * which have no information at the national scale

Korea and Japan. Yoon (1991) showed for Korea that the direct annual average landslide-costs was about NZ$ 88 M over eight years combined with restoration costs for rural landslides of approximately NZ$ 60 M over the last decade. Between 1973 and 1984 the annual cost of landslide damage in Japan varied between NZ$ 242 M and NZ$ 743 M (Oyagi, 1989).

Clearly there are significant costs arising from landslide activity but current recording procedures make it difficult to separate landslide costs from other land management costs and to derive an accurate figure.

THE LEGISLATIVE DEMAND

Prudent management of land and soil resources has a well established place in New Zealand legislation. It was the predominant theme of the Soil Conservation and Rivers Control Act 1941 (SCRCA). Other acts with relevance to management of the landslide issue are the Land Drainage Act 1908 (LDA), the Local Government Act 1974 (LGA) and the Civil Defence Act 1983 (CDA) which are discussed by Clough and Hicks (1992) and Crozier (1993).

In many instances the Resource Managment Act 1991 (RMA) and parts of the Building Act 1991 (BA) make specific reference to the influence of mass movement erosion and the related phenomena of subsidence, sedimentation, flooding, and 'earth pressure' on property and the environment. These acts set broad goals for the nature and direction of resource use and provide a planning and legislative framework within which management decisions can take place. The RMA explicitly promotes sustainable management of natural and physical resources. The definition of `sustainablemanagement' given in RMA (Part II, Sec. 1) is as follows: ...

managing the use, development, and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural wellbeing and for their health and safety while:
(a) Sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations; and
(b) Safeguarding the life-supporting capacity of air, water, soil, and ecosystems; and
(c) Avoiding, remedying, or mitigating any adverse effects of activities on the environment.

The '*... protection of natural and physical resources ...*' as stated by Clough and Hicks (1992) points unavoidably to the need to consider and control the role of landsliding in degradation of the soil resource. Furthermore, point (a) of the purposes of the RMA states clearly the requirement of '*... sustaining the potential of natural and physical resources ...*'. Consequently, determining the rate of soil erosion and assessing influencing factors must form a major focus of management.

Part III, Sec. 9 of the RMA sets out restrictions on use in relation to land, building, excavation, destruction of fauna or flora and to any other use of land which contravenes a rule in a district plan or proposed plan, unless the activity is permitted. In addition, the functions (Part IV, Sec. 30, 31) and duties (Part IV, Sec. 35) of the governmental departments concerning natural hazard, including landslides are defined in the RMA. The requirements of gathering information, monitoring and keeping records of natural hazard, are also specified. Clearly there are sufficient mechanisms under current legislation to execute effectively the spirit of the Act.

Resource management legislation in New Zealand places an onus on territorial authorities to consider the significance of landslides and where they constitute an issue to define policies and establish rules with respect to the landslide problem. The aspects of that problem requiring assessment and management under current legislation are the hazard, the sustainability of the soil resource, and the adverse effects of human activity.

Examination of existing regional

council policy statements indicates that the legislative imperative with respect to landslides has to some extent been taken up; at least in terms of broad intentions. The translation of these intentions into action will require the identification of specific management tasks and the information necessary to carry them out.

CURRENT INFORMATION AVAILABLE

The status of the current information base should be assessed with respect to identified requirements. The foregoing discussion of current economic and social impact of land instability together with specific legislative requirements point to the following objectives that must be met to allow appropriate management:

- assessing the degree of degradation to the soil resource,
- determining the trends and rates of change to the soil resource,
- identifying controlling factors for landslides and vulnerable locations and specifically identification of the role of human activity,
- identifying potential slope stability problems,
- analysing the triggering factors and thresholds for landslides for frequency/magnitude purposes,
- damage assessment for events and for future comparisons and frequency/magnitude analysis,
- employment of damage assessments as precedents in hazard, assessment, vulnerability, risk, and
- determing real costs with respect to the landslide phenomenon.

Whereas a few local studies have attempted to provide information to meet identified management objectives, there has been little effort spent on the provision of a systematic information base.

