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PROCEEDINGS OF TECHNICAL GROUPS

VOLUME 9
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NEW ZEALAND GEOMECHANICS SOCIETY

AND

NEW ZEALAND PLANNING INSTITUTE

Proceedings of the Symposium

GEOMECHANICS IN URBAN PLANNING

I.P.E.N.Z. Proceedings of Technical Groups cover the technical material presented to the various technical groups of the Institution, and published by them.

The names of the groups, and the code letters by which their issues of these proceedings are identified, are shown below.

The Building Services Group (BSG)

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The New Zealand Geomechanics Society (G)

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The Technical Group on Water (W)

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GEOMECHANICS IN URBAN PLANNING

Proceedings of a Symposium
held in
Palmerston North
New Zealand

April 29-May 1st
1981

organised jointly by

New Zealand Geomechanics Society
New Zealand Planning Institute

GEOMECHANICS IN URBAN PLANNING

EDITOR : J G HAWLEY

ABSTRACT

These are the proceedings of a symposium on "Geomechanics in Urban Planning" held in Palmerston North in 1981.

The nature and distribution of nine physical hazards to urban development are described. Hazards considered are Volcanic, Earth Deformation and Shaking (earthquakes), Mining, Settlement, Landslides, Soil Dispersion, Soil Shrinkage and Swelling, Flooding and Coastal.

Ways in which the significance of each of these hazards may be investigated and the results integrated into the planning process are described.

Questions of responsibility and liability of local bodies and their professional advisers are examined.

The Symposium was organised jointly by the New Zealand Geomechanics Society and the New Zealand Planning Institute.

KEYWORDS: Urban planning, hazards.

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CONTENTS

continued/...

Page

GEOMECHANICS IN URBAN PLANNING - PALMERSTON NORTH APRIL/MAY 1981
NEW ZEALAND PLANNING INSTITUTE : NEW ZEALAND GEOMECHANICS SOCIETY

OPENING ADDRESS

B G C ELWOOD, MAYOR OF PALMERSTON NORTH

In the late sixties and early seventies New Zealand seemed set upon a course which would rapidly escalate its population to beyond four million and planners talked in terms of new town concepts to accommodate population growth. Those exciting and heady years have been replaced by the realism of the late 1970s and early 1980s with the recognition that population as a development factor can have negative as well as positive characteristics. In short, in planning for the future, a factor of zero growth has given us all time to reassess both sociological and physical factors in the planned management of population growth. We have more time to think which requires but commitment and effort. It is therefore a most appropriate period for your Society to reconsider the technological factors which are fundamental to deciding where urban growth will be permitted. Yours must always be a discipline concerned with the future and the making of current decisions which allow for the use of land for urban purposes in a physical sense, having a low probability of structural failure at an acceptably reasonable financial cost. No human skills will guarantee anything as absolutely safe, but citizen expectation of the many disciplines associated with the provision of the developed land which make up our urban communities will ensure a growing input by members of your technical group into the location and style of New Zealand's urban centres. Abbotsford will have affected us all and our attitudes in both the advisory and decision-making arena. Inevitably we will be more cautious in making recommendations and in reaching decisions.

From this Symposium may develop the opportunity to review your Society's 1977 handbook on Slope Stability in Urban Development as a further contribution to the proper physical development of our urban centres. Whilst one must hesitate to place too much significance upon the role played by any one discipline, I cannot help but feel that the work of your members is totally fundamental to the decisions which will need to be made in planning the further urbanisation of New Zealand. But in making that assessment, I cannot too strongly emphasise the need to recognise your role as part of an interdisciplinary team making recommendations to those with whom ultimate responsibility rests in allowing the utilisation of land for urban purposes. The Councillor of city, borough, county and regional councils will increasingly seek the advice of that interdisciplinary team before making current decisions on the future use of land.

Lest there be any doubt about the significance of the issues you will discuss, let us all remind ourselves that for most people their greatest investment is in the home they own. We are entitled, as homeowners, to assume that reasonable care has been exercised by those to whom responsibility has been delegated for allowing land to be used for urban purposes. The capital investment in our homes probably remains at stake at all times from the consequence of potential geological instability. Whether we recognise it or not, we have a long term vested interest in the advice given to the decision makers. The standard of care expected of those decision makers is increasingly being enunciated by the courts and in New Zealand will be highlighted by the findings of the Commission of Enquiry into the Abbotsford land slip disaster. But what the future holds in the planning of our expanded urban communities may be as unstable as Abbotsford and with consequences not yet forseeable. But if from this symposium comes a further publication to guide urban development, you will have contributed to the stabilization of the instability I predict.

Let us now consider two of the areas of instability which lie ahead in providing further urban facilities:

1. With the national planning objectives being to preserve good productive farmland, is it not inevitable that New Zealand will face increased pressure to urbanise less productive, often steeper, and therefore generally less stable areas?

2. With increasing emphasis upon local authority liability for consequences flowing from the negligent performance of

statutory duties, will we not find an increasing reluctance to allow urban development when there is the slightest risk of geological failure?

The potential for conflict therefore arises between planning objectives on the one hand and sound engineering principles, on the other, based among other things upon geological considerations. All of us in the decision making process will need to avoid the potential consequences of legal liability flowing from geological failures in areas in which urban development is permitted. My fear is that all disciplines associated with the approval of land for urban purposes will exercise an increased standard of care to avoid subsequent allegations of negligence. The consequence will inevitably be either more highly productive farm land approved for urban purposes, or higher engineering standards to lessen the possibility of geological failure. In either event, the costs of selection development are likely to soar. If this be so, there will be great difficulty in housing any significant population growth in the years ahead. In one case the cost to the national economy will be high. In the other case, the cost to the purchaser could be prohibitive. This conflict between planning objectives and engineering consideration will place increasing demands upon your members to devise codes of practice which aim for an acceptably low probability factor of slope failure at an acceptably low cost factor. The housing of a significantly larger New Zealand population will depend upon the solutions you devise.

The 1974 Local Government Act has placed increased responsibility upon local government in stipulating conditions applying to the urbanisation of land approved for that purpose under the Town and Country Planning Act. It is unrealistic to assume that local government or its officers will be exempt from the consequence of the negligent performance of duties under the Local Government Act. It is naive to assume that professional advisors to local councils or local councils themselves, will run risks in approving the zoning of land for urban purposes. Caution will be uppermost in the minds of advisors and councillors. There therefore exists the potentiality for further conflict between those who wish to develop land for urban purposes and those who make the decisions which allow urban development to take place. That conflict may be increasingly resolved through the Planning Tribunal. If so, then we must ask these questions:-

- What will be the legal consequence of a council declining to zone land for urbanisation and being directed on appeal to so zone that land?
- What will be the consequence flowing from stringent conditions attaching to subdivisional approval of land directed by the Planning Tribunal to be zoned for urban purposes and those conditions themselves being made the subject of appeal to, and amendment by, the Planning Tribunal?
- Will the Planning Tribunal, without legal liability to compensate those suffering loss as a consequence of slope failure, in fact become the final arbiter on where urban development will take place in New Zealand?

Let us express the hope that common sense will prevail; that those willing to give considered and careful advice, and those willing to make intelligent decisions based on that advice, will not be deterred from carrying out their allotted responsibilities. It would be a sad day indeed if the Planning Tribunal achieved a significance in urban development beyond that of conflict resolution. Local councils should remain responsible for the urbanisation of their own communities based upon the best advice available to produce sections which are reasonably safe from slope failure and at reasonable cost.

GEOMECHANICS IN URBAN PLANNING - PALMERSTON NORTH APRIL/MAY 1981
NEW ZEALAND PLANNING INSTITUTE : NEW ZEALAND GEOMECHANICS SOCIETY

GEOTECHNICAL HAZARDS TO URBAN DEVELOPMENT

D K TAYLOR, C P GULLIVER, N W ROGERS
TONKIN AND TAYLOR, AUCKLAND

CONTENTS

1. INTRODUCTION

The purpose of this paper is to list hazards to urban development which arise from geotechnical causes, to suggest their relative importance in New Zealand, to indicate how they may be detected and evaluated, and how the risks can be reduced.

The paper is intended to provide a framework (or check list) to be filled out by subsequent papers and discussion at the symposium so that conclusions may be reached as to the appropriate land-use planning, and control measures, which should be adopted to reduce the cost to the community of the effects of the hazards.

Referring to the Abbotsford disaster Gallen et al (Ref. 4) observe that *"Planning is a serious matter which affects the fundamental rights of citizens to deal with their property. This involves the exercise of far reaching powers. In this country it is considered appropriate that such powers should reside in the elected local authority which is answerable to its electors at regular intervals"*.

The technology of geotechnical hazard detection and evaluation, while not always at all precise, is far ahead of our social capacity to accept the warnings and to act upon them.

To quote Fornier (Ref. 3)

"Whatever the nature of the hazard the passage from prediction and scientific exercise to warning as a public service will certainly raise complex and difficult social problems ...."

and Campbell (Ref. 2)

"If a generalization can be made from this review, it is that in many situations people react only *__after__* *a catastrophe and the response may be somewhat piecemeal".*

"Unquestionably economic factors are largely responsible for what, to a scientist, may seem the very slow pace of appropriate legislation. Many people would rather take the chance that they will not be hit by a landslide or an earthquake in their lifetime, than spend the relatively few dollars needed to prevent or lessen such hazards".

and commenting on Altors et al (Ref. 1)

"The coming quarter century should provide an interesting test of geological estimates economic pressures from self-interest groups and legislative response".

the authors of this paper hope that discussion at the symposium will focus upon the planning decisions which should be reached and enforced, using technology as a guide to those decisions and not as an excuse for not taking them.

The term "Geomechanics" (or "Geotechnics") includes the sciences of Geology, Soil Mechanics, Rock Mechanics and Soil Science but some of the hazards identified involve seismology, meteorology, oceanography, botany and hydrology - in fact just about the whole spectrum of the study of the earth's surface and atmosphere. Whilst the word "urban" means "of or belonging to a city", we have taken our brief to include any centres of human habitation.

All living involves risk taking. No amount of geotechnical expertise or planning control can produce absolute safety in the urban setting and we do not believe the community expects that to be achieved. What the community can rightly expect is that "geotechnologists" and "planners" do their best to show it how far identifiable hazards can be reduced at a cost which it will accept.

2. THE MAJOR HAZARDS

The tables which follow list hazards which may arise to urban development in various environments, the means by which they might be detected and evaluated and what might be done to reduce them. While the list may not be exhaustive it looks formidable; the significance of various risks and causes to the New Zealand scene need to be kept in perspective so that we direct our planning of land use, or perhaps more significantly our energies in persuading the public to accept land use constraints, towards the major hazards and those which we have the best chance of reducing or eliminating.

2.1 Headings in the Tabulation

The table is only a check list and it is not intended to be a definitive classification, indeed such would be a matter of endless debate thoroughly confused by the interaction of one hazard upon another (e.g. flood resulting from erosion of slip debris to release impounded water).

2.1.1 Hazard

A broad grouping of results rather than causes (with the exception of volcanic eruption), subdivided in the direction of causes of the major hazards.

2.1.2 Rating in New Zealand

A very subjective appreciation by the authors of the apparent significance in the New Zealand scene.

2.1.3 Causes

These are subdivided into natural or manmade causes but some hazards can be caused by either - or both in combination. All too often man's contribution comes from ignorant or ill-advised actions which are avoidable.

2.1.4 Environmental Factors

Includes both physical and social aspects. This could be expanded and subdivided into geological, climatic, topographic and demographic (or social) zones. It is probably easier in "town" planning to consider each factor in the geographic zone in question. "Micro-zoning" in specific areas could be done.

2.1.5 Hazard Detection and Evaluation

A broad statement of the general means available but it begs two questions,

(a) the cost and
(b) the certainty of the result;

both of which must be balanced in justifying the means adopted to reduce the risk.

2.1.6 Means of Risk Reduction

For most of the hazards there always exists the avenue of avoiding them by not carrying out urban development in risky areas - a decision which must be taken by the "community", only advised by planners, engineers, geologists:- this is the real kernel of this symposium. The "means" listed are mainly the physical engineering and land management operations which may be appropriate.

2.1.7 Cost

A very broad rating of the cost of the physical means available. The economic cost of one land use as against another is obviously of the greater significance. However, this requires judgement of political and sociological issues quite apart from economic analysis.

2.2 The Main Hazards - General Appraisal

2.2.1 Settlement

A predominantly vertical downward movement of the ground surface affecting anything supported by it; differs from landslip in not involving shear displacement; caused by reduction in volume of the soil, either as a result of compression or of slow combustion (peats); particularly significant where the amount of movement varies under different parts of the supported structure (differential settlement); the chief cause of unsatisfactory performance of structural foundations.

The causes are generally well known and the extent and timing of likely settlement can reasonably be determined by established methods of investigation, testing and analysis - more reliably so than most other kinds of ground deformation.

2.2.2 Ground Heave

An upward vertical movement of the ground generally due to swelling caused by absorption of moisture. Not a common problem in New Zealand. The potential for ground swelling can be identified by soil tests but the extent of it is harder to predict. Can occur at the toe of a rotational slope failure, or where compression is occurring due to ground movement.

2.2.3 Shear Failure under Foundations

Caused by overstressing of the ground under superimposed loads, generally leading to some horizontal deformation and tilting of supported structures. Methods of identification and evaluation are well established and it is generally well guarded against by current methods of foundation design.

2.2.4 Landslip

Downslope movements of ground varying in speed, from slow widespread soil creep due to seasonal weathering processes, to more localised failure of discrete masses of ground in weeks or hours, or in the extreme to high velocity flows of liquified soil. The nature and degree of the hazard can be defined by geotechnical investigation, in general terms, but the margin of safety and the timing of the failures cannot be fixed with any certainty.

The incidence of failures in New Zealand is considerable and the risk increases as urban development becomes more intense and moves onto steeper ground. Remedial work to restore adequate stability is very expensive and in crowded urban areas it may be impossible.

Soil "surface erosion" is generally less of a problem in the urban environment than mass movement, although the loss of land and consequent increased sediment load and aggradation downstream may involve enormous costs both to individual landowners and the community at large. Most soil surface erosion results from the physical removal of soil by water and wind. Recently attention has been focused on dispersive soils. Clays which deflocculate in the presence of relatively pure water are termed dispersive clays. Soils containing such clays thus appear particularly susceptible to erosion and piping.

2.2.5 Flooding

Inundation of land by excess water. Not strictly "geotechnical" in origin in its most serious incidents, but geotechnical factors often contribute and disputes between insurers often arise.

Nothing can be done to avoid climatic and meteorological events which cause the hazard but control of the resulting run-off water involves very large expenditure in New Zealand, even in urban areas. Means of evaluation of the extent of the hazard are well established but precautionary measures, because of their cost, involve value judgements about the size of the event to be guarded against short of the most extreme.

2.2.6 River Bank Erosion

Loss of ground due to flowing water, either at "normal" flows or in rainfall events which lead to floods as well. Flood control measures include protection against river bank erosion.

2.2.7 Coastal Erosion

Loss of ground to action of the sea in the coastal margin. Generally a natural occurrence due to forces beyond man's control but often a delicate natural balance can be seriously upset by apparently insignificant actions by man.

Resulting losses in New Zealand have become serious as resort development has intensified close to sand beaches.

Areas of risk are easily identified but quantification requires prolonged expensive investigation, which can not be precise in its results.

Effective remedial measures are very expensive and usually uneconomic in the urban setting.

2.2.8 Earthquake

The sudden and often destructive release of energy, in the form of elastic waves within the ground, is a well recognised hazard in New Zealand.

It is stated (Ref. 7) that "Compared with some other parts of the Pacific margin, such as Japan, Chile and the Philippines, the level of seismic activity in New Zealand is moderate. It may be roughly compared with that prevailing in California. A shock of Richter magnitude 6 or above occurs on the average about once a year, one of magnitude 7 or above once in ten years, and one of about magnitude 8 perhaps once a century, but in historic times only one shock (the south-west Wairarapa earthquake in 1855) is known to have approached this magnitude in New Zealand.

The most serious seismic disasters in New Zealand have been the Hawke's Bay earthquake of 1931 in which 256 deaths occurred, and the Buller earthquake of 1929 in which there were 17. The total resulting from all other shocks since 1840 is less than 15 deaths. The last earthquake to cause deaths occurred at Inangahua in 1968, when 3 people died.

Within New Zealand itself, at least two separate systems of seismic activity can be distinguished. The Main Seismic Region, which is the larger, covers the whole of the North Island apart from the Northland peninsula, and the South Island north of a line passing roughly between Banks Peninsula and Cape Foulwind. The Southern, or Fiordland, Seismic Region includes southern Westland, western Southland, and western Otago. Less clearly defined activity covers the remainder of the two main islands, and extends eastwards from Banks Peninsula to include the Chatham Islands.

Shallow earthquakes, which are the most numerous, originate within the Earth's crust, which in New Zealand has an average thickness of some 35 km. These shocks are responsible for almost all damage to property, and now and in the past they have been widely scattered throughout the country. In historically recent times, the Main and Fiordland Seismic Regions have been significantly more active than the rest of New Zealand, but neither the Central Seismic Region that lies between them nor the Northland peninsula has been free from damaging shocks. The details of the present pattern are not necessarily unchanging, and could alter significantly after the occurrence of a major earthquake. Because of this, because of the broader geophysical setting, and because of the distance to which the effects of a large earthquake extends, <u>it would be highly imprudent to treat any part of New Zealand as free from the risk of serious earthquake damage</u>." It must also be recognised, however, that different pieces of adjacent ground experience different accelerations and displacements during any earthquake;for example, soft valley floor alluvial deposits experience larger amplitude movements than neighbouring more rigid basement rock outcrops.

2.2.9 Seismic Displacements

The hazards caused by seismic events more remote from the urban areas have been covered under the preceding headings.

Significant displacements of the ground along faults are unique events which have great significance in New Zealand and will have more as urban development intensifies.

Active faults are identified by geological and precise survey investigations, potential movements are the subject of prolonged and sophisticated studies which do not lead to precise predictions.

The social and economic costs of over-reaction to the only real precaution, evacuation of the urban area, are a great problem.

2.2.10 Volcanic Eruption

Many of the hazards already mentioned can arise or be contributed to by volcanic eruption as a cause, (e.g. landslip, flooding). Inundation of land by flowing molten rock, airborne debris or water-borne debris are hazards more uniquely attributable to volcanic eruption.

Where surface volcanic activity is presently occurring the nature of the hazard is obvious, and has been much studied and its location is more or less predictable. Where the current situation is dormant but in an environment with a history of potentially catastrophic events widely spaced in time, (e.g. Auckland isthmus) the risk is much harder to appreciate. Certainly there is no prevention of such events - only avoidance of the highest risk areas is possible.

2.2.11 Loss of Natural Resources

The study of geological hazards in California (Ref. 1) revealed the surprising economic importance of the loss of sand, gravel and rock deposits, used in road and building construction, because expensive urban development has covered them.

This has not attracted much public attention in New Zealand yet but the process is far advanced in Auckland, for example, (where a resource study is in hand) and becomes more serious as the cost of transportation over greater distances rises.

Also in New Zealand, and this is especially evident in South Auckland, some of the most highly productive flat land is being urbanised, resulting in loss of agricultural and horticultural resources. In some places this continues in spite of Section 3 of the Town and Country Planning Act 1977, which requires that "In the preparation, implementation, and administration of regional, district, and maritime schemes ... the following matters shall be recognised and provided for ...

(d) the avoidance of encroachment of urban development on, and the protection of, land having a high actual or potential value for the production of food:

(e) The prevention of sporadic subdivision and urban development in rural areas:

(f) The avoidance of unnecessary expansion of urban areas into rural areas in or adjoining cities:".

3. TABULATION OF HAZARDS

(See fold-out page 178).

4. PUTTING THE HAZARDS IN PERSPECTIVE

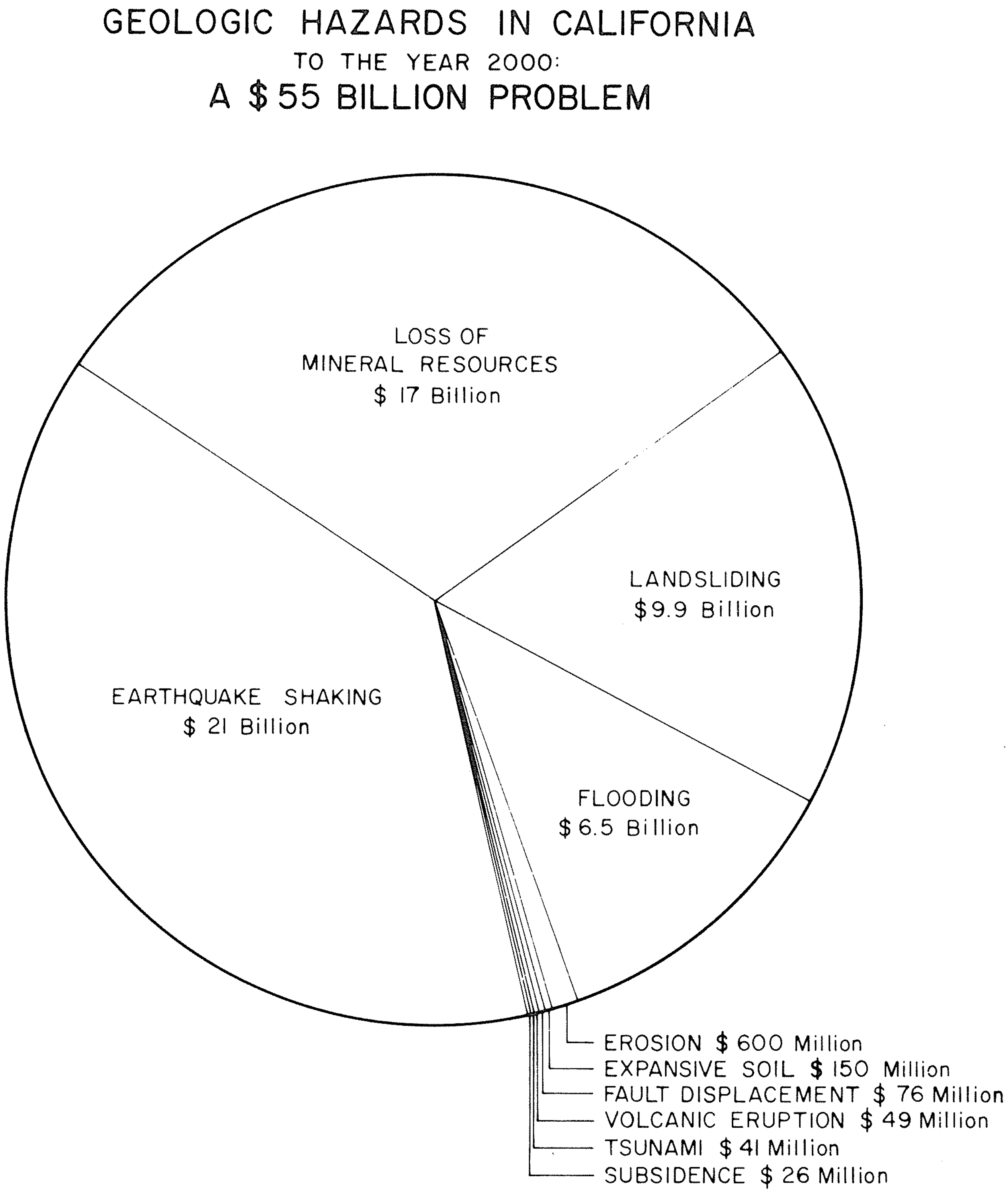
Having listed all the hazards to urban development which may exist we must acknowledge that our efforts to mitigate them will be discredited in the public mind if we do not put them into some order of importance and concentrate upon the ones about which we can do something effective.

To quote Gallen et al (Ref. 4) reporting upon the Abbotsford disaster in New Zealand.

"A general lack of adequate statistical data in respect of natural or geological hazards means that an accurate assessment of risks is virtually impossible. The writing of disaster insurance therefore becomes a gamble which can be accepted only if Government is prepared to underwrite losses fully".

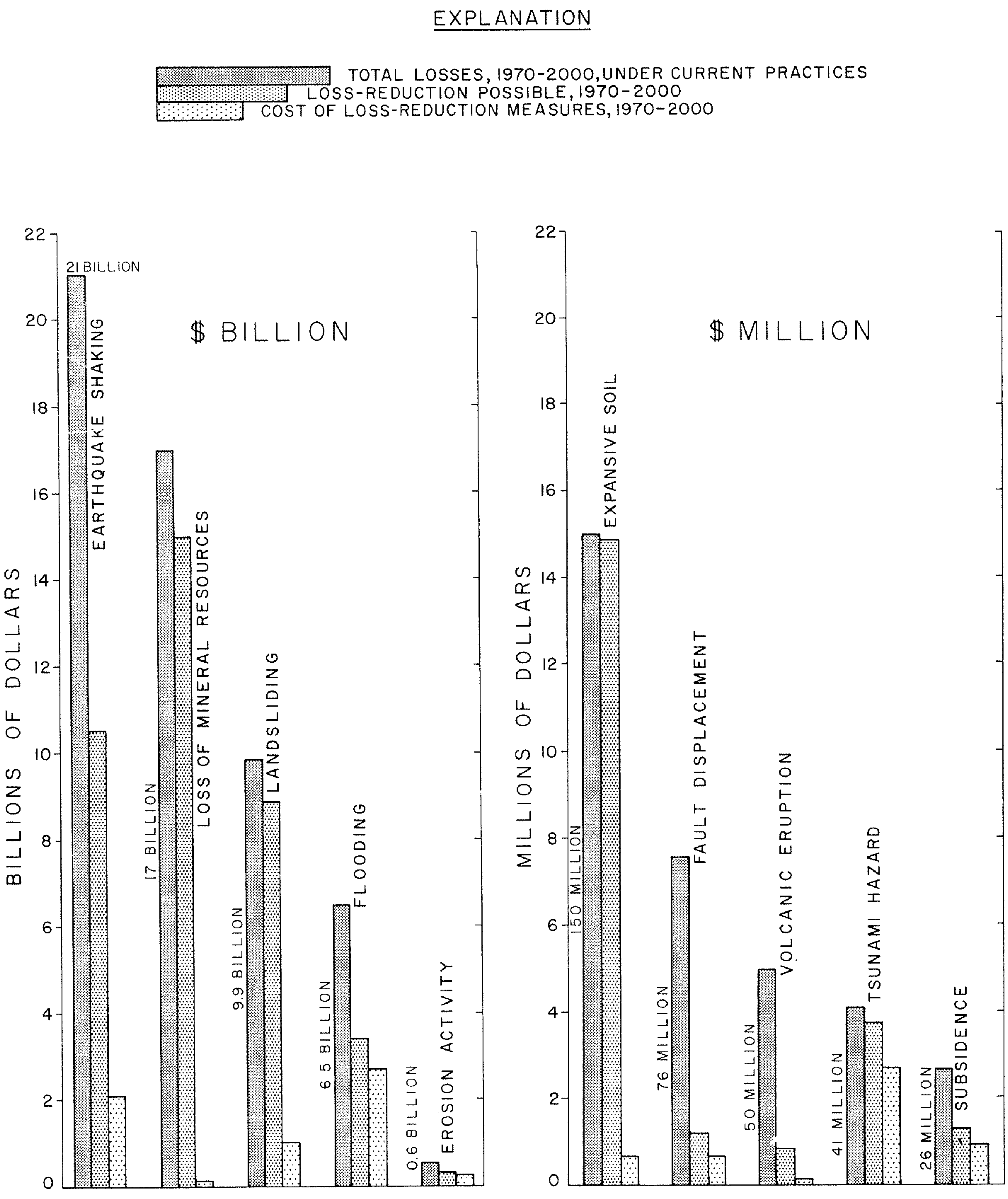
Gill (Ref. 5) quotes the experience of the Earthquake and War Damage Commission in dealing with those of the risks for which the Commission provides cover:

> From the inception in 1944 of the Earthquake and War Damage Fund, 40,000 claims for earthquake damage have resulted in payments of $5.5 million.
>
> Since the disaster fund was introduced in 1949 - 55,000 extra-ordinary disaster flood and volcanic eruption claims - payments $19 million, and 1,500 claims for landslip damage - payment $1.25 million.
>
> In the first 26 years 32,000 claims payments $5 million.
>
> In the last ten years 65,000 claims - payments $21 million.



Geologic hazards in California to the year 2000: a $55 billion problem. Estimated magnitude of losses due to ten geologic problems in California projected from 1970 to the year 2000, if current loss-reduction practices continue unchanged.

(From Ref.1) Figure 4.1



Estimated total losses due to each of ten geologic problems in California for the period 1970–2000, under current practices; amount of loss-reduction possible, if state-of-the-art practices were used; and cost of applying state-of-the-art loss-reduction practices.

(From Ref. 1) Figure 4.2

The most comprehensive study of the relative economic importance of geological hazards of which the authors are aware is that conducted in California (Ref. 1). Figures 4.1 and 4.2 reproduced from that study are illuminating and probably could be regarded as being at least indicative of situations in New Zealand. The footnote in Figure 1 makes the point that the assessment of financial loss is based on the assumption that current loss-reduction practices continue unchanged. We would suggest that in this respect the situation in New Zealand differs only in that more attention has been paid to seismic design of structures but that even less attention has been given to the loss of mineral resources.

Referring to Figure 4.2 the small cost attributed to measures to reduce the cost of lost mineral resources, is notable.

Probably it is fair to say that the "geotechnical" hazards uppermost in the public's mind in New Zealand at present are flooding and landslip while the potentially larger scale hazards of Seismic Disturbance and Volcanic Eruption occur so infrequently as not to be kept in mind although the Technologists have a wider view.

Table 4.1 summarises our view of the relative significance of geotechnical hazards in New Zealand. There is not a direct correlation between this table and the "Rating" column of the table in Section 3 of this paper.

Statistics mean little to the layman and even less to those who suffer personal distress and financial loss when the worst happens.

Geotechnical hazards are relevant to:

property	-	"unimproved"
		"improved"
persons	-	death
		injury
		peace of mind

and the notion of "cost" includes all of those factors.

TABLE 4.1

Significance of Hazards in N.Z.	Scale of Hazard	Risks level in N.Z.		Periodicity	Predictability	
		Property	Life		In Space	In Time
Settlement	Small	Moderate	Nil	Frequent	Confident	Fair
Foundation failure	Small	Small	Nil	Rare	Confident	Confident
Ground heave	Small	Small	Nil	Continuous	Confident	Fair
Landslip - natural - man induced	Small to Large	High	Moderate	Frequent	Fair	Uncertain
Flooding - natural - man induced e.g. dam burst	Large	High	Low	Frequent	Confident	Fair
Coastal & River erosion	Small	Moderate	Nil	Continuous	Fair	Uncertain
Seismic probably N.Z. greatest hazard	Very Large	High	High	Long Term	Fair	Uncertain
Volcanic (lahars)	Very Large	Moderate	Moderate	Very Long Term	Fair	Fair for local events
Tsunami	Moderate	Moderate	Moderate	Long Term	Uncertain	Impossible

5. CONCLUSIONS

The introductory paper to a symposium on this topic is hardly the place to draw conclusions. May we hope that the symposium will reach conclusions as to the means by which the warnings and advice and assistance of technology can be brought into perspective, and contribute to land use planning constraints and prohibitions which the community can be brought to accept as being in its own best interest.

Some hazards are unavoidable, but too much distressing, and costly, damage has been caused in New Zealand by ignorance of inexpensive and elementary precautions.

Education of the public must be as important as legislated restraint.