There are no national standards in New Zealand for measuring, recording, storing, or accessing landslide data. Current information on landslides in New Zealand is in different forms, widely dispersed and difficult to access. Every authority concerned with landslides has developed or is considering developing its own system for handling the landslide problem. The type of information currently available in New Zealand on landslides is summarized in Table III.

Figure 6: Spatial distribution of rainfall-triggered landslide events in New Zealand between 1870 and 1995.

Note: Each point reflects one or more events. Magnitude of the event and extent of damage is independent of point size.

Source: See Table III

Lack of standardization and varying scales of information within the existing data bases make it difficult to perform empirically-based statistical hazard analysis and to identify controls on magnitude and frequency as well as to establish regional comparisons of landslide activity. The inconsistent record also makes it difficult to interpret the significanceof gaps in the record.

Analysis of the existing information on the frequency and distribution of rainstorm-triggered soil landslide events provides some indication of the status of available information. A summary of major landslide events throughout New Zealand on a national scale was made by Eyles and Eyles (1981), and updated by Crozier (1990), and Hicks (1995). This shows that since 1970 nearly every year a major rainfall-induced mass-movement event occurs within the country. A literature study of all the different available sources listed in Table III expands the picture of the nationwide landslide occurrence for the period 1870 - 1995 (Figure 6). The conclusion that landslide activity is a factor in most New Zealand regions can be confirmed by looking at the widespread landslide distribution, in some areas recognized since 1870 and noting the almost yearly occurrence throughout the country (Glade, in press).

Figure 6 shows a clear disparity in areas affected by landslides in the North and South Island. This difference is unlikely to result wholely from the varying occurrence of triggering rainstorms, or from differences in landslide susceptibility. It is possible that differences in population density and subsequent level of reporting influence the record. The differences in density of occurrence between the North and South Island accords with population density: the North Island has 74 per cent of New Zealand's inhabitants while only 26 per cent live on the South Island which represents 56 per cent of the total land area.

The conclusion that Figure 6 represents a reporting artifact rather then a real occurrence pattern is supported from other sources. For example, the NZ Land Inventory (Eyles, 1983), which is based on air photo analysis of former landslide scars, shows little difference in earth and soil slip occurrence between the two main Islands (33 per cent of all mapping units in the North Island and 24 per cent in the South Island).

Although Figure 7 is likely to represent an incomplete record, it gives some indication of the widespread occurrence of shallow mass movements throughout the country. Because of inconsistent and unreliable data on record, there is a real need to develop a standard national approach towards a landslide information base.

TABLE IV
INFORMATION REQUIREMENTS FOR FULL GEOMORPHIC LANDSLIDE RECONNAISSANCE

1. General Information
1.1 Basic notes
1.1.1 Reporting organisation
1.1.2 Name of reporter
1.1.3 Location
1.1.4 Principal property owner
1.1.5 Latitude/Longitude
1.1.6 Grid-reference
1.1.7 Date of examination
1.1.8 Date of occurrence
1.1.9 Who notified event
1.1.10 Scale of investigation

1.2 Documentation
1.2.1 Sketch drawn
1.2.2 Mapping
1.2.3 Photograph taken
1.2.4 Other reports existing

2. Terrain
2.1 Regional Description
2.1.1 Bedrock Geology
2.1.2 Surficial Geology
2.1.3 Dominant landcover
2.1.4 Dominant landform

2.2 Site Description
2.2.1 Local relief [m]
2.2.2 Mean slope angle [0]
2.2.3 Rock type
2.2.4 Regolith type
2.2.5 Position on slope (upper, mid, lower)
2.2.6 Slope form (convex, concave, planar)
2.2.7 Aspect

2.3 Percent erosion area in:
2.3.1 Natural condition
2.3.2 Farmland
2.3.3 Infrastructure
2.3.4 Community/Residential
2.3.5 Industrial/Commercial

2.4 Percent deposition area in:
2.4.1 Natural condition
2.4.2 Farmland
2.4.3 Infrastructure
2.4.4 Community/Residential
2.4.5 Industrial/Commercial