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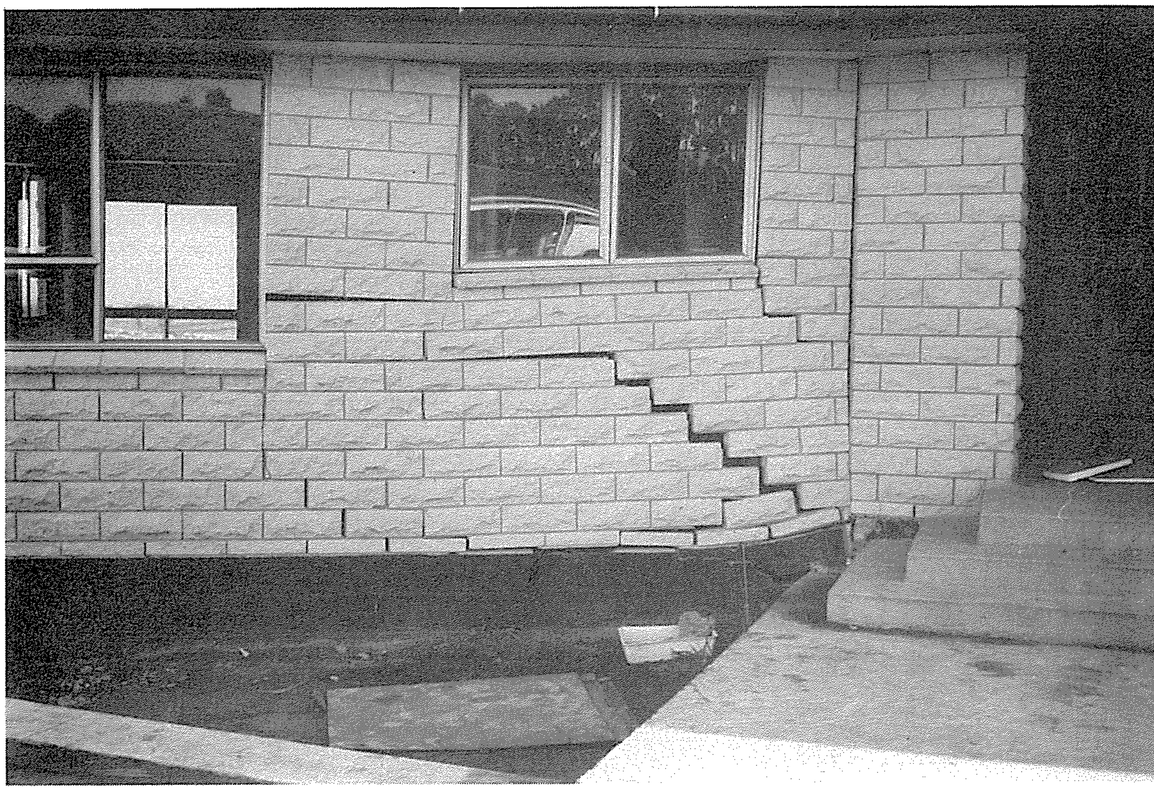

Ministry of Works and Development

HAZARD	RATING IN N.Z.	CAUSES: NATURAL	CAUSES: MAN MADE	ENVIRONMENTAL FACTORS	HAZARD DETECTION AND EVALUATION	MEANS OF RISK REDUCTION	COST
SETTLEMENT Shrinkage of soils	XX	Atmospheric drying		Highly plastic soils Records of low rainfall Declining water table	Soil surveys Long term meteorological records Surface level observation GW observation	Special engineering design Groundwater recharge Stream bed erosion control	X XXX XX
			Overdrainage	Highly plastic soils Peat & highly organic soils Use of poorly drained land	Soil surveys Soil surveys	Restrict drainage Complete drainage before land use	XX
			Accelerated atmospheric drying	Removal of top soil High transpiration planting Removal of low plant growth	Well known Well known	Maintain topsoil Space away from structures Special engineering design Maintain low ground cover Vapour barriers	X X XX X X
Consolidation	XXX	Result of atmospheric drying		See above			
		Increased vertical load	Drainage Fill over compressible soil	See above Fill on poorly drained ground Wide variation of soft soil depth	Soil and subsurface surveys	Removal of compressible soil Special engineering design of structure	X to XXX XXX
			Poorly compacted fill	Uncontrolled filling	Well known	Control and inspection of filling operation Special engineering design of structure	X XX to XXX
			Imposed structural loads	Large bulk x area loads Wide variations of load intensity Wide variation of depth of fill	Soil & subsurface surveys See above	See above See above Control and inspection of filling	XX X to XX X
	X	Seismic vibration	Vibration from traffic, or construction operations, Quarry Blasting	Geological recent deposits of loose granular soils high water table	Subsurface surveys	Recompaction of ground	XX to XXX
			As above		Subsurface surveys	Control of operations Recompaction of ground	X to XXX
Compaction	X	Seismic vibration	Seismic vibration	Geologically recent deposits granular soils low water table		Recompaction of ground Special engineering design of structures	X to XXX X to XXX
				Large new artificial lakes	Geotechnical study World wide study of occurrence		
Ground heave (swelling) (soils)	X	Rising soil moisture content		Increasing rainfall Highly plastic soils	Long term meteorological observations & surface level observation	Slow, long term movements rarely of significance in N.Z	
	X	Reaction to overburden erosion	Wetting of unsaturated soils	Plastic soils overdried prior to completion of structures	Soil survey and structural load analysis	Avoid excessive exposure or drainage, or rewet prior construction Avoid excessive watering after construction Permanent drainage	X X XX
Shear failure under foundations	X	Major seismic disturbances		Soft plastic soils or loose granular soils with high ground water proximity to source of shock	Soil surveys Seismological records, tectonic surveys	Special engineering design of foundations	XX to XXX
		Erosion		River or sea erosion Subsurface erosion of silts, sands, loess	Soil surveys ground water surveys	Soil stabilization, control of ground water movement	
			Foundation soils overloaded	Undetected low strength soils	Subsurface surveys	Adequate subsurface investigations and foundation design	X
Subsidence			Underground mining	Cavities remove support, further degradation with time	Retention and examination of mine maps	Backfill cavities Mine to induce controlled collapse Special foundations	XXX X XX
LANDSLIP	XXX	Seismic shock		Steep topography in soft rocks and recent soils proximity to shock source	Topographic and geological surveys seismological records tectonic surveys	Avoid development in high risk areas Special engineering designs	XXXX
		Weathering		Active erosion, high rainfall, depletion of vegetation, swelling overconsolidated rocks, soluble cementing agents, structural discontinuities.	Soils surveys Hydrological investigations Botanical studies	Avoid development in high risk areas Regenerate vegetation	
		Rising ground water pressures		Intense freeze & thaw Increasing rainfall, concentration of seepage	Long term ground water surveys	Drainage	
		Fault Displacement		Regions of active faulting	Geological study	Avoid construction on active faults Design flexible constructions	XX
			Slope steepening by excavation	Cost and space restrictions	Geological and geotechnical investigations	Flatten slopes Retaining structures Establish vegetation	XX XXX X
			Slope steepening by filling Loading slopes with structures	Cost and space restrictions		Resite the structure Retaining structure Deep foundations	XXX XXX
			Increase in soil weight by saturation Increase in seepage pressure Increase in pore water pressure	Fill compacted well below saturation Concentrated seepage		Control and inspection of filling Drainage and runoff control Avoid draw down of ponded water at base of slope	X X X
			Erosion of the slope	Concentration of runoff	Surface water and subsurface water study	Drainage and diversion	X
			Leaking water pipes, drains or reservoirs	Unstable ground Erodible soils and rocks Dispersible soils	Geotechnical study Routine inspection of works	Flexible pipes Impervious linings Regular maintenance	X XX X
FLOODING	XXX	High rainfall	Urbanisation leading to increased stormwater discharges and flood heights	Large catchments in steep ground upstream of flat ground	Meteorological & hydrological records and analysis	Avoid development in flood prone areas River channel improvements Stop banks	XXX XXX
		Sediment deposits in river channels		Vegetation depletion Active upland erosion	Erosion and botanical studies	Replace vegetation Control botanical population River channel improvements Detention dams Establish reserves	XX XX XX XXX X
			Depletion of vegetation	Intense urban development Clear felling forest Overgrazing	Hydrological studies	Controlled & selected felling Good management of farms	X X
			Increase in impervious surfaces	Intense urban development	Hydrological studies	Adequate storm water drains Detention dams	XX XX
			Collapse of dams	Dams upstream of urban development	Hydrological studies, geotechnical investigations	Adequate investigation and design, especially at spillways	X
			Constriction of water ways	Intense urban development	Hydraulic studies Routine inspections	Design adequate culvert and bridge water ways Control of vegetation Clearing of slips	X X
RIVER BANK EROSION	XX	Similar causes as flooding					
			Oversteepening banks by excavation or felling	Gravel and sand mining Intense urban development	Hydraulic studies	Control of gravel and sand extraction River bank reserves	X X
			Drain outfalls to the river	Urban development	Hydraulic studies	Properly designed outfall structures	X
COASTAL EROSION	XX	Storm events		Storm weather Sand beaches		Set back development behind buffer zones	
		Long term changes of ocean currents			Expenses long term studies	Artificial supply of sediment to beaches	XXX
		Long term rise of sea level		Isostatic movement of earths surface		Construct sea walls Beach training structures	XXX
				Interglacial ice melt	Studies of glaciation		
		Tsunami waves from seismic disturbances		Coast facing towards seismic zones	Geographical & oceanographic studies	Avoid development on low coastal land	
		Increasing stream discharges		Climatic and vegetation changes			
			Removal of beach, dune or near shore sediments	Sand beaches Demand for sand supply Harbour and navigation Channel dredging	Geotechnical and hydraulic studies Hydraulic model experiments	Control of sand removal Engineering design	X X
			Depletion of sediment supply	Regenerated vegetation inland following depletion	Land use studies		
			Depletion of dune vegetation	Urban or resort development increased vehicle or pedestrian traffic	Land use studies	Avoid development Control access Regenerate vegetation Prevent fires	X
			Impervious rigid sea walls	Expensive building development, sand & gravel beaches	Geotechnical & hydraulic study	Adequately deep walls	XXX
			Drainage outfalls	Land and building development close to sand beaches	Land use and hydraulic study	Construct adequate outfall structures Divert outfalls away from erodible beaches	XX X
			Increasing stream discharges	Vegetation depletion inland	Land use study	Control of land use	X
LOSS OF MINERAL RESOURCES	XXX		Urban development	Expanding large urban development over rock sand gravel (and metallic ores)	Geological and land use studies	Plan urban expansion to avoid economically valuable deposits (at least until they are exhausted)	
LOSS OF WATER RESOURCES (surface and ground water)	XX	Climatic changes	Urban, rural development	Pollution, depletion	Hydrological and ground water studies	Water management	
VOLCANIC ERUPTION	XX	Volcanic activity		Regions of current activity or events widely spaced in time	Geological & vulcanological study	Avoid development in high risk regions Develop clear channels leading from volcanic centres Develop away from likely deposition of debris from the air	
Seismic Displacements	XXX	Fault movement		Margins of fault bounded blocks of land, generally piedmont	Geological and seismic studies	Avoid development Special engineering designs	XX

GEOMECHANICS IN URBAN PLANNING - PALMERSTON NORTH APRIL/MAY 1981
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THE DEVELOPMENT OF LOCAL AUTHORITY LIABILITY FOR HAZARDS IN URBAN AREAS, AND A REVIEW OF RECENT LITIGATION

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A BRIEF LEGISLATIVE HISTORY

The first major legislative control on urban development was the 1959 amendment to the Soil Conservation and Rivers Control Act 1941, where under sections 34 and 35, the Soil Conservation and Rivers Control Council or a catchment authority could prohibit any use of land that causes erosion, flooding, or deposits in water courses.

In 1960 the town planning regulations were published, seven years after the Town and Country Planning Act was passed, and Regulation 16 stated that:

> "every district scheme shall provide as far as practicable against land being used for purposes for which it is not suitable having regard to earthquake fault lines, liability to flooding, erosion and landslip and to stability of foundations."

In 1966 the Town and Country Planning Amendment Act inserted a new clause 10A in the Second Schedule to the Act that required district schemes to deal with the "control of development in areas containing earthquake faults or land likely to be affected by geothermal activity, flooding, erosion, landslip, and subsidence and other special areas."

The other early controls were exercised in the subdivisional field where Councils had the power to refuse approval to a scheme plan where the land was thought to be unsuitable. Three measures were provided:

1. district scheme planning controls under the Town and Country Planning Act 1953,
2. legislative controls under the Municipal Corporations Act 1954 and Counties Amendment Act 1961, and
3. local body engineering standards.

Although these powers were readily available, they were clearly not used to their fullest extent. Criticism was also frequently levelled at the scope and meaning of the subdivisional controls by the Planning Appeal Boards and professionals in the field.

The current position has improved in that the 1977 Town and Country Planning Act has a wide-ranging provision that now requires the Council to avoid or reduce the danger, damage or nuisance caused by earthquake, geothermal and volcanic activity, flooding, erosion, landslip, subsidence, silting and wind (Clause 8(a) Second Schedule).

The other advances are set out in the 1978 and 1979 amendments to the Local Government Act 1974. The 1978 amendment spelt out subdivisional controls (Sections 313, 274, 277 and 279 in particular) while the 1979 amendment provided for building controls (Sections 641 and 684).

As a result of these statutory provisions, there is now a stronger emphasis on the significance of erosion and flood risks Whereas formerly Councils had the power to refuse approval to a scheme plan where the land was thought to be unsuitable, the whole emphasis has now changed to a positive obligation to refuse approval in certain circumstances. These include Council's opinion, not only that the land is unsuitable for subdivision, but also that "the subdivision is likely to accelerate, worsen, or result in erosion or subsidence or slippage of any land (whether part of the subdivision or not) from any source, or inundation by the sea, river, stream or lake" (S. 274(f) L. G. Act).

There is also a proviso covering situations where satisfactory protection measures are taken. This provision has the effect of imposing a positive obligation on Councils to satisfy themselves that either the risks do not exist in any considerable degree, or adequate protection measures have been taken. Doubtless this will entail much more resource to professional advice than has sometimes been the case.

Regional water boards have a growing role under the subdivisional legislation. Under S. 277 of the L.G. Act they are directly involved in major subdivisions (over 50 lots) if the Council considers that the subdivision "will affect matters relating to the use or quality of water or to soil conservation or erosion".

They also have a new right of appeal against subdivisional approvals where these matters are at stake (S. 300(1)(d)). This gives regional water boards a much wider opportunity to apply their expertise to subdivisional questions than ever before.

The 1979 amendment to the L. G. Act extends the Council's obligation to refuse subdivisional approval to building permits. Sections 641 and 684 thus provide Councils with the widest possible power to control buildings in areas where a natural or manmade hazard exists - or is likely to exist.

A recent case bears this out. In Southland County Council v Southland County Council (1981, Decision No C4/81, 9 Digest of Planning Tribunal Decisions 12) the Council brought an appeal against its own decision to refuse to grant to a building permit as a means of obtaining a ruling on the meaning of Section 641 (2) (b) of the L. G. Act.

The permit was to enable the Council to construct a truck shelter on its own land. The land adjoined the Waikaia River, a tributary of the Mataura River and whenever the river floods, the land becomes part of the river floodway.

The Planning Tribunal was asked to determine whether the Council was right to refuse itself a building permit under S. 641(2)(b) on the grounds that part of the land is subject to inundation. This was seen as a test case of some importance because of the widespread inundation of the intensively farmed and closely populated plains of the Mataura and Oreti River valleys during the floods of October 1978, January 1980 and August 1980.

From the evidence, it was concluded that all the Council's land (including the area where thr truck shelter was to be erected) is "subject to inundation by a river" in terms of S.641(2)(b). Because the Council could not be satisfied the protection from inundation could be made, it had no alternative but to refuse to grant a building permit.

Although this finding disposed of the appeal, the Tribunal looked at the meaning of the subsection in some detail as a means of assisting the Council in its administration of "a difficult piece of legislation".

It is interesting to note that the control provisions under the Soil Conservation and Rivers Control Act (sections 34 and 35) were used in urban areas for the first time in 1976, when the North Canterbury Catchment Board issued a public notice in respect of Christchurch's Port Hills. Since that time they have been used in other urban areas such as Nelson and the catchments of Lakes Tarawera, Okareka and Rotoma near Rotorua. They had previously only been used in rural areas.

THE RISE IN LOCAL AUTHORITY LIABILITY

The starting point is 1932 and the law of negligence. Prior to this time a person could only be held liable for causing direct physical harm, personal injury or property damage by a negligent action.

The general duty of care associated with the law of negligence was examined by the English House of Lords in Donoghue v Stevenson (1932) AC 562, a case that dealt with a snail in a ginger beer bottle. Lord Atkin, a leading judge of the day, stated:

> "The rule that you must lover your neighbour becomes in law: you must not injure your neighbour, and the lawyers' question, 'Who is my neighbour?', receives a restricted reply. You must take reasonable care to avoid acts or omissions which you can reasonably foresee would be likely to injure your neighbour. Who then, in law, is my neighbour? The answer seems to be - persons who are so closely and directly affected by my act that I ought reasonably to have them in contemplation as being affected when I am directing my mind to the acts or omissions".

This statement became the test in subsequent negligence cases and led to the idea of a standard of prudence of the ordinary reasonable person in the circumstances.

The concept of a duty of care being owed to those who you could foresee could be injured by your act or omission has since that time been transformed and updated by judges to accord with the ideas of justice appropriate to the times.

In 1964 liability was extended for the first time to words (oral or written) that caused personal or physical harm - or economic loss alone. The English House of Lords in Hedley Byrne & Co Ltd v Heller & Partners Ltd (1964) AC 465 (a case involving careless investment advice from a banker), established the principle that, subject to a disclaimer being given, a person who possesses a special skill or knowledge is liable for financial loss if careless advice is given to another who relies on that advice to his detriment. In everyday terms this means that if an engineer or building inspector gives advice about a site, there is an obligation to exercise reasonable care where there is reliance by the landowner. This duty of care does not normally apply to informal or social situations.

THE NEGLIGENT EXERCISE OF STATUTORY POWERS

In recent years a principle has been established that where a power of control is given to a local authority (especially under health and safety by-laws) a duty of local authorities have had direct experience with this legal duty, usually to their detriment.

In 1976 Manukau City faced this problem when a Mr Hope purchased a house in which parts of the plumbing were incorrectly installed (a plumbing permit had not been obtained) and damp proof course had not been installed under the basement's concrete floor contrary to the Council's building by-law. The builder had left for Australia so Mr Hope sued the Council.

In the decision (Hope v Manukau City Corporation (1976) Current Law 762) the judge held that the Council was liable for the total cost of the remedial work since its inspectors had been careless and negligent in failing to make a proper inspection and seeing that a plumbing permit had been obtained. The judge said:

> "I accept that it was primarily the builder's duty to ensure that the plumbing complied in all respects with the by-laws and regulations, but the powers conferred on the Council are so embracing that they had the power to control the builder in his work very tightly indeed.
>
> The fact that proper housing standards were not maintained is as much the fault of the Council as of the builder".

In 1977 Mt Albert Borough came under fire when subsidence of filled ground caused damage to flats. The builder purchased land for a subdivision knowing that part of the land had earlier been filled. He built a block of own-your-own flats but took no special steps to ensure the foundations were adequate to prevent subsidence in such ground. The Borough Council, which also knew that the land had been filled, issued a building permit and later inspected the foundations. It did not insist on more adequate foundations. Some years later subsidence caused damage to the flats and the owners sued the builder for his negligent actions and the borough for the negligent issue of a building permit and for the negligent inspection of the foundations.

In its decision (Johnson v Sydney Construction Co Ltd and Mt Albert Borough (1977) 2NZLR 530) the Court held the builder and the

Council to be equally liable for the cost of remedial work. The Borough was at fault in that it knew that the flats were built on filled ground but it issued a building permit without requiring adequate foundations. It also failed to ensure by inspection that adequate foundations were used. In 1979 on appeal (reported at (1979) 2NZLR 234), the Court of Appeal reduced the Borough's liability to 20% and increased the builders to 80%. It stated that the Council's negligent inspection was not as serious as the breach of the builder's obligation to go down to a solid base.

Another important point emerged from the case. Normally a legal case has to commence within 6 years of the cause of action (by virtue of the Limitation Act 1950). In this case, however, more than 6 years passed between the building of the flats and the subsequent damage to them. It is now accepted that the 6 year limitation period starts to run from the date of the damage rather than the alleged negligent act when the building first took place. This point had also emerged in Gabolinscy v Hamilton City (1975) 1 NZLR 150 where the Council as the owner and subdivider of filled land was held to be liable when the land subsided and caused damage to the Gabolinscy's house. One of the consequences of this point is the necessity to maintain particularly accurate and detailed local authority records.

Other cases have seen the Courts apportion responsibility for negligent actions between the offending builder and the Council:

In Callaghan v Robert Ronayne Ltd, Creedon and Northcote Borough (1979) Current Law 173, the Court of Appeal considered the case of town house units leaking badly from defective storm water drains, the lack of damp coursing and other deficiencies. These matters were all contrary to the requirements of the local authority building by-laws. The building company was held to be primarily liable, but blame was apportioned to the Borough Council for negligent inspection.

In Tomlinson v Young (1979) 2 NZLR 441, a house and garage in Wellington had been built on land which was steeply sloping and known to have been filled. The building permit stipulated that the foundations must go down to solid ground. The foundations were inspected by a Council building inspector. One of the piles had not been set in solid ground and after a wet winter some movement was found in the foundations. The builders were held to be negligent in failing to build the foundations on solid ground. The building inspector had also failed to ensure that the foundations were on solid ground and this made the Council liable. Damages were assessed at 90% on the builder and 10% on the Council.

One of the walls of the house was also in danger of collapsing due to a design fault, probably as a result of the architects moving into a sphere where they should have consulted a structural engineer. The Council was held to be liable because it had failed to detect the design fault as it had not referred the plans to its Structural Engineering Department. Contribution for damages were assessed at 75% on the architects and 25% on the Council.

In Taupo Borough Council v Birnie (1978) 2NZLR 397 (reported on the question of damages only), the Court of Appeal looked at damage to the Spa Hotel from flood waters caused by the Council constructing the Centennial Drive and a pool upstream of the hotel. The flood waters had backed up behind twin culverts, built by the Council, that were unable to cope with the volume of water in the stream. The Borough was held to be negligent in constructing the works. The damage suffered by the hotel was caused by the addition to the water level which the works engendered together with the consequent acceleration in flow caused by an increased runoff from the lands in question. Considerable damages were awarded to the hotel's proprietor.

The principles in the above cases will not doubt cause alarm to many local authorities, so it is important to state just what is required before a Council is liable for damage resulting to property:

1. The first point is that there has to be a clearly defined statutory duty on the Council to exercise controls for the protection of public health, safety and comfort. The wideranging powers and duties set out in the subdivisional building by-law and building permit sections of the Local Government Act come within this category.

2. The second requirement is that there has to be a physical damage to person or property. More remote economic losses, such as the loss of profies only with no physical interference with the property, are not claimable against a local authority.

3. Thirdly, there has to be negligent advice or actions on the part of the local authority officers.

The law of negligence is certainly moving towards stricter liability on local authorities, particularly where Council subdivisions have been inadequately compacted (as Gabolinscy v Hamilton City illustrates), and in the above cases where building inspections have been carried out negligently and the structure has later failed.

The additional responsibilities under the Local Government Act subdivisional controls have yet to be tested in the courts. However the principle is certainly capable of extension to cover the Council's failure to conduct reasonable investigation into the ground stability of any new subdivision. Certainly, local authorities are becoming more aware of the problem and are making more use of independent engineering advice.

Of course advice, however competent, will not guarantee land stability, but a Council acting on it in good faith will be protected against future claims. The affected owner may have a claim against the advisor if the advice was given negligently - but proof of negligence is the problem, particularly when the damage does not arise for many years. Then, whatever the circumstances, the owner affected is likely to face difficulties of proof when records have been lost and memories dimmed by the passage of time.

The importance of proving the fault principle was stressed by the Court of Appeal in Blewman v Wilkinson (1979) 2NZLR 208, discussed in the 1980 Law Journal at page 115. The case dealt with the collapse of land and the local authority was not involved. However, the comments of Mr Justice Cook indicate that the fault principle will always have to be proved before there can be a successful legal action involving negligence and the slipping of land. The Judge looked at the New Zealand conditions and said:

> "A great many urban subidivisions have taken place in steep and sloping terrain with extensive earthworks. The idea of imposing strict liability (i.e. liability without having to prove fault) on a subdividing owner when a subsidence occurs many years later, and notwithstanding that he acted on proper professional advice at the time, is unattractive. Unless he or his agents can be shown to have been at fault, it seems to me more just to leave the loss lying where it falls. Hillside subdivisions and the like are so typical in this country and slips and other subsidences such common place hazards that, unless fault can be demonstrated, a purchaser can fairly be expected to accept the risk. Insurance, if any, should be his concern."

Although negligence actions are by far the most common means of attempting to get redress for land slippage or subsidence, they are not always successful and other legal remedies can be attempted. These points are borne out in the following cases.

In Dennis Ryan Ltd v Wellington City Council (Supreme Court 24 April 1979) the company purchased land from the City Council in order to erect flats on it. Under the contract for sale the Council undertook to ensure that the land was suitable for the erection of flats. The land was in fact unsuitable and the builders sued the Council for negligence and breach of contract. But because no professional men were involved during the land negotiations, a duty of care did not arise and the negligence action failed. However the Council was held to be fully liable for a breach of warranty and the company was successfully awarded damages for their loss.

In Harris & Son Ltd v Demolition & Roading Contractors (1979) 2NZLR 166 the Christchurch City Council was involved in a negligence action concerning a crib wall. The wall was erected with a building permit and during the course of its construction it was inspected by the Council's inspector. The builder mistakenly failed to comply with the permit issued to it, and the inspector honestly but erroneously supposed that the permit was being complied with. The wall collapsed and a new one had to be built at a cost of over $9,000.

The landowner sued the negligent builder who in turn brought the Council into the hearing on the basis that it should idemnify the builder for its negligent inspection. The court found the builder liable, but it held that the Council owed no duty of care to the builder and was thus not liable to indemnify the builder.

This case raises a fine, but substantial, legal point. Had the landowner sued the Council as well as the negligent builder, a different decision may have resulted. A duty of care is clearly owed by the Council (through its inspectorate) to its citizens, and in such a case liability would have rested on whether or not the building inspector had been negligent in his investigation of the work on the wall.

Here, however, the judge said that the duty of care owed by the building inspector is limited to the owners of land who may suffer injury or damage through negligent actions. The duty is not owed to a negligent builder - the source of his own loss. A right of action can only be conferred on an owner or occupier of land who suffers damage. This limitation disposes of the problem of an endless class of potential claimants being called into existence when a negligence action arises.

Even though the Council was held not to have been negligent (since the duty of care did not exist), the judge held that should the matter be taken to appeal and the Council found liable to contribute, it should pay 20 per cent of the damages. An appeal did not eventuate.

The problem remains, however, of how to ensure that purchasers of sections are aware of the position. The old rule caveat emptor (let the buyer beware) is hardly adequate to the section or home purchaser in these rapidly changing times with more and more pressure on less and less suitable development land. The ordinary buyer is generally unable to afford the cost of sophisticated investigations that would inform him of the precise nature and state of the site he intends to purchase. He or she must rely very heavily upon the competence of the local body and the integrity of the developer and builder.

There will obviously be cases where the Council may feel that there are risks but that adequate protective measures have been taken. The question then, is whether prospective purchasers should be warned - and how. Should there be a warning in the district sheme and if not, should the local authority carry the responsibility of compensating people who suffer innocently?

The district scheme provisions undoubtedly hold the key to effective controls for natural and man-made hazards. There are clearly adequate powers in the 1977 Planning Act to implement appropriate measures. These could include

- suitable zoning controls for hazards (such as those in Eastbourne, Mt Maunganui and Waiapu County and the proposed micro-zoning for earthquakes in Wellington),
- the use of passive zoning (e.g. forestry or recreation) for specified risk areas for public purposes (such as the Hutt River reserves),
- strict controls of new subdivisions, and
- the use of the district scheme as a vehicle to convey warnings where risks exist.

The Planning Tribunal clearly supports a long term view in coastal erosion prone areas as the following cases indicate: Armstrong v Whakatane District Council (1977) 6NZTPA 240, and Waikanae Ratepayers Association v Horowhenua County Council (1979) Decision No 18/80. A somewhat curious decision emerged in MOWD v Taranaki County (1978) 6NZTPA 485 where the Tribunal preferred to see the powers under the Soil Conservation and Rivers Control Act used for coastal erosion reserve purposes rather than the town planning procedures. It is notable that this decision was based on the 1953 Planning Act which did not contain the more extensive powers of the 1977 Act (clause 8(b) Second Schedule), or the provision in S.4(3) that relates the administration of district schemes to the principles and objectives of the Soil Conservation and Rivers Control Act 1941 and the Water and Soil Conservation Act 1967. Had these powers and objectives been considered, a different decision may have resulted.

The town planning provisions have the advantage of being a proven forum for community aims and activities. They are amongst the most accessible of all legal procedures and probably amongst the most trusted. If the district scheme format cannot be properly used we can ask ourselves just what other options exist, and what the likelihood is of further major disasters occurring. Surely the lessons of Abbotsford and Omaha do not have to be repeated.

The extent of the powers and duties delegated to local authorities is no doubt viewed by some as awesome, and it is thus not surprising that grumblings are surfacing from some local authorities who want the Local Government Act powers watered down. There is obvious concern about the cost to Councils of the greater use of independent advice on subdivisional matters - and the attendant risks, along with the need for an enlarged inspectorate.

These costs will obviously be very real, but there are other measures that can be considered. The first is the strengthening of insurances available to property owners under the auspices of the Earthquake and War Damage Commission. The recommendations of the Abbotsford Commission of Inquiry are obviously crucial in this regard.

Qualified approvals or permits can also be given - the disclaimer idea (although there are problems in this area since the disclaimer or an express power delegated by Parliament to a local authority could well be held by a Court to be contrary to public policy and thus invalid). Indemnity agreements could be required from the landowner and warnings could be given. There are a number of options in this last area. Warnings could be placed on the land title by way of notation (another controversial matter), they can be expressed through the district scheme, or, as is the case with Rodney County Council, a warning information centre can be established for public use.

Last but not least, we can do well to remember the protection of all parties that comes from the specialist acting in good faith along with the abundant expertise that is available from our government agencies and local authorities.

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I would like to acknowledge assistance from the work of Dr Ken Palmer, Auckland University Law School and Jonathon Field, Auckland Regional Authority solicitor in this area. In particular see Ken Palmer's article "Local Authorities and Negligence" 1976 New Zealand Law Journal 541, and "Urban erosion - whose responsibility" Soil and Water, June 1978 by Jonathon Field.

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VOLCANIC RISK TO URBAN DEVELOPMENT IN NEW ZEALAND

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1. INTRODUCTION

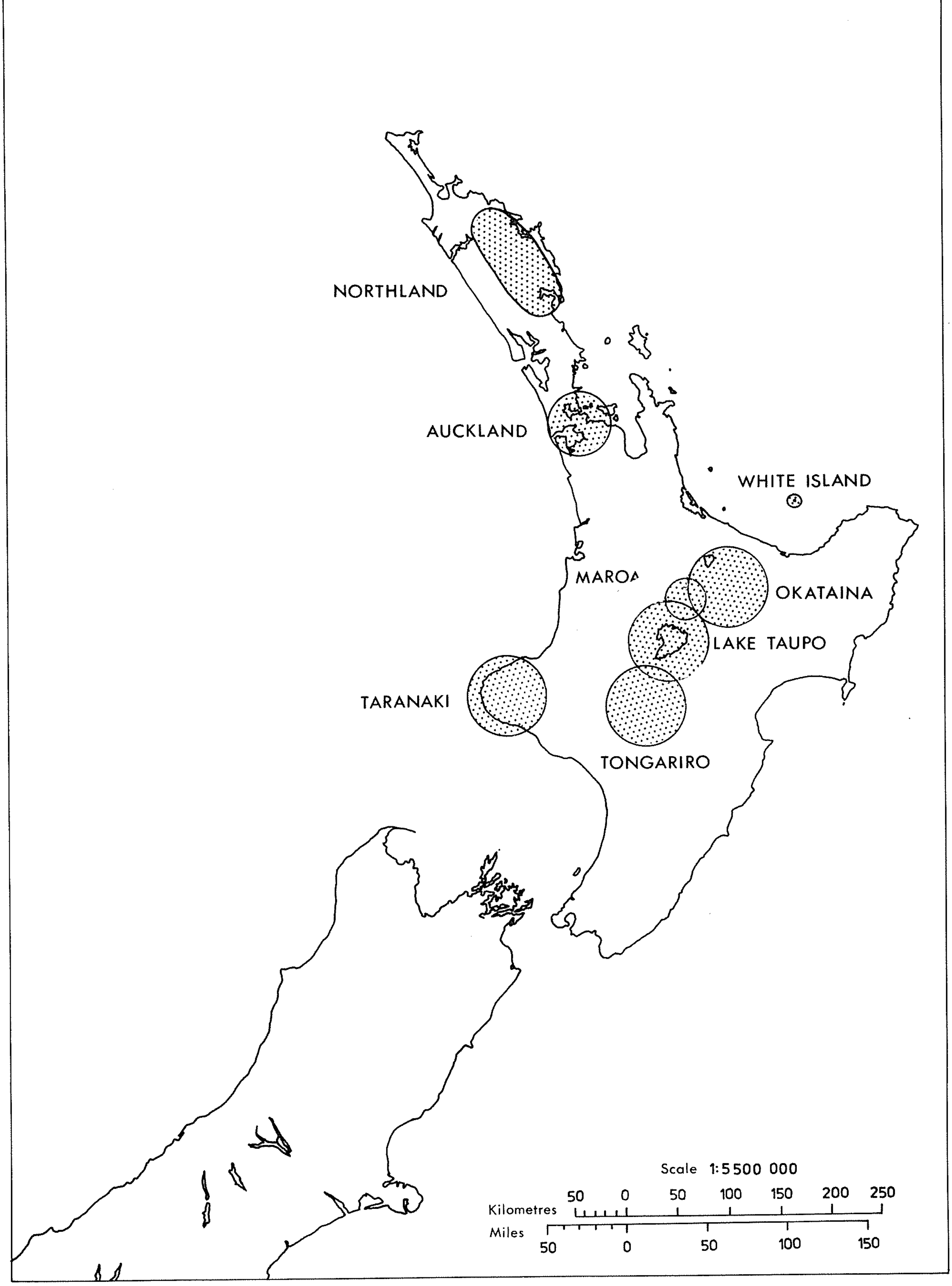
Late Quaternary volcanism in New Zealand has been located entirely in the North Island and at small adjacent submarine and offshore islands. Eight volcanic districts are recognised as principal areas of volcanic risk, each district having displayed characteristic modes of volcanic behaviour. In assessing volcanic risk and likely hazards emphasis is placed on the magnitudes and types of volcanic activity in the past as being most likely indicators of expected future activity. By detailed mapping of the distributions and types of eruptive products it is possible to construct detailed records of the volcanic history of each district, the frequency of eruptive styles and the effects on surrounding regions. From this information the volcanic risk associated with urban development in New Zealand can be considered most obvious in six of the eight volcanic districts (Fig 1). These six are grouped under three headings as follows:

Northland and Auckland
Central North Island-Bay of Plenty, and
Taranaki.