3. Causative Factor
3.1 Climate
3.1.1 Date of event
3.1.2 Type of event
3.1.3 Approx. extent [km2]
3.1.4 Total rainfall [mm]
3.1.5 Rainfall duration [h]
3.1.6 Max. daily rainfall [mm]
3.1.7 Max. hourly rainfall [mm/h]
3.1.8 Antecedent climatic conditions
3.1.9 Return period [y]

3.2 Earthquake
3.2.1 Date of event
3.2.2 Epicentre
3.2.3 Magnitude (Richter - M)
3.2.4 Intensity [MM]

3.3 Human Induced
3.3.1 Date of event
3.3.2 Type of cause

3.4 Associated causes
3.4.1 Fluvial undercutting
3.4.2 Marine undercutting
3.4.3 Glacial undercutting
3.4.4 Human-induced
3.4.5 Geological conditions
3.4.6 Drainage condition
3.4.7 Other

4. Landslide parameters
4.1 Landslide features
4.1.1 Nature and length of any warning
4.1.2 Mechanism (fall, slide, flow, topple, spread)
4.1.3 Material (rock, debris, soil)
4.1.4 Mean angle of rupture surface [0]
4.1.5 Type and shape of rupture surface
4.1.6 Degree of disruption
4.1.7 Degree of evacuation of displaced material from scar
4.1.8 Presence of adjacent cracks
4.1.9 Age of landslide
4.1.10 Activity of landslide
4.1.11 Duration of movement [h, d, m, y]
4.1.12 Maximum velocity [dist./time]
4.1.13 Area surveyed [ha]
4.1.14 Area affected [ha]
4.1.15 Number of slides
4.1.16 Landslide density [no/ha]
4.1.17 Average landslide length [m]
4.1.18 Average landslide width [m]
4.1.19 Average landslide depth [m]
4.1.20 Average landslide volume [m3]

4.2 Landslide dimensions
4.2.1 Width of displaced mass [m]
4.2.2 Length of displaced mass [m]
4.2.3 Depth of displaced mass [m]
4.2.4 Width of rupture surface [m]
4.2.5 Length of rupture surface [m]
4.2.6 Depth of rupture surface [m]
4.2.7 Volume of displaced mass [m3]

5. Economic effect
5.1 Extent of remedial work required
5.2 Claim or request concerning slip
5.3 Parties responsible for works
5.4 Carrier of damage costs

6. Potential future risk evaluation
6.1 Degree of risk
6.2 Nature of threat
6.3 Infrastructure affected
6.4 Community affected
6.5 Industry affected
6.6 Property owners affected (list)

7. Nature of existing reports and of this investigation including references
7.1 Desk study (e.g. air photos)
7.2 Field reconnaissance
7.3 Geological/Geomorphological survey
7.4 Subsurface geology survey
7.5 Geotechnical tests
7.6 Geological section available
7.7 Topographic survey

Notes:
1. Recordings should note: NC = not considered; NI = no information at reporting time;
2. It is recommended to define landslide types by Varnes (1978) system;
3. It is recommended to explain landslide features and measurements by WP/WLI (1990, 1991, 1993) standards;
4. A comprehensive explanatory manual is in preparation.

SURVEY OF INSTITUTIONAL LANDSLIDE INFORMATION SYSTEMS

In order to determine what landslide information is being recorded throughout the country a questionnaire survey was carried out. Approaches were made to the Regional and District Councils, the DOC centres for the whole country, the EQC, as well as

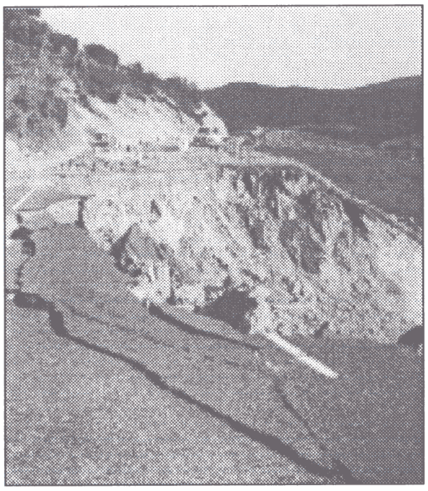

Figure 7: State Highway 1, North of Dunedin.

transport authorities (Transit New Zealand with its regional branches and New Zealand Rail Ltd.). The results give an overview of the current status of information available concerning landslide problems of the appropriate organisations (Glade and Crozier, in prep.).

Of the 130 organisations surveyed 99 (76 per cent) replied with 55 per cent of the respondents stating they kept records which include information on landslides. Looking solely at responses from territorial authorities, 7 (64 per cent) out of 11 Regional Councils and 24 (41 per cent) out of 59 District Authorities state they keep records concerning landslide problems. Most of the Regional Councils appear to be responding to the two duties under the RMA '... *gathering information and keeping records of natural hazards* ...' (Part IV, Sec. 35), but 37 of the District Councils do not. The survey revealed that there were few set procedures for recording and storing landslide information; only 17 per cent of responding organisations used computer files and many relevant records are subsumed under other headings (e.g. insurance reports, road damage files) (Figure 7). As a consequence, getting an overview of existing landslide information and a statistically sound data base is time consuming and expensive.

Responses on the existence of either regional or district plans indicating areas of slope instability or landsliding are revealing. Twenty-three District Councils operate district plans which make reference to slope stability issues and 30 District Councils either have yet to develop plans or have plans that do not refer to the slope stability issue. Only one Regional Council has developed a regional plan that includes slope stability considerations.

Regional plans are optional, while District Councils must prepare a district plan by October 1996 in consultation with the public to guide resource use resolutions under the Act. Thus, 30 of the District Councils without district plans have yet to enact decisions on the importance of slope stability to land use practices or consider the issue insignificant.

In surveying the intentions of territorial authorities 4 out of 11 Regional Councils intend to address slope stability issues in future regional plans. Also 22 of the District Councils are in the process of developing district plans which will include slope stability references against 16 who do not intend to establish district plans addressing slope stability issues.

Existing research (Eyles and Eyles, 1981; Eyles, 1983; Crozier 1990; Hicks, 1995) indicates that few areas of New Zealand are free from the effects of landslide activity (Figure 6). Territorial authorities may consider that landslidesdo not constitute an issue in their jurisdiction. However, that is a decision that should be based on good quality information and subject to review. Even if the current situation is not considered serious, the long-term implications of landsliding and policy requirements appear to demand that an information gathering role at least be considered by all territorial authorities.

INTERNATIONAL LANDSLIDE DATA BASES

Discussion of economic and legislative demands and the current state of available information demonstrates a need to establish a National Landslide Data Base (NLDB) or at least national standards for measurement and recording. There are a number of international precedents for collecting and storing landslide information for management or scientific purposes. In Europe, USA and Mexico, different groups and organisations have developed landslide data bases. All these data bases are held in paper files in the form of a standard protocol and/or in digital files managed mainly by a GIS. The records include information of geotechnical, lithological and/or geomorphological data from individual landslide sites. Examples of these resources are the Data Bases on a national scale of France (Flageollet, 1994) and of the United Kingdom (Brunsden and Ibsen, 1994). Landslide data bases on a regional scale have been developed in Germany (Dikau *et al.*, 1994), Hong Kong (Wong and Hansen, 1995), Italy (Guzetti et al., 1994), Nepal (Jäger, *pers. comm.*, 1995), Sri Lanka (Jäger, *pers. comm.*, 1995), Spain (Chacon and Soria, 1992), Switzerland (Mani and Klaey, 1992) and in the United States of America (Brabb, 1989). Suggestions for a data base with European-wide standards were made by Brunsden and Ibsen (1994). International activities for establishing a Worldwide Landslide Data Base are in progress under the auspices of 'The International Geotechnical Societies `UNESCO Working Party on World Landslide Inventory' in cooperation with the International Association of Engineering Geology (WP/WLI 1990; 1991; 1993).

All these Data Base protocols have been reviewed and provide a guide for the development of a New Zealand standard format for recording information concerning landslide problems in this country. Special attention has been given to characteristics typically found in New Zealand.