2. NORTHLAND AND AUCKLAND

In these two volcanic districts eruptions of basaltic ejectamenta have tended to be localised in the Kaikohe-Whangarei region and in the Waitemata-Manukau harbour region. Volcanic vents are numerous but comparatively small in size and are largely surrounded by lava flows, scoria cones and explosion ejecta (the latter structures called maars). Of these eruptive types, maar formation must be considered the most hazardous. Maars form where magma

Figure 1. - Principle late Quaternary volcanic districts in the North Island of New Zealand.



rising upwards through the crust encounters groundwater and a violent explosion of steam rips the surrounding cover rocks apart as they are expelled radially from the explosion site. Well known examples of maars in the Auckland city area include the Orakei Basin and Lake Pupuke on the North Shore (Heming 1976).

In the Northland district much of the volcanism has been in low population density areas and it is only near Whangarei and in the Bay of Islands that areas of very low volcanic risk to urban development are recognised. The Te Puke volcanic cones, north of Waitangi, are probably the youngest volcanoes in Northland. These last erupted between AD 200 and AD 700 (Wellman 1962).

Plots of the ages and distribution of late Quaternary volcanism in the Auckland district show no evident trends with time and it appears unlikely that on current information one could reliably forecast future eruptive sites (Searle 1964). The greatest risk of further activity must be attached to Rangitoto Island, because it was the most recently active volcano in the Auckland district, last active sometime before AD 1800 (Heming 1976). In the Auckland city region, one potential secondary hazard is collapse of lava tunnels particularly in areas where lava flowed along former river valleys. Maps of the distribution of basaltic cover rocks within Auckland city are available in the NZ Geological Survey's Industrial Map Series of geological maps at 1:25 000 scale.

3. CENTRAL NORTH ISLAND - BAY OF PLENTY

The highest risk areas for future volcanic activity lie in the Taupo Volcanic Zone, three districts presenting potential hazards for urban development:- the Okataina district encompassing the region from Rotorua in the west to Mt Tarawera in the east, the Lake Taupo district and White Island (indirectly).
New Zealand's largest historical eruption was centred in the Okataina district when on 10 June 1886 Mt Tarawera and the adjoining Lake Rotomahana erupted, spreading scoria and lake mud over a 4,500 km^2 area and killing 153 persons. A much higher casualty figure would be expected if a similar sized eruption

occurred again, because of the significantly higher population density in the region today. In pre-historic times, very large eruptions of hot pumiceous flows and pumiceous air-fall materials have been generated in the Okataina district (Pullar and Birrell 1973). Over the last 10,000 years these have occurred on an average of one every 1,700 years (Healy 1977).

At Lake Taupo voluminous eruptions of hot pumiceous flows and pumiceous air-fall materials have occurred in pre-historic times. During the most violent of these, about AD 186, up to 24 km^3 of pumice was blanketed across the surrounding country-side (Walker 1980). So explosive were these eruptions that they had a profound effect well beyond the immediate zones of damage. Air-fall pumice was spread across much of the east coast North Island region and profound changes occurred in the hydrological regimes of all the major rivers draining the central North Island to as far away as Hamilton, Wanganui and Hastings. These voluminous eruption types are so enormous, that they cannot be realistically contemplated when planning for urban development today - they are the remote risk that one has to accept when living in the region. However, one can apply some of the common sense practices of avoiding localised areas of known recent hydrothermal activity where steam explosions may recur. The fact that, within a region of higher volcanic risk than the rest of the country, there are zones of varying volcanic hazards, needs to be more widely appreciated.

Other considerations that have been mooted from time to time involve influencing architectural styles. Clearly, in any air-fall volcanic eruption A-framed houses will be less likely to collapse under the weight of ash accumulation compared with flat-roofed houses. It has been calculated that at Whakatane, where pre-historic air-fall volcanic deposits exceed 0.5m thickness, the weight on a house roof for this ash thickness would total 20 tonnes (Pullar 1973). One of the largest secondary hazards from renewed volcanic activity in the central North Island would be increased sediment loading of the rivers draining an eruptive area. Large scale siltation and river bed aggradation with a marked decrease in channel capacity would lead to an increased flooding risk for downstream communities. This would be particularly evident on the lower surfaces of the Bay of Plenty and in particular around Whakatane (Pullar 1973).

The principal hazard to urban development that future eruptions at White Island may contribute is a secondary phenomenon. If in the remote possibility that sea water entered the magma chamber by breakdown and removal of the crater walls or floor, there is a potential situation for generation of a tidal wave (tsunami) along the Bay of Plenty coastline. The effects of such an event would be widespread on the settled portions of the coastal sand country which are very close to sea level.

Future eruptions from the Maroa and Tongariro volcanic districts are not discussed in this paper as both districts are sited considerable distances away from areas of current urban development.

4. TARANAKI

The last volcanic district where renewed volcanic activity would have a major impact on both urban and industrial development is Taranaki. Between 500 and 200 years ago at least nine eruptions originated from Mt Egmont. These spread air-fall pumice or hot gaseous avalanches up to 15 km from the summit. In pre-historic times larger eruptions, together with former collapses of the volcanic cone that generated lahars (volcanic mudflows and debris flows), constructed much of the western and central Taranaki landscape. Hazards to urban development in the region comprise accumulation of air-fall volcanic ash, which is likely to be principally directed eastwards from Mt Egmont, and inundation from lahars along all the major stream channels that radiate from the mountain. In late Quaternary times most of the lahars have been directed westwards, but some have been mapped along the Waiwhakaiho River towards New Plymouth and in the Inglewood region (Neall 1979). A map of areas inundated by lahars over the last 1,000 years in Egmont County has been included as an inset in the soil map of that county recently compiled by Massey University and about to be published by Soil Bureau, DSIR.

5. CONCLUDING REMARKS

Six centres of late Quaternary volcanic activity are recognised in New Zealand that present potential hazards to urban development. In recognising specific hazards at each centre, only three main types of volcanic activity can be readily considered by those planning urban development.

These are:

1) the frequency and distribtuion of volcanic ash deposition
2) areas of known hydrothermal activity or of historical steam explosions, and
3) areas of late Quaternary lahar deposits and floods associated with eruptions. These hazards would be particularly applicable to urban planning in the Central North Island and Taranaki regions.

Other forms of volcanic activity are so infrequent and unpredictable that no known methodology is currently available to take them into account.

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GEOMECHANICS IN URBAN PLANNING - PALMERSTON NORTH APRIL/MAY 1981
NEW ZEALAND PLANNING INSTITUTE : NEW ZEALAND GEOMECHANICS SOCIETY

EARTH DEFORMATION AND SHAKING EFFECTS

G J LENSEN, NZ GEOLOGICAL SURVEY, LOWER HUTT

Introduction

Given time, there is no place on earth, let alone in New Zealand, that will not experience the unavoidable hazard of earthquake shaking. However, the effects of shaking on the earth's crust, its topography and sediments can be minimised if an assessment of the geological conditions of any area to be developed is carried out. If the remedial steps that must be taken in the development are insufficient or if the required restraints on the development are uneconomic, a more suitable area should be selected.

Faulting

Additional to the shaking hazards which exist everywhere in New Zealand, is the hazard of sudden ground displacement which can be as large as 6 metres (20 ft) in both the horizontal and vertical shift. This hazard can be avoided where the geologist can precisely locate active faults and man can avoid the inevitable ultimate disaster resulting from building across them.

Sudden displacements are not confined to the fault plane itself but decrease outwards and the resulting differential displacement away from, but close to, the fault will also destroy buildings erected in this zone of deformation.

The N.Z. Geological Survey (N.Z.G.S. Report 89 "Active Earth Deformation" 1979) recommends not to build within a zone of minimum width of 20 m on either side of the fault thus totalling 40 m. However, in many cases faulting is complex or may develop that way in the future and thus the width of the deformation zone may increase to 200 m and in a few places even to one km or more.

However the presence of an active fault need not exclude an area from development nor need the development be more expensive when the presence of the deformation zone is taken into account.

The Totara Park Subdivision in Upper Hutt is chosen as an example.

In the early 1960's a major New Zealand company intended to develop the Totara Park area. Through the Ministry of Works Town and Country Planning Division the N.Z. Geological Survey objected to the scheme on the grounds that the presence of a Class I active fault had not been taken into account and buildings with high population concentrations were planned to straddle the fault. After the subsequent local body hearing of objections, the subdivider was required to show the location of the active fault on the subdivision plan; this resulted in the developer abandoning the site.

Three years later a second developer in consultation with the N.Z. Geological Survey designed a scheme that avoided the fault hazard which is additional to the unavoidable shaking hazard. Totara Park developed accordingly and the fault scarp became the median strip between two roads and the deformation zone which in this case is the minimum required width of 20 m, cannot be built upon (Fig. 1).

The local council must be congratulated for their wisdom in creating the then unique New Zealand subdivision. Unfortunately the New Zealand wide habit of providing insufficient safeguards in dwelling design against the earthquake shaking effects has also prevailed at Totara Park where in order to provide garage space underneath the dwellings, diagonal bracing has been partially or totally omitted. When a major earthquake occurs nearby but not necessarily on this fault, those dwellings are very likely to be severely damaged or destroyed and some resulting loss of life can be directly attributed to this omission in design.

Other methods of taking the deformation zone into account range from "reserve contributions" (either passive or active such as bowling greens, athletic tracks, etc.), carparks, open marshalling yards etc., to planning sections which back onto the fault trace and where an encumbrance on the titles will prevent building construction within the deformation zone.

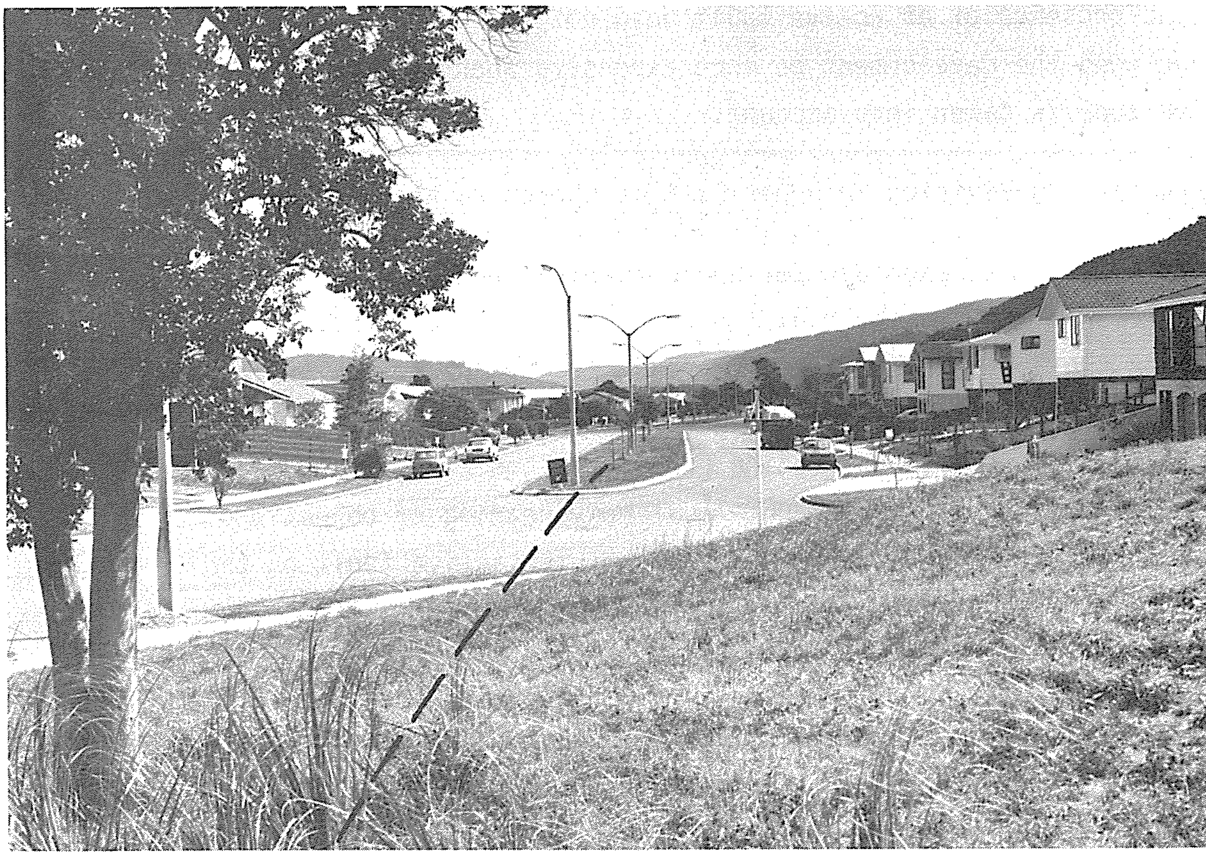

Fig. 1. The Totara Park Subdivision in Upper Hutt has in its design taken the presence of an active fault into account. Dashed line is the location of the fault.

Other considerations to be taken into account are the lifelines such as telephone, electricity, water, gas, sewage, etc. which must not cross active deformation zones unnecessarily. Where this cannot be avoided, they should be crossed in such a direction that a sudden horizontal displacement will tend to shorten the lifeline which preferably should be installed at or close to ground level in order that quick repairs may be made at times when they are of vital importance.

As stated above, faulting is not always simple and the width of the deformation zone varies with the age of the ground surface it displaces. In general the fault complexity increases with the geological age of the surface and with the nature of faulting, tension, shear or compression.

This has been discussed in some detail by the author (Lensen, 1976) and is summarised in his figures 3 and 4.

Apart from sudden faulting, block tilting and folding, both resulting in tilting of the ground surface, can in coastal and lake areas produce small to large scale inundations, depending on the amount and the regional extent of tilting. Sensitive installations and lifelines such as sewage and stormwater disposal and irrigation schemes may also be affected and tilting effects should thus also be taken into account at the initial planning stages.

The amount, density and frequency of faulting and folding varies considerably within New Zealand and is shown in Fig. 2.

Responsible planning can avoid a natural hazard from becoming a man-made disaster.

Microzoning

The degree of earthquake shaking effects on buildings etc. is not related to the distance a building or construction is located from an active deformation zone, but depends largely on the ground response at the site.

Relatively young, soft, wet sediments whose individual particles during earthquake shaking are each independently in motion, are specially prone to failure as they have dynamically insufficient bearing strength under earthquake shaking conditions.

The number of parameters that individually or in combination affect the bearing strength of such sediments are considerable: uniformity of particle size, watertable, vertical and horizontal variation in the nature of sediments and the shape of the basin that contains these sediments are just a few.

Topographic stability depends on the nature of the rock, its degree and direction of jointing and the steepness of the slope. While under normal and even under earthquake shaking conditions the natural slope may be stable, any interference by man may result in instability under earthquake conditions. Similarly, waterlogged deep soils on hill slopes may fail under earthquake conditions.

Fig. 2. Active Faults in New Zealand.

In general any area to be developed may show evidence of past instability or lack of bearing strength that can be identified by specialist geologists. In borderline cases subsurface investigations may be required to verify the area's past and thus future likely geological record.

In Summary

Natural geological hazards can in most cases be avoided or mitigated by geological investigations preceding selection and development of any area. It should be the developer's responsibility to prove that any area is safe for the purposes for which it is proposed to be developed prior to any scheme being accepted by the authorities concerned, who should carry the ultimate responsibility of safeguarding the trusting users.

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THE PROBLEM OF MINING IN THE URBAN ENVIRONMENT

N FOWKE and D DEPLEDGE
STATE COAL MINES, HUNTLY

INTRODUCTION

Historically, insufficient attention has been paid in New Zealand to the location of economic rock and mineral deposits during urban development.

In a few cases, genuinely unexpected deposits have been located in developed areas, but in most, available geological evidence has not been given due regard in town planning.

A fivefold classification of the situation where either planned or existing development is underlain by identified economic rock or mineral deposits can be made.

1. Deposits previously fully extracted.
2. Deposits previously partially extracted (some overlap with group 4).
3. Virgin deposit, known to be economically exploitable.
4. Deposit, believed to be uneconomic to extract.
5. Probable, possible or hypothetical deposits, the economics of which must necessarily be unknown.

With groups 1 and 2 there is the possibility of damage to surface structures being caused by previous mining. With groups 2 to 5 there is the possibility of subsequent mining causing damage and disturbance.