RECOMMENDATIONS FOR

ESTABLISHING A LANDSLIDE DATA BASE

The suggested National Landslide Data Base for New Zealand is developed with reference to existing international information systems. Selby (1979) was the first researcher in New Zealand to suggest a standard format for a landslide protocol, based on a format developed by Rapp (1974). But this suggestion was not picked up by any organisation. The Institute of Geological and Nuclear Sciences developed a database format for a landslide map of New Zealand aimed at identifying all large (> 100,000m3) landslides. The same system was recommended to Environment Waikato as a way of establishing a regional inventory (Graham and Crozier, 1993). Only the Auckland Regional Council has expressed plans to compile a regional map (1:250,000) of slope stability areas based initially on the Land Resource Inventory Erosion Classification, supplemented by information held by the District Councils and some field work. This information will be held on GIS and will be part of a Regional Natural Hazards Database (Daly, *pers. comm.*).

An important aspect of any landslide report designed for management purposes is that the data gathering can be carried out by non-specialized persons (Hicks, 1992). Personnel from different agencies should be able to record the appropriate information by following easily understood guidelines in a standard landslide protocol. Furthermore it should require only the minimum of landslide and event information appropriate to the purpose of the survey. However, evaluation of the reports, statistical analysis and especially the interpretation leading to risk assessment should be done by a specialized staff member.

Together with satisfying particular regional needs, information gathering and reporting should conform to a national standard. Attention must be given to summarizing, storing, and comparing the results in a national landslide inventory accessible by all concerned parties.

When considering the landslide issue, organisations need to identify the specific management tasks, the appropriate information requirements and the methods by which they will be met. At the regional/district scale four different levels of investigation may commonly be required: preliminary inventory, event damage assessment, hazard zonation, and full geomorphic reconnaissance for all or parts of the area. The preliminary inventory is the first stage in determining whether landslides constitute a sufficient issue to warrant the development of further policy or action. The results may indicate a need for a full geomorphic reconnaissance in a particular area or hazard zonation, if a risk to people and/or property is indicated. As major events can yield important underpinning information for future decision making, mostauthorities should be in a position to carry out an event damage assessment. Indeed such a survey may be necessary for disaster relief or insurance purposes.

A full geomorphic reconnaissance (Table IV) offers the most comprehensive level of investigation that can be carried out without specific geotechnical or engineering expertise but it can still provide appropriate information for regional hazard zonation, and event damage assessment. This level of investigation would be warranted only if there was the possibility of actual or potential risk to communities, resources, or proposed developments. Investigations of this nature may also be applied selectively to known problem areas as a way of determining whether more detailed geotechnical investigations, remedial work, or continuous monitoring were required.

Because we have assessed the potential for some level of landslide risk in most regions of New Zealand, we consider that as a matter of course, all regions should carry out a *preliminary landslide inventory* and maintain a *minimum monitoring record*. The preliminary inventory should identify all fresh landslides (< 5 years old) over about 2000 m3 in volume, all active or inactive landslide that present potential risk, and all large areas (> 0.5 km2) that show landslide morphology. For all these features, the minimum information for a preliminary inventory should include: location, date of occurrence (or estimated age), landslide type, areal extent, volume, associated damage, assessed cause, and potential future risk evaluation. The minimum monitoring record should identify on an on-going basis any new appearance or reactivation of the above features and record the same information as required for a preliminary inventory.

CONCLUSION

The study demonstrates the widespread influence of landslide occurrence throughout New Zealand. Landslides severely deplete the hill country soil resource, affect development costs and influence development decisions, as well as posing a continual threat to life and property. Some estimates of economic impact have been provided but losses from immediate damage are clearly only one component of the costs. The degradation of the soil resource itself and the loss of future development options are other important factors, which are difficult to calculate. The landslide hazard has generated sufficient economic, ethical and legislative concern for it to represent an important resource management issue.

The existing data base in New Zealand was evaluated with respect to the identified management requirements. Clearly there is a discrepancy between the real and recorded landslide occurrence, resulting mainly from different recording procedures and perception of importance. One of the first priorities must be to reduce this discrepancy in order to gain a comprehensive understanding of New Zealand's landslide problem. The RMA provides an important instrument. The Act describes the functions, powers, and duties of central and local government and thus provides the management direction and a legal basis for addressing the landslide problem.