A survey of case histories throughout the world shows that an inordinately large number fall into Group 4. There are good reasons for this. With groups 1 to 3 the pros and cons are mainly geological. Some or all of the potentially hazardous consequences will be known to local authorities, developers and purchasers - although reactions on learning of them vary widely!

Group 4 however is governed by economics. Rapidly changing and largely unpredictable economic circumstances are a characteristic feature of the mining industry.

As geological knowledge of an area accumulates, the proportion of it within Group 5 decreases, whereas the proportion within the other 4 groups will increase.

Some New Zealand examples are given below.

These groupings were applicable when urbanisation began. Some have already changed subsequently.

Group 1. Parts of Huntly township - coal.

Group 2. Numerous areas of past underground coal mining e.g. northern fringes of Whangarei City, Huntly and Rotowaro townships. Gold mines at Waihi and other Coromandel townships.

Group 3. Coal beneath Kopuku village - Maramarua coalfield.
Pumice on northern fringes of Hamilton City.
Alluvial aggregates in many low-lying areas.

Group 4. Titanomagnetite beach sands beneath several coastal townships in the western North Island.

Group 4. contd. Several geothermal fields in the Bay of Plenty.
Coal beneath Ohai, Cromwell, Roxburgh and several eastern Southland townships.

Group 5. Coal beneath Auckland city and several King Country and West Coast, South Island townships. Gold beneath coastal areas also on the S.I. West Coast.

THE EFFECTS OF MINING IN URBAN AREAS

The extraction of minerals or rock from the ground results in surface movement. The characteristics of such movement ranges from localised random broken or fractured ground to regional basin subsidence.

The ground movements include reduction in general levels, changes in ground slope lateral displacement causing compressive and extensive strains, and isolated caving depressions.

The effects of differential displacement and settlement in the urban environment included cracking and distortion of buildings and fracturing of pavements and service pipes. Other effects of subsidence include mass sliding of structures and an increased proneness to flooding.

The magnitude, development and significance of such phenomena depend on:-

(a) mining factors - the method and extent of extraction.

(b) site factors - the depth, thickness, extent and geological nature of the deposit and overburden.

(c) structural factors - the tolerance of planned or existing surface structures towards transmission of the effective ground movements.

In addition to the physical hazards mentioned above the removal of minerals from the ground can cause noise water and visual environmental problems.

The use of explosives, heavy machinery, the creation of dust in extraction and processing, the introduction of fines from washplants into natural waterways and the creation of spoil piles and cut landscapes can be particularly offensive in urban areas.

The physical dangers, particularly to children of steep quarry slopes and heavy road traffic should also be noted.

SOME SOLUTIONS TO THE PROBLEM

The adverse effects of mining either below ground or in open cuts can be avoided or alleviated by engineering, mining or planning methods.

The group 1 situation may only require a system of compensation where damage to a structure can be attributed to mining activities.

Some compensatory action may also be required for group 2 situations but, in general terms, planned or existing areas covered by groups 2 to 5 can be dealt with by structural precautions or alterations, by adaptions of mining methods or by comprehensive systematic regional or district planning.

A. Engineering Solutions

The shape, size and design of foundation and superstructure together with the materials used and degree of maintenance will all have a bearing on the reaction of a structure to ground movement.

In general, structures should either be completely flexible or completely rigid although rigid buildings are usually more costly.

Some tried and tested methods of mitigating damage include the use of:-

(i) reinforced-concrete rafts on sand beds.

(ii) discontinuities in larger structures.

(iii) jacking devices for correction of tilt.

(iv) flexible pavements

(v) flexible joints in service pipes.

B. Mining Solutions

For underground workings, if all the relevant geotechnical site factors are known and no abnormal conditions exist, maximum subsidence created by various configurations of openings can be predicted accurately.

Maximum subsidence for a given extracted thickness is a function of depth to the deposit and the width of the opening.

Thus for shallow workings it is general practice under urban areas to leave stable pillars to restrict subsidence to a minimum.

For deeper mines, higher percentage extraction methods such as longwalling can be used with caution and adequate monitoring of surface structures.

The practice of stowing or filling the voids created either hydraulically or pneumatically can further reduce the maximum subsidence.

Surface mining or quarrying can be planned, where economically possible, to limit the size and operation of a pit in the vicinity of inhabited areas. Time of working, the maintenance of a buffer zone, limitations on blasting, dust suppression measures and sediment traps for mine water can all be used to minimise disturbance and damage.

C. Planning Solutions

The extraction of economic minerals and rocks is regulated by a variety of local authority and government by-laws and licences.

For the purposes of this paper, only planning by use of district or regional schemes will be considered.

Where possible areas with known or inferred mineral resources, i.e. those areas in Groups 2-5, where urban development is planned or existing, should be noted as such in any plan produced.

Also where possible such areas should not be built on until the majority of extraction has taken place or at least until it can be established that future mining will not have severe adverse effects on development.

Regional requirements of industrial aggregates should also be estabished and allowances for future extraction made by reserving areas for such purposes.

In these ways multiple sequential land use can be practiced in favourable situations.

SUMMARY

It must be remembered that urban development is only one of several means by which mineral deposits can be alienated. Forestry, water storage areas, farming and communication routes can also conflict with the need to extract minerals and rock.

It should also be noted that fluids and gases, such as oil, water, steam and natural gas, are minerals and extraction of these can cause similar physical and environmental problems to the urban area to those mentioned above for solid stratified or other deposits.

Ideally a full national inventory of mineral resources should be kept and made available to local authorities for planning urban development.

Planning legislation is the simplest way to limit the adverse effects of mining in urban areas.

However the practical effect of mining and the response of surface structures to mineral extraction in the ground below and adjacent to town areas are sufficiently understood to allow development of both activities without great conflict.

FIRST DISCUSSION

- of papers by Taylor, Gulliver and Rogers; Horsley; Neall; Lensen; Fowke and Depledge.

G J Lensen (NZ Geological Survey, DSIR, Lower Hutt)

I wish to refer to section 2.2.8 of the paper by Taylor, Gulliver and Rogers which contains I believe an incomplete statement regarding seismic activity which, as it stands, could be misleading.

Their statements could be taken to imply that the Central Seismic Region of the South Island can be expected to have fewer, or less destructive, eqrthquakes than the other regions mentioned. This is not the case.

Works overseas and in NZ has shown that in many areas earthquakes appear in spasms of a few hundred years followed by tranquil periods of equal or longer duration.

Our historic record is too short for us to be sure whether particular areas are at the onset of a spasm, in the middle of one, or near the end.

Fortunately, however, displacements which have occurred during earthquakes are often preserved in the landscape: these can be identified and described by geologists where the evidence has not been destroyed by nature - by erosion or by being covered up by alluvium or colluvium. Although the crust of the earth only gives the total displacement which has occurred since a particular surface was formed, and although the times of occurrence can be gauged only approximately, the evidence we have does not indicate that the Central Seismic Region of the South Island is likely to have fewer or less destructive earthquakes than any other part of New Zealand.

J G Hawley (Aokautere Water and Soil Science Centre, MWD)

Do we have information available which would allow us to calculate the probability of an eruption of (say) the size of St Helens or larger occurring somewhere in the North Island in the next one hundred years?

Reply (Neall)

In quantitative statistical terms - no. In qualitative terms Rotorua might be the most difficult case in the world to pronounce on. It is one of the few cities which is sited within a caldera. It provides an example of the dilemma which arises where cities have been founded before the volcanic risk was appreciated. The same dilemma must arise in relation to other hazards.

J G Hawley

If people are prepared to live in Rotorua can we reasonably exclude any area of New Zealand from urban planning on the grounds of volcanic risk?

Reply (Neall)

We can expect to exclude some highly hazardous areas, such as areas of current hydrothermal activity. Once these obviously dangerous areas have been excluded the level of risk falls to the point where other factors - social, economic, and so on - can reasonably be allowed to overide that of volcanic risk.

J P Blakeley (University of Auckland, Applied Research Office)

When volcanic risk is considered in the Auckland area, it is generally associated with one of the existing sixty volcanic cones or some other local volcanic source area. I understand that there is geologic evidence in Auckland of material deposited from eruptions in the Central North Island. These must have been catastrophic events - many times greater than the St Helens event. Is there any risk to Auckland from a future such eruption?

Reply (Neall)

I think the answer to that would be that obviously there are tremendous implications when one appreciates that material reached Auckland from eruptions in the central North Island. I have spoken with the discoverer of these deposits on the question of whether the material arrived there by some sort of ground-hugging mechanism or whether it went through the air. The likelihood of something like this happening again would be extremely remote, - more remote than renewed volcanism occurring in the Auckland region. I think the thing we have to appreciate is that the spectacular nature of former eruptions in the North Island, - together with the possibility of repeat performances during our lifetimes - are part and parcel of the environment in which we live. These are things that one just has to accept, - or emigrate.

I would like to draw a distinction here. Two different kinds of study come to mind when people talk of volcanic risk. One deals with the history of volcanism, and interpretations showing which areas around a volcano have been encompassed by various volcanic processes. That is different from the question of monitoring risk once an eruption has begun. On the one hand we can only go on the volcanic history while on the other hand we can use all sorts of sophisticated measurements in the geophysical field in particular (tiltmeters and so on) to try and ascertain what might happen from day to day in such a situation, - that is volcanic monitoring.

If we are talking about planning urban development we are looking at the volcanic history of an area. That is very different from the situation which arises when an eruption is imminent, and questions arise on the whole day to day running of large areas - on identifying areas of high risk and advising on what people should do. Prior to a big eruption in the central North Island we would expect some time period of warning, pre-volcanic earthquakes and all sorts of tremors beforehand. In the case of Mt St Helens there was a period of about a week of tremors before the eruptions began and another six week period before the culminating eruption.

G E Orbell (Soil Bureau, DSIR, Hamilton)

Would you like to make any comment or extend the comments you made re Mt St Helens in respect of the waterways? If a major eruption took place in the central North Island the Waikato river would be polluted for some considerable time and this of course is now being used as a major water supply for a whole range of uses, - from human consumption through to industrial processes. How long do you think it would be before the river water was useable again?

Reply (Neall)

The North American experience showed that there are two aspects of pollution when you get a volcanic eruption affecting water supplies. They are the physical and the chemical aspects. There is no question at all that in a large number of cases it is the physical presence of that material (ash) rather than the chemical pollution which causes by far the greater problems. This was shown clearly after an eruption in Alaska soon after the second world war.

I refrained from talking about power stations on the Waikato river and the effects of power cuts on urban life as being outside the topic of this symposium. Clearly both the loss of power and the loss of drinking water would have incredible effects, and not just in the central North Island. In Taranaki most urban areas draw their water supply from Mt Egmont. A relatively small eruption there would have a very profound effect on domestic and rural water supplies.

Everything would depend on the size of an eruption: a very large one could lead to changes in river courses and that would be catastrophic in the case of the Waikato.

M J Crozier (Victoria University of Wellington, Dept of Geography)

Is it feasible to base some sort of seismic zoning on the frequency of past activity? I understand that there is an elastic rebound theory which suggests that stress builds up between earthquake events. You might then tend to classify an area that hadn't had movement recently as being more of a hazard than one that had had lots of movement recently?

Reply (Lensen)

The periods of fault movements in different parts of New Zealand are reasonably well established. They are generally of the order of once every thousand years, - on any one fault in any locality. They can vary plus or minus 200-300 years: we are never precise - the Lord doesn't leave very precise evidence behind.

In northwest Nelson (a compression region) the period can be in excess of ten thousand years while in the central volcanic region (a tension region) the period is more like 500 years.

The number of faults in an area is very significant. In the Wellington peninsula (including the east coast areas) we have six major faults. Each in turn can produce a quake of magnitude 7 or 8 or higher even. Fault movement will only affect those buildings that are built across that fault - but the shaking associated with movement will affect a larger area, and do so more often because of the large number of faults.

The historic record (as distinct from the geologic record) of fault movement in New Zealand is very short - less than 150 years. We do not know when the Wellington fault moved last. If it was 900 years ago and if (as is likely) it moves about every 1000 years then we would have reason for concern. The geological record is - fortunately or unfortunately - very imprecise about when such faults last moved.

Most of our buildings have limited lifespans of the order of 50 to (say) 200 years. The time to the next movement may be greater than this. The buildings which will be wrecked may not therefore be the ones which are straddling the fault today.

M J Crozier

How do you know whether a fault is dead or whether it is storing up stress?

Reply (Lensen)

Several ways. One is simply by monitoring the area geodetically. If stress is applied, strain must be occurring in a manner dictated by the elastic properties of the rocks: a square area becomes a diamond gradually. This is being done for the Wellington region. Between 1929 and 1969 Terawhiti moved north by 128 mm relative to the other side of the fault line. So the area is at present accumulating strain. Sooner or later it must reach an elastic limit and the fault will move again. So we know that the fault is still active.

We know also that the fault has moved 70 m over the last 20,000 years and that this movement occurred in regular steps. To plead that from now on the fault won't move any more because the Pakeha came - is ridiculous!

M T Mitchell (Soil mechanics consultant, Hamilton)

How great a distance should buildings be set back from faults?

Reply (Lensen)

The minimum width we recommend not to build on is 20m on either side, which leaves 40m clear. However where the fault trace is not just a line, where there is splaying, buckling or whatever, we recommend larger distances - say 100m or 150m clear.

There are areas in New Zealand where bedding faults occur, with say 15 traces over a distance of 1 km. As the bedding planes are parallel to the fault new ones can develop in between. In such cases we recommend that the area not be built on at all.

A J Olsen (Worley Consultants Ltd, Tauranga)

The case cited of the Totara Park subdivision in Upper Hutt, where a road was aligned with the Wellington fault so that no dwellings were built across the fault, were any special provisions made for services such as water supply, sewerage etc crossing the fault?

Reply (Lensen)

We recommend that where possible those services which had to be placed near the fault be kept fairly close to the surface so that they could be fixed more quickly.

It is generally better to arrange for services to cross the fault in such a way that when movement occurs the lines will be shortened. It is easier (quicker anyway) to take one or two pipes out and put them together again than to have to start looking for more pipes of the right size and type to stick in between. This principle of shortening applies also to telephone cables, local power lines and power transmission lines.

N Kananghinis (Deputy City Engineer Upper Hutt)

I am pleased to be able to say that the services in Totara Park have all been installed in the manner recommended by Mr Lensen and his colleagues in the Geological Survey of DSIR.

There has been comment about some houses in Totara Park having inadequately braced car parking areas beneath them. Most of these have been closed in now and firmly braced - there are only three left to be done. We had to set a new standard for the area which we could apply at the building permit stage.

C P Gulliver (Tonkin and Taylor)

Could you comment on the influence that the depth to bedrock might have on the width of a fault deformation zone as for instance in the Hutt Valley, where gravels of variable depth overlie basement rock?

Reply (Lensen)

Even if you have got a sequence of homogeneous gravels with roughly the same density as the bedrock and not waterlogged, I can see some problems. On the other hand if you have an inhomogeneous material, gravels, peats, clays, silts, and sands and a water table which is very high, and then the shape of the basement varying with say one steep side going a thousand feet down and petering out withir a few miles to zero, you get surging effects, you get compaction effects, you get ------- , you get the whole lot. If you have uniform sediments but a non-uniform depth you have problems. For example, where the basin is a half circle, the seismic energy in the basement rock all travels through the same point. This would cause a lot of trouble.

We are now talking about microzoning : there are very many factors to be taken into account - the Lord only knows how many - I guess there are 26. We know about 4 or 5 and we try to approach 3 and well, - microzoning basically is an art, - in very small letters.

M R Jessen (Aokautere Water and Soil Science Centre, MWD)

Are there standard methods available to measure the location and extent of the surface area likely to subside where the location of an underground shaft is known? If these methods are available, can they be incorporated into the planning procedures?

Reply (Depledge)

Yes, in many parts of the world the location and degree of subsidence has been predicted. An empirical formula is used based on many, many observations of subsidence: a lot of time and expense in surveying work is involved. There are many factors to be considered, - the depth to the working, the width of the working, and whether there is any "stowage factor" - that is whether you actually put anything back into the mine to reduce subsidence. The width of the working is particularly significant with new mining methods such as the 'long wall' method. Whole areas can be lowered as a result of subsidence. Parts of towns (e.g. Newcastle in Australia) have been lowered fairly successfully. In Germany mining methods have actually been used to lower a harbour. They lowered the harbour bed several metres to deepen the harbour.

J S Gandar (MWD, Wellington)

Can the authors give the symposium an idea of the frequency and extent of the effects of mining (e.g. subsidence) based on their experience in the Huntly area?

Reply (Fowke and Depledge)

The subsidence events don't happen very often. There have been none in Huntly itself in the last 15 months. There has been a lot of buckling of streets which has been smoothed over by the local council.

In Rotowaro numerous holes have appeared. One by the bowling green is causing that club a bit of trouble.

There are some time lags in this. The mines are filled with water when they are abandoned and the coal pillars which have been left start to deteriorate. The Huntly coal is weak and it deteriorates under these conditions. Collapses most commonly occur at the intersections of the (underground) roadways. Quite significant deterioration of columns can occur in 30 years. It is not a major problem at this stage, but in new mines, particularly in the east mine which we were describing in Huntly, we have to leave fairly large stable pillars under areas where there are fairly expensive buildings. These are larger than the ones left after the earlier mining operations.

We have had one instance where a stream went down a hole near an open cast mine near Rotowaro. We knew that there were old workings in the face of the mine. We were pumping water out of the mine into this stream for some time before we realised that the stream was running down a hole, through the old workings and back into our open cast area. We put 17 skips (small trucks) and many logs down the hole but they just disappeared, - tremendous suction. The answer was a $6000 job re-routing the stream.

GEOMECHANICS IN URBAN PLANNING - PALMERSTON NORTH APRIL/MAY 1981
NEW ZEALAND PLANNING INSTITUTE : NEW ZEALAND GEOMECHANICS SOCIETY

SETTLEMENT PROBLEMS - NATURAL GROUND

G E ORBELL, SOIL BUREAU, HAMILTON

Throughout New Zealand there are extensive areas of soils which have limitations for engineering use because of inherent high settlement characteristics. Two main classes may be considered.

1. Organic Soils.
2. Mineral Soils.

1. Organic Soils

There are many areas in New Zealand where organic soils (peats) are to be found. A survey of New Zealand peat resources has been carried out by A Davoren, of the Hamilton Science Centre, NWASCO. It is published as Water & Soil Technical Publication No 14, 1978. Sixty seven peatlands in the North and South Islands were investigated. These cover an estimated 1400 km^2 and have a volume in excess of 300 billion m^3. (This does not include Stewart and Chatham Islands and the region west of the main divide between Palmerston North and Wellington, which have been covered by other surveys.)

The practical engineering problems presented by peatland fall into three general categories.

Access Problems - Problems of vehicle mobility and terrain trafficability, and the interface between vehicle and terrain.

General Construction Problems

Road and Railway Construction - problems of route selection in peatland areas, stability of embankments and settlement.

Buildings - involve settlement problems.

Transmission Tower Foundations - stability and settlement as well as adequate anchors in peat.

Pipeline - problems of excavation and backfilling and access of equipment.

Airstrips - problems of embankment stability, bearing capacity and settlement.

Fire - likelihood of longlasting subterranean fires.

Water Problems

Drainage - problems of location for drainage ditches, cutbank stability and general hydrologic considerations.

Corrosion - designing protection measures for concrete and metal structures subjected to the aggressive action of peat waters.

The City of Hamilton is adjacent to some of New Zealand's largest peat bogs and significant areas of these bogs lie within the existing city boundaries on proposed extensions to the city. Past experiences have indicated that significant settlement of the peats occurs under various forms of urban development.

The collapse of road foundations has been a continuing problem especially in areas of industrial traffic. Building foundations have failed in both the residential and industrial areas. Sewage services have been lost, and relaying of sewers has been necessary where in fact "backfall" has resulted. In one subdivision all of the sewage now has to be pumped as a result of the sewer lines being placed at the base of the peat below possible gravity outfall levels.

In a specific case, Kakikalia Drive, a major road through a rapidly developing industrial area on the edge of the Rukuhia peat bog, has developed serious "waves" on its surface within five years of construction. The City Council is already contemplating reforming and resurfacing this road.

A residential subdivision, again on the edge of the Rukuhia bog, has a number of twin unit dwellings built on sand raft foundations. In at least one case the concrete fire wall between the two units has, as a result of uneven loading of the foundation, sub-divided with consequent failure of the whole structure.

In another case an industrial building built to a specific design failed where a test well had been back filled with concrete and subsequently covered with a concrete slab floor. Loading of the floor resulted in settlement of the peat and the covered concrete "pile" then punched a hole through the subsiding floor. Where structures have been built on piles which have penetrated right through the peat to solid ground below the peat, subsequent settlement of the peat has left the structures high above the lowered groundsurface.

All of the problems outlined above for large, surface peats can also apply to areas where buried peat layers exist. These have been encountered underneath alluvium (e.g. in the Hutt Valley) and beneath coastal sands which have migrated over peat swamps (e.g. in the Paraparaumu area).

2. Mineral Soils

Various special mineral soils show serious settlement problems. Soils which exhibit degrees of sensitivity, dilatancy, or thixotropy are all likely to give rise to settlement problems. Diatomaceous earths, and various weathering products of volcanic ashes are the most common pure mineral materials with high potential compressibilities, but "organic rich" mineral sediments are also important. River flats, old lake beds and other geologically young deposits are all areas where soft unconsolidated materials are likely to be encountered.

Diatomaceous earths have been found extensively around Rotorua

City and though no building failures have been directly attributed to this material it is of concern when planning land use in such areas. West of Hamilton City a section of the main highway to Whatawhata encountered sensitive material which resulted in failure of the subgrade materials in the road. The use of a filter cloth material has substantially overcome the problem.

Organic rich sediments have been encountered in various areas but especially in shallow explosion craters in the south Auckland region. These "rich" soils seem to suffer from the limitations imposed by their organic content and from certain dilatant and/or sensitivity properties. (An example will be discussed by a subsequent speaker.) These craters act as natural sediment traps which fill with fine material often incorporating a high percentage of organic material. Some such sediments have remained geologically wet and when developed for urban use undergo serious changes, mainly as a result of drainage. Dessication and compaction can result is substantial changes in the volume of the original sediment, and structures erected before these settlements are stabilized will experience very high (and probably uneven) settlements, and will usually fail. In some cases these settlements will take place quickly but, depending on the exact mineralogical composition and particle size distribution (compressibility and permeability) of the sediment, may extend over a very long time.

Conclusion

Areas of highly compressible soils can generally be detected and delineated by appropriate professionals (geologists, pedologists, geotechnical engineers et al) and structures can usually be designed for the special conditions. An exception is the buried peats which may occur in small lenses within alluvium or beneath wind blown sands: the smaller they are the more difficult they are to detect and a small highly compressible area can give rise to serious differential settlement in a building.

It is invariably cheaper to plan, design and construct with the high compressibility in mind than to have to undertake remedial action at a later date.

GEOMECHANICS IN URBAN PLANNING - PALMERSTON NORTH APRIL/MAY 1981
NEW ZEALAND PLANNING INSTITUTE : NEW ZEALAND GEOMECHANICS SOCIETY

SETTLEMENT - MAN-MADE GROUND

T J KAYES, TONKIN AND TAYLOR, WELLINGTON

1.0 INTRODUCTION

This technical review outlines two case histories. In the first, due regard was not taken of rubbish dumped and loose filling tipped over an area in the subsequent development of a subdivision and construction of blocks of flats. In the second case, involving an industrial subdivision, fill was placed to an adequate standard but without appreciation of the settlement that the fill loading would induce in the underlying natural compressible soils.

2.0 GENERAL COMMENTS

It should be appreciated that the presence of "fill" per se does not imply compressible unstable ground, as properly engineered filled ground can in fact have better strength and compression properties than the surrounding natural ground. One only has to consider earth dams to appreciate the high quality that can be designed and achieved in fills. However, it is essential that even well-engineered fill has adequate support from the underlying natural ground.

The presence of loose filling or rubbish, at some cost, also can be accommodated if due cognizance is taken of these subsoil conditions in the design of the foundations for structures. It is not uncommon to find circumstances where a previous owner has "filled in" hollows in uneven ground with rubbish, vegetation, topsoil, and then landscaped the surface. Adequate foundations then are either required to penetrate through this fill, or the fill must be processed or treated to reduce its compressibility prior to founding on it. The most vulnerable situation is where a building extends from natural ground on to a filled area, the damaging effect being the differential settlement or relative movement between adjacent parts of the structure. Many examples of this general problem, however, are small-scale occurrences on individual lots, and as such I assume to be outside the scope of the Planner. They require individual attention in the way of appropriate subsoil investigation prior to constructing the foundations.

3.0 CASE I

This particular case involves an area of land of approximately 1.2 ha, which is sited on and near the edge of one of Auckland's basalt flows. These lava flows poured out from individual vents in the volcanic field, and on cooling and solidification resulted in a hummocky, uneven rocky surface. At this particular site the ground was very rough prior to development, with large hollows in the basalt rock surface.

Prior to 1961, the landowner arranged for the hollows to be filled over a period of time, principally with waste Gibraltarboard from a nearby manufacturing plant. Once the hollows were filled, he arranged for the loose fill to be covered with a layer of clay type fill. Subsequent investigations revealed other rubbish including car bodies in the underlying fill. At the completion of this work he sold the land to a developer (Sydney Construction) in 1961, informing them of the filling which he had placed. Roading was formed, and nine or ten blocks of flats were designed. Building permits were granted in 1965, issued subject to compliance with the Council's bylaws, which included a requirement that foundations be taken down to a solid and approved bottom. However, foundations for the blocks of flats were constructed at shallow depth. During construction, the Council's inspector apparently inspected the foundation trenches prior to pouring of concrete.

The history of legal action to date centres around a flat in one of the blocks which was sold in October 1966, soon after which cracks appeared in the walls. At the purchaser's request, Sydney Construction arranged for six underpinning piles to be constructed and the cracks to be filled. The original purchasers sold to a Mr and Mrs Harris in 1968, who in turn sold to a Miss Johnson in 1970, who knew nothing of the underpinning work, and noted the flat to be in excellent condition. However, cracks appeared towards the end of 1970, becoming worse in 1971, and subsequent continuing differential movement caused the floor to slope, window frames to jam and warp, and the front steps to tilt away from the house. Legal action was commenced in December 1973. The cause of the differential movement was readily established as inappropriate foundations to support part of the block of flats on the inadequately compacted and uncontrolled fill. The foundations should have comprised piles taken through the fill to solid natural ground below.

Legal action was taken by Miss Johnson against the Mount Albert Borough Council, with Sydney Construction as second defendant. The judge found Sydney Construction to be negligent in failing to ensure that the foundations were adequate, and thought that in view of their knowledge of the extensive filling it was the company's responsibility to undertake a series of test bores in order to avoid the very obvious risk that the foundations would rest, even in part, on unstable soil. The judge found that the Council was negligent in failing to exercise reasonable care in the issuing of a building permit (the part on the form requiring a description of the soil was left blank), and in failing by their authorised officer to observe the inadequacy of the foundations upon inspection, having regard to the knowledge of the Council of the unstable ground. The two defendants were found to be equally liable.

The judge's decision was taken to Appeal in 1979, where the apportionment of liability was amended to 80 percent against Sydney Construction and 20 percent against the Mount Albert Borough Council. It is possible that the case may be taken to the Privy Council, although I understand that this is still being considered.

The deficiency of the foundations was not confined to the flat owned by Miss Johnson and many of the blocks of flats in the subdivision have been subject to considerable differential movement. There is little doubt that, depending upon the outcome of the

Johnson case, numerous other legal actions by owners in the street will follow. The considerable degree of damage sustained by some of the blocks of flats has been compounded by their form of construction, being concrete masonry and brick veneer which are "brittle" and have very limited ability to tolerate differential movement.

A general lesson from this case history would be that there are many locations in New Zealand where there have been rubbish dumps, waste from saw-milling operations, old shafts and mining workings and other legacies of the activities of our predecessors. More often than not, details of these sites are known and recorded in some form. This information should be collected, collated and brought to the attention of the parties who become involved in the sites, as part of the planning process.

4.0 CASE 2

The second case involves part of an industrial subdivision in Manukau City which extends across an old explosion crater. The crater originated when molten basaltic rock below the earth's surface came in contact with groundwater which vaporized, resulting in a violent explosion. The deep crater which formed subsequently became infilled with organic deposits. European settlement saw the development of the area as farm land and the "peat swamp" in the crater was drained. However, even with the drainage system, springs emitted water from the crater rim during winter, at which time the surface of the swamp became too wet to drive on with a tractor.

In 1969 approximately 0.9 m depth of fill, taken from the rim of the crater, was placed across the floor as part of the development of the area as an industrial subdivision. Stormwater and sewer lines were laid and streets were developed, extending partly on to the floor of the crater. The subsequent settlement due to the weight of the fill was dramatic, the most noticeable effect being settlement of the roads, as fortunately building on the lots on the crater floor did not follow immediately. Investigation of the subsoil conditions revealed up to 6 m depth of soft fibrous peat underlaid by highly compressible, very soft organic silt extending to a maximum depth of 20 m. Analysis, based on laboratory test results, indicated that settlement of the ground by up to 1.4 m over a 10-year period, would result from the loading of the 0.9 m fill depth. Insitu pore pressure measurements and surface settlement records confirmed this trend.

The crater floor was not suitable for development within the industrial subdivision, without particular special treatment. Either all buildings would require to have been founded on long piles at considerable expense, or alternatively, settlement could have been induced in advance of building by "preloading" the floor with in excess of 3 m depth of fill and/or artificially lowering the groundwater table. This latter approach, however, would have meant delays in building by up to ten years, while waiting for sufficient consolidation of the compressible organic soils to take place.

It is interesting to note that information was available, even without subsoil investigations, suggesting the compressible nature of the crater infilling. For example, Ferdinand von Hochstetter's geological map of Auckland of 1859 labelled the crater as "Styak's Swamp". The lesson is perhaps similar to the first case - information and records exist pointing to many of the areas where hazardous subsoil conditions exist. This information should be one of the inputs into the planning process.

GEOMECHANICS IN URBAN PLANNING - PALMERSTON NORTH APRIL/MAY 1981
NEW ZEALAND PLANNING INSTITUTE : NEW ZEALAND GEOMECHANICS SOCIETY

LANDSLIDES IN THE URBAN ENVIRONMENT

M J CROZIER, VICTORIA UNIVERSITY OF WELLINGTON

Introduction

There is not a great deal written on the nature and significance of landslides within the New Zealand urban setting. This is partly because most of the country's landslides occur in rural areas and partly because the state of our scientific knowledge still has us pursuing basic questions on causative factors and fundamental mechanisms. Out of the 130 or more publications on mass movement in New Zealand (Selby, 1976) only a few discuss landslide activity in the urban setting (e.g., Auckland: Wright, 1966; Wellington: Eyles, Crozier and Wheeler, 1978; Dunedin: Abbotsford Commission, 1980; Nelson: O'Riordan, 1973; general: Taylor, Hawley and Riddolls, 1977).

What literature there is allows us to put the urban landslide problem into some perspective within the country as a whole. Probably hundreds and sometimes thousands of landslides occur throughout New Zealand every year: most are small, unrecorded and occur unseen in rural and steepland areas. The potential for damage and casualties is therefore high but the current risk is low because of the country's low population density (12 persons/km^2). By comparison, Japan, with a population density of 310 persons/km^2, has about 90 people killed every year by debris avalanches (Ashida and Takahashi, 1981), in a physical environment and terrain with many similarities to that of New Zealand.

Even within the more densely populated urban areas of New Zealand, our relatively short urban history has provided only a few instances of disasterous landslide activity. In only a few cases have death or catastrophic damage resulted from landslide activity; for the most part landslides cause isolated property damage or disruption to services. Some of the costs of landslide damage are identifiable and cumulatively quite high (Figure 1); others are well hidden. Clearance of debris from a driveway and installing a crib wall may, for example, represent only some of the costs borne by an individual houseowner; the psychological concern over what might happen, and the drop in market value of the property are others.

The nature of slope instability in New Zealand makes it inevitable that some of these costs must be borne directly or indirectly by the community. But the type and level of these costs can be controlled by the appropriate use of scientific data in the planning process.

Planning Requirements

In dealing with the slope stability problem there are two principal areas of concern which must be addressed by the planner. The first is the characterization of the terrain in terms of its stability conditions and the second is the question of how slope instability should be accommodated with respect to potential land use. The most important information required and the options to be considered in the planning process are as follows:

A. Stability Conditions

1. The degree of slope stability, i.e. the frequency of present landslide activity on the likelihood of landslide occurrence.
2. The effect of a proposed landuse on accelerating or inducing slope instability.
3. The type of landslides (actual or potential; particularly the rate, depth, duration, volume and mechanism of movement).
4. The likely consequences of instability. This relates to the site conditions (e.g. over what distances will debris travel and hence what sort of danger zone should be demarcated?) and the cultural conditions (e.g. what is the intensity of habitation or vulnerability of landuse within the zone of influence of a landslide?)
5. The degree of instability which can be tolerated by various landuse activities.

B. Planning Options

1. Permanent avoidance of unstable areas.
2. Temporary avoidance of unstable areas: e.g. evacuation with the onset of critical conditions (as is practised in Hong Kong after cumulative rainfall values have reached a certain threshold conditions) or seasonal use of certain areas.