The results of a national questionnaire survey, administered in January 1995 indicated variable progress associated with translating the Act with respect to slope stability and landslide issues. Although most territorial authorities are making some progress in this direction few standard procedures are in place for obtaining landslide data or monitoring hazard. Those that exist may be satisfactory in the local context but they are not easily transferable to other regions or, importantly, to other scales.

It is proposed, that a standardized reporting scheme of landslide activity throughout the country could assist territorial authorities in determining and implementing policy. The positive aspects of such a nationwide standard reporting scheme are the low-costs for its development and low running expenses. General staff can be used in most cases to collect and file data with specialists required only for special purpose analysis. Central storage and access would provide information for planning decisions at the local, regional or national levels. In recommending landslide information requirements attention has been directed to establishing the minimum information requirement for meeting identified management needs. Furthermore, the standardized reports could feed into a National Landslide Data Base available for political and management decisions on any scale.

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REFERENCES

BELL, D. H. 1976: High intensity rainstorms and geological hazards: Cyclone Alison, March 1975, Kaikoura, New Zealand. *Bulletin International Association for Engineering Geology*, 14 189-200.

BLONG, R. J. and EYLES, G. O. 1989: Landslides: Extent and economic significance in Australia, New Zealand and Papua New Guinea, in Brabb, E. E. and Harrod, B. L. (eds)*Landslides: Extent and Economic Significance*. A.A. Balkema, Rotterdam, 343-355.

BRABB, E. E. 1989: Landslides: extent and economic significance in USA, in Brabb, E. E. and Harrod, B. L. (eds) *Landslides: Extent and Economic Significance*. A.A. Balkema, Rotterdam, 25-50.

BRUNSDEN, D. and IBSEN, M.-L. 1994: The nature of the European archive of historical landslide data, with specific reference to the United Kingdom, in Casale, R., Fantechi, R. and Flageollet, J. C. (eds) *Temporal occurrence and forecasting of landslides in the European Community. European Community*, 21-70.

CHACON, J. and SORIA, F. 1992: Inventario y caracterizacion de movimientos de ladera en la vertiente septentrional de sierra nevada. 3. *Simposio Nacional sobre Taludes y Laderas Inestables*. La Coruna, 149-160.

CLOUGH, P. and HICKS, D. L. 1992: *Soil Conservation and the Resource Management Act*. Unpublished Contract Report for MAF Policy NZ Institute of Economic Research.

CROZIER, M. J. 1990: Landslide hazard in New Zealand, in Crozier, M. J. (eds)*Natural Hazard 90: Natural Hazard Assessment in New Zealand*. RSES, Victoria University Wellington, 31-39.

CROZIER, M. J. 1993: Management issues arising from landslide and related activity. *New Zealand Geographer*, 49 (1), 35-37.

CROZIER, M. J. 1995: Theme report, in Bell, D. H. (eds) *Landslides*. A.A. Balkema, Rotterdam, 1843-1848.

DALY, M. 1995: Natural Hazard Scientist, Auckland Regional Council, Personal communication, 18 May 1995.

DIKAU, R., CAVALLIN, A. and JÄGER, S. 1994: Databases and GIS for landslide research in Europe, in Casale, R., Fantechi, R. and Flageollet, J. C. (eds) *Temporal occurrence and forecasting of landslides in the European Community*. European Community, 95-116.

EAST CAPE CATCHMENT BOARD 1988: *Waihora Catchment: Cyclone Bola storm damage survey*. unpublished East Cape Catchment Board, Gisborne.

EYLES, G. O. 1983: The distribution and severity of present soil erosion in New Zealand. *New Zealand Geographer*, 39 (1), 12-28.

EYLES, G. O. and NEWSOME, P. F. 1991: A soil conservation approach to sustainable land use. *Proceedings of the International Conference on Sustainable Land Management*. Napier, New Zealand, 216-220.

EYLES, R. J. and EYLES, G. O. 1981: Recognition of storm damage events. *Proceedings 11th New Zealand Geography Conference*. New Zealand Geographical Society, Wellington, 118-123.

FLAGEOLLET, J. C. 1994: The time dimension in the mapping of earth movements, in Casale, R., Fantechi, R. and Flageollet, J. C. (eds)*Temporal occurrence and forecasting of landslides in the European Community*. European Community, 7-20.

GILLON, M. D., FOSTER, P. F., PROFFITT, G. Y. and SMITS, A. P. 1991: Monitoring of the Cromwell Gorge iandslides, in Bell, D. H. (eds) *Landslides*. A.A. Balkema, Rotterdam, 1135-1140.

GLADE, T. in press: Temporal and spatial occurrence of rainstorm-triggered landslides in New Zealand, in Mäusbacher, R. and Schulte, A. (eds)*Barsch - Festschrift*. Heidelberger Geographische Arbeiten.

GLADE, T. and CROZIER, M.J. in preparation: The current status of landslide information systems in New Zealand, submitted to*Proceedings of the New Zealand Geography Conference*. New Zealand Geographical Society, Christchurch.

GORDON, B. M. 1991: Earthquake claims in New Zealand - A loss adjuster's perspective. *Natural and Technological Hazards: Implications for the Insurance Industry*. Australia, 119-129.

GRAHAM, C.J. and CROZIER, M.J. 1993: *Overview of land instability in the Waikato region*. Report to Environment Waikato, Hamilton.

GUZETTI, F., CARDINALI, M. and REICHENBACH P. 1994:*The AVI project: A bibliographical and inventory of landslides and floods in Italy*. Environmental Management (in print).

HARMSWORTH, G. R. and PAGE, M. J. 1991: *A review of selected storm damage assessments in New Zealand*. Scientific Report 9, DSIR Land Resources.

HAWLEY, J. G. 1980: Introduction.*Workshop on the Influence of Soil Slip Erosion on Hill Country Pastoral Productivity*. Water and Soil Division, Ministry of Works and Development, Aokautere Science Centre, 4-6.

HAWLEY, J. G. 1984: Slope instability in New Zealand, in Speden, I. G. and Crozier, M. J. (eds)*Natural Hazards in New Zealand*.

UNESCO, Wellington, 88-133.

HICKS, D. L. 1989: *Some Ways to Estimate the Frequency of Erosion-Inducing Rainfall*. Technical Record LH14, Land and SoilSciences, DSIR.

HICKS, D. L. 1992: A low-technology method for assessing the effectiveness of soil conservation in steeplands, in *Environmentally Sound: Technology for Sustainable Development*. United Nations Centre for Science and Technology for Development, 93-98.

HICKS, D. L. 1995: A way to estimate the frequency of rainfall-induced mass movements. *Journal of Hydrology (New Zealand)*, 33 (1), 59-67.

HICKS, D. L., FLETCHER, J. R., EYLES, G. O., McPHAIL, C. R. and WATSON, M. 1993: *Erosion of Hill Country in the Manawatu-Wanganui Region 1992: Impacts and Options for Sustainable Land Use*. Unpublished Contract Report LC 9394/51, Landcare Research New Zealand Ltd.

JÄGER, S. 1995: Dipl. Geog., Bundesanstalt für Raumplanung in Germany, Personal communication, 20 July 1995.

KING, J. M. and KRAUSSE, M. K. 1995: The impact of land use change in Wairoa. Report to Wairoa District Council, Landcare Research New Zealand Ltd.

LAMBERT, M. G., TRUSTRUM, N. A. and COSTALL, D. A. 1984: Effect of soil slip erosion on seasonally dry Wairarapa hill pastures. *New Zealand Journal of Agricultural Research*, 27, 57-64.

MANI, P. and KLAEY, M. 1992: Naturgefahren an der Rigi - Nordlehne. Schweiz. *Zeitschrift für Forstwesen*, 142, 131-147.

OYAGI, N. 1989: Geological and economic extent of landslides in Japan and Korea, in Brabb, E. E. and Harrod, B. L. (eds) *Landslides: Extent and Economic Significance*. A.A. Balkema, Rotterdam, 289-302.

PAGE, M. J., TRUSTRUM, N. A. and DeROSE, R. C. 1994: A high resolution record of storm induced erosion from lake sediments, New Zealand. *Journal of Paleolimnology*, 11, 333-348.

RAPP, A. 1974: Slope erosion due to extreme rainfall, with examples from the Tropical and Arctic Mountains, in Poser, H. (eds) *Geomorphologische Prozesse und Prozesskombinationen in der Gegenwart unter verschiedenen Klimabedingungen*. Abhandlungen der Akademie der Wissenschaften in Göttingen, 118-136.

RMA 1991: *Resource Management Act*. Government Printer, Wellington.

SCHUSTER, R. L. 1978: Introduction, in Schuster, R. L. and Krizek, R. J. (eds) *Landslides Analysis and Control*. National Academy of Sciences, Washington DC, USA, 1-10.

SCHUSTER, R. L. and FLEMING, R. W. 1986: Economic losses and fatalities due to landslides. *Association of Engineering Geologists, Bulletin*, 23 (1), 11-28.

SELBY, M. J. 1979: Slope Stability Studies in New Zealand, in Murray, D. L. and Ackroyd, P. (eds) *Physical Hydrology: New Zealand Experience*. New Zealand Hydrological Society, 120-134.

SIDLE, R. C., PEARCE, A. J. and O'LOUGHLIN, L. 1985: *Hillslope Stability and Land Use*. Water Resources Monograph Series 11, American Geophysical Union.

STEPHENS, P. R., TRUSTRUM, N. A. and HICKS, D. L. 1983: Experimental aerial photographic survey of erosion and catchment condition, Gladstone district, Wairarapa. *Remote sensing for soil conservation 29 June-1 July 1982*. Soil Conservation Centre, Aokautere, Water and Soil Miscellaneous Publication No. 52, 129-154.

TAKAHASHI, T. 1981: Debris flows. *Annual Review of Fluid Mechanics*, 13 57-77.

TROTTER, C. 1988: Cyclone Bola: the inevitable disaster. *New Zealand Engineering*, July 1, 13-16.

TRUSTRUM, N. A., THOMAS, V. J. and LAMBERT, M. G. 1984: Soil slip erosion as a constraint to hill country pasture production. *Proceedings of the New Zealand Grasslands Association Conference*, 45, 66-76.

TRUSTRUM, N. A., BLASCHKE, P. M., DeROSE, R. C. and WEST, A. W. 1990: Regolith changes and pastoral productivity declines following deforestation in steeplands of North Island, New Zealand. *Transactions 14th International Soil Science Congress*. Section I Kyoto, Japan, 125-130.

VARNES, D. J. 1978: Slope movement and types and processes, in Schuster, R. L. and Krizek, R. J. (eds) *Landslides: Analysis and control*. Transportation Research Board Special Report, National Academy of Sciences, Washington, DC, 11-33.

WAIKATO CATCHMENT BOARD 1989: *Final Report, 1979-1989, The Last Decade*. Waikato Valley Authority/Waikato Catchment Board, Hamilton.

WONG, T. T. and HANSEN, A. 1995: The use of GIS for inventory and assessment of natural landslides in Hong Kong. *Proceedings of GeoInformatics '95 Hong Kong* 2(2), 930-937.

WP/WLI (International Geotechnical Societies' UNESCO Working Party on World Landslide Inventory) 1990: A suggested method for reporting a landslide. *Bulletin of the International Association for Engineering Geology*, 41 5-12.

WP/WLI (International Societies' UNESCO Working Party on World Landslide Inventory) 1991: A suggested method for a landslide summary. *Bulletin of the International Association for Engineering Geology*, 43 101-110.

WP/WLI (International Geotechnical Societies' UNESCO Working Party on World Landslide Inventory) 1993: A suggested method for describing the activity of a landslide. *Bulletin of the International Association of Engineering Geology*, 47 53-57.

YOON, G. G. 1991: Extent and economic significance of landslides in Korea, in Bell, D. H. (eds) *Landslides*. A.A. Balkema, Rotterdam, 1071-1076.