3. Prevention of potential landslides with the use of engineering structures.
4. Control of landslide activity, e.g. installation of rock fall shutes, debris run-out areas, tree planting to reduce movement rates.
5. The acceptance of landslide activity and damage, with a) community responsibility for the consequences and rehabilitation, e.g. local bodies repairing damage or financial compensation through insurance schemes etc., or b) individual landowners assuming responsibility for repair and rehabilitation.

Slope Instability

Only the first two topics from the foregoing list will be discussed: viz. assessment of the degree of slope stability and the effect of urbanization on slope stability.

Landslides are the manifestation of instability which is brought about by a change or disturbance to the terrain. If the landscape is free from disturbances, either natural or cultural, the geomorphic processes in operation work rapidly to remove unstable conditions. Landsliding is thus a self-annihilating process - it works to produce lower or gentler slopes, upon which, given enough time, landslides can no longer occur. The first task of a land-use planner then should be to determine which terrain is presently within a state of disequilibrium and which is adjusted to the prevailing environmental conditions. There is some terrain in New Zealand which is inherently so unstable or for which the consequences of instability are so great that human occupance must be ruled out.

The costs involved in carrying out a comprehensive geomechanical stability analysis are such that the initial survey of any large area is best achieved through the field and aerial assessment of stability indicators - a topic well covered in the literature (Eckel, 1958; Taylor et al, 1977; Crozier, 1981). The most useful way of presenting this aspect of stability assessment is in terms of the frequency of occurrence (Table 1). Unfortunately the data base for such an approach is extremely limited and indirect methods need to be employed. A promising method being used in stability assessment of this type relies on the fact that most landslides in New Zealand are triggered by intense rainfalls or unusually wet conditions. Through the use of a water balance model based on readily available climatic data and the record of landslide activity for various regions, Crozier and Eyles (1980) have been able to identify sensitivity of various regions to triggering conditions by determining the climatic thresholds required to produce landslides. By linking this information into terrain classifications, such as the 'N.Z. Land Resource Survey' and by applying frequency/magnitude analysis to the climatic record for the terrain concerned, a classification of slope stability can be established on the basis of probability of occurrence. Important data on the type of movement: rate, duration, depth, material and mechanism can then be superimposed on this classification.

The next task for the planner is to determine what degree of landuse change can be tolerated by the terrain without either accelerating or inducing slope instability. From the study of landslide activity within New Zealand cities, certain terrain modifications accompanying urbanization have been identified as contributing to slope instability, including:

1. increase in the angle of slope
2. exposure of rock surfaces
3. surcharge of slopes
4. creation of textural discontinuities
5. localization of runoff
6. change in the vegetation cover
7. the production of unconsolidated material.

Slope failure occurs when these modifications either increase the level of stress on the slope beyond the resistance which can be mobilized or when slope resistance decreases below the prevailing stress levels. Most urban hill country has undergone, at least with traditional methods of land development, both an increase in mean slope angle and increase in the number of individual slope facets. If a slope is steepened beyond its minimum stability angle a 'short term' or 'end of construction' failure will result. This sort of problem is soon discovered and rectified during the earthwork phase of development. In the months following the formation of a slope, increased drainage from the freshly cut slope and consequent lowering of the water table is thought to strengthen the slope.

If a slope is stable at the end of construction it is therefore often considered to be stable in the long term. However, the continual failure of cut slopes in Wellington, for example, shows this not to be the case. The cutting of a face in fact removes the insulating regolith and re-exposes the slope material to active weathering processes. The action of these processes along with unloading tends to open the joints, destroy cohesion, increase the void space and reduce internal friction to some sort of residual value. The slopes, with time, become ripe for failure during a triggering rainfall which previously might have had little effect.

Although long-term failures of this sort are most common, stress induced failures can result from over-zealous ditch digging operations causing the oversteepening of the toe of an otherwise well designed slope, or from the home handyman digging out the bank at the back of his section for barbecue area or the like.

Concentration of runoff onto one part of a slope is recognized as one of the principal factors in initiating movement on both natural and modified slopes. Urban surfaces shed water and systems are designed to localize and remove the increased runoff produced. With time, however, stormwater drains either deteriorate or become overloaded with the consequence that sufficient water is spilled onto a slope to destabilize it.

Another consequence of urban earthworks which tends to localize gravitational water within the slope is the creation of textural discontinuities. The effect of this is particularly noticeable in areas of gully fill. In certain instances water tends to move at the contact between the emplaced material and the former slope. Eluviation in the zone of contact can weaken the bond between the two materials and eventually lead to evacuation of the gully fill.

In most instances the maintenance of a strongly rooting, actively transpiring vegetation cover enhances slope stability by providing root cohesion and reducing the levels of antecedent moisture. However, where a slope consists of steep open-jointed rock there is evidence to suggest that woody species with a large biomass are in fact detrimental to stability.

Conclusion

Evidence suggests that as our urban environments age and urbanization continues to take place, both the incidence and costs of landslide activity will increase. However, enough information exists to provide planners with at least an appropriate approach to minimizing the consequences of slope instability. The success of such an approach will depend on the degree to which it is adapted by both authorities and individual inhabitants as well as to continued scientific research into urban slope stability problems.

TABLE 1

SLOPE STABILITY CLASSIFICATION: FREQUENCY AND POTENTIAL CRITERIA

Class I	Slopes with active landslides. Material is continually moving, and landslide forms are fresh and well-defined. Movement may be continuous or seasonal.
Class II	Slopes frequently subject to new or renewed landslide activity. Movement is not a regular, seasonal phenomenon. Triggering of landslides results from events with recurrence intervals of up to five years.
Class III	Slopes infrequently subject to new or renewed landslide activity. Triggering of landslides results from events with recurrence intervals greater than five years.
Class IV	Slopes with evidence of previous landslide activity but which have not undergone movement in the preceding 100 years. *Subclass IVa* Erosional forms still evident *Subclass IVb* Erosional forms no longer present - previous activity indicated by landslide deposits.
Class V	Slopes which show no evidence of previous landslide activity but which are considered likely to develop landslides in the future. Landslide potential indicated by stress analysis or analogy with other slopes.
Class VI	Slopes which show no evidence of previous landslide activity and which by stress analysis or analogy with other slopes are considered stable.

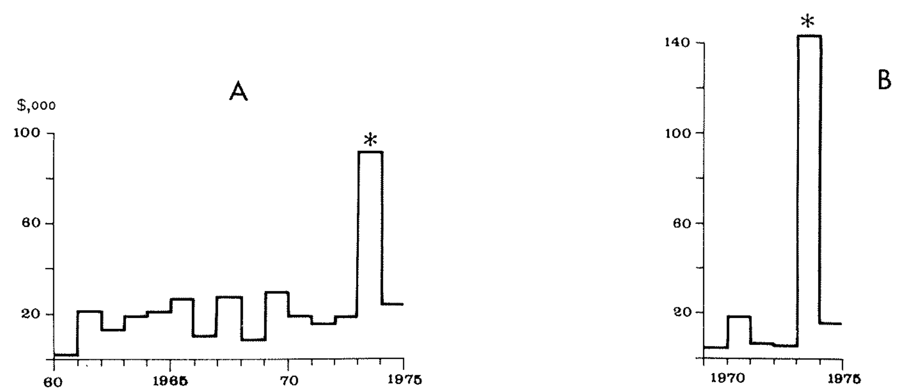

FIGURE 1 A: Wellington City Council expenditure on slip damage (standardized to 1965 values by wholesale price index.

B; Number of claims for slip damage in Wellington City made to Earthquake and War Damages Commission. (Eyles *et al.*, 1978)

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GEOMECHANICS IN URBAN PLANNING - PALMERSTON NORTH APRIL/MAY 1981

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A SLOW MOVEMENT LANDSLIP IN A HILLSBOROUGH SUBDIVISION, AUCKLAND

C P GULLIVER AND D K TAYLOR

TONKIN AND TAYLOR, AUCKLAND

As an example of a slow movement landslip in an urban area I would like to briefly describe stability investigations within a 39 lot subdivision known as Stephen Lysnar Place, in the suburb of Hillsborough, Auckland.

In October 1973 a purchaser of one of the lots in this subdivision asked Tonkin & Taylor for an opinion as to the stability of his lot. During the course of inspection signs of large scale slope movement were recognised which affected not one, but a number of the undeveloped lots on the subdivision. The matter was reported to the Earthquake and War Damage Commission who in turn engaged our firm to carry out an investigation of the areas. The investigations included drilling, testing, aerial photo examination, groundwater observations and the installation of surface movement markers.

Slide 1

The investigation identified two areas of probable old instability which predated subdivision development. In one of these areas, covering six lots, ground movements had been reactivated since subdivision, the other area of five lots appeared not to have moved significantly.

Slide 2, 3 and 4

Drilling proved the ground profile to consist of a thin upper layer of tuff underlain by about 4 to 10m of weak Pleistocene clays and silts which in turn were underlain by sandy silts of the Waitemata Formation which graded into more cemented sandstones and siltstones at depth. Groundwater levels were generally near to the surface.

It became evident that fairly deep seated slow movement was occurring, possibly along an old slip surface. Further investigations and a period of surface movement monitoring was recommended to the Earthquake and War Damage Commission to enable better definition of the slip areas and provide a basis for design of remedial work, prior to allowing any building to proceed on the worst affected lots.

The Earthquake and War Damage Commission decided not to accept responsibility for further investigations and exercised its powers not to cover building on the affected land against damage by landslip. The local body declined to issue permits for buildings on the land unless owners absolved the Council of responsibility should any failure occur. To-date the six worst affected lots have not been built on.

In 1978 funds were made available, to treat the Stephen Lysnar subdivision as a research project in view of recurring problems of slope failure in urban subdivisions.

Further investigation work was then undertaken which included more drilling, soil testing, piezometer and inclinometer installation. Ground movements which had taken place since the initial investigation were measured and these indicated that in places up to 0.6 metres of downhill movement had occurred over the preceding six year period.

Slide 5

The more detailed investigations and inclinometer results enabled the slip surface to be defined with reasonable accuracy and showed that significant ground movements were occurring to a depth of about 6 metres.

Slide 6

Standpipe and sealed piezometer measurements indicated that a contributing factor to the instability was a very high groundwater level in the hillslope and that artesian pressures were present to a slight extent.

Clearly, remedial work in the form of deep soil drainage to lower groundwater levels would be the most appropriate measure to control further movement, perhaps together with some slope regrading to redistribute soil loads. Horizontally drilled relief drains or deep trench drains were envisaged. Any such remedial work would still require a period of observation and ground movement monitoring, before deciding how effective the work had been and whether building could be permitted to proceed with certain restrictions.

The latter part of the Stephen Lysnar investigation was undertaken as a research project, which was in part sponsored by the Ministry of Works and Development in view of the recurring problems of slope failure in urban areas. A number of conclusions were drawn from the investigation in response to specific questions posed in the research brief.

The investigation demonstrated that sampling and effective stress testing followed by stability analyses, would not have defined the extent of the problem in the subdivision prior to development. Inclinometer and piezometer observations defined the geometry and mechanics of failure after it had occurred, but the results of effective stress testing and analysis did not correlate with the obvious instability. Thus the results of such analysis prior to failure would have been highly uncertain and probably would not have justified the high order of cost in obtaining the results.

However, what can be done relatively cheaply prior to land development is to objectively examine the surface geology and topography as well as aerial photographic records, for signs of instability. Where instability is detected then subsurface investigation, testing and analysis may do much to clarify basic causes of instability and indicate remedies, but they are unlikely to be conclusive enough to obviate the necessity of precise surface movement monitoring which could extend over several years.

Clearly a responsible subjective decision has to be made whether suspect land should be included in the development of an area.

The brief for the Stephen Lysnar investigation included consideration of possible alternative courses of action which might have been taken if stability problems had been appreciated at the outset. The subdivision was actually approved by the local Borough Council and title given to the building lots before land instability was suspected. Obvious instability now affects six of the 39 lots and five other are on land where continuing instability is possible but has not been demonstrated.

Alternative lines of action which could have been taken were:

(a) not subdivide and turn the whole area into reserve. This would involve some loss to the land owner and local body revenue, but provides a public amenity,

(b) subdivide but exclude unstable lots which become reserve area. This provides reasonable return to the subdivider, provides a small public amenity and involves a small loss of Council revenue,

(c) complete the subdivision including stabilisation of the affected lots prior to sale. This would give a lower return to subdivider than in (b),

(d) complete subdivision and sell lots, investigation and stabilisation at purchaser's cost. This gives a high return to the subdivider, but very high cost to purchasers of affected areas, both in monetary terms (cost of remedial work estimated as $6,000 to each affected land owner) as well as a very considerable social cost arising from long delays in resolution of the problem.

Clearly the worst thing that can happen in such a subdivision is that instability is not recognised until lots are sold and investigations and remedial costs must be borne by the unfortunate land owners. This is assuming also that stability measures are successful, which may not necessarily be the case and could result in far greater loss to purchasers.

The Stephen Lysnar example is unfortunately only one of many such legacies around the country which serve to demonstrate how essential it is that land proposed for urban development is subjected to engineering geological examination and that any signs of superficial instability are taken very seriously. A value judgement is needed to decide the appropriate extent of subsurface investigation but this will depend upon:

1. the significance of possible ground movements to the ultimate land owners,
   and
2. the extent to which the investigation and stabilisation costs can be spread over the total development, and the total acceptable cost on this basis.

These judgements must be made with a clear sense of responsibility to the community.

Ministry of Works and Development

Ministry of Works and Development

SECOND DISCUSSION

- of papers by Orbell; Kayes; Crozier; and Gulliver

I M Grierson (Harrison and Grierson, Auckland)

Mr Orbell has outlined the risks associated with peat soils - volumetric change and the subterranean fire hazard. Does he consider that the construction of the high pressure Maui gas pipeline through peatlands poses an unacceptable and foreseeable risk?

Reply (Orbell)

I expect that the pipelines are placed below the permanent water table in most places - in which case the questions of settlement and peat fires do not arise. Where the pipeline is to be in peat and above the permanent water table I would think that the problems of settlement and of peat fires should be considered and designed for.

Because the pipeline is hollow it has some buoyancy and should not be exerting large compressive forces on the peat beneath - so the settlement problem may only arise after (slow) combustion of peats beneath such a line, - and this can only occur if the peat dries out.

Another factor is of course, corrosion. Many of these peats have low pH's (3.5 to 3.8) so steps must be taken to protect the pipeline from corrosion.

R High (MWD, Auckland)

Is there a rule of thumb method or a simple test which enables one to set lateral limits on ground subsidence in peatland following construction of a trench drain?

Reply (Orbell)

Recent work at Waikato University (using Tritium tracing methods) suggests that water does not move more than 1 metre laterally in any peat. However the lowering of the water table extends asymptotically back a very long way from a drained or open trench - in time. No, I don't know of any rule of thumb. The simple test of course is to monitor levels of the groundwater.

G L Lensen (NZ Geological Survey, DSIR, Lower Hutt)

One of the major concerns of the engineers in Hamilton City Council, I know, is the way that peatland is likely to react under seismic conditions. We have a situation there of course where you have the under-mass, which has its own period of vibration. You have a peat mass which is largely a fluid material which has a different period and you have a set of piles standing below the house or the structure (if it is piled) which has its own response period and at the junction of those piles to the structure above it, you have a horizontal weakness because they are non-continuous piles. I would like to know what is likely to happen because so far geophysicists haven't been able to tell us what is likely to happen under that set of conditions under any energy input that goes into it.

Reply (Orbell)

One thing that I did not mention in my paper was a situation which occurs around Rotorua city. We have there some substantial deposits of the material known as 'diatomaceous' earth. Diatoms are small plant-like organisms which grow in silica rich waters. After our major rhyolitic type eruptions, there have been a massive growths of diatoms in the shallow lakes and swamps. These things accumulate as a sediment. Whether they are a mineral material or whether they are organic is open to some conjecture but they do have some most peculiar properties. They are dilatant and they are sensitive. If you take a handful of the stuff which is solid and just bounce it in your hand it will suddenly turn to a liquid and pour through your fingers. We have areas of Rotorua city already built on this material, we have areas zoned for industrial and commercial use on this material, areas where high, larger structures are likely to go with heavy machinery moving down the roads - heavy trucks. Perhaps some of the engineers might like to predict what is going to happen to some of those buildings on that diatomaceous earth material when an earthquake occurs.

The interesting thing is that parts of Rotorua city are already on it and there have not, to date, been any failures. But the material does have this very peculiar composition and mechanical behaviour.

N S Luxford (Babbage Partners Ltd)

Has any means been found whereby you can treat 'Gib-board' fill so that you can develop over an area like the one in Mt Albert? Considerable land areas exist which have such filling.

Reply (Kayes)

Treatment at Mt Albert after development would have been 'not on', - prior to development it would have been very difficult because of the undulating surface with isolated pockets of fill. Excavation and compaction of the 'Gib-board' would have been very expensive.

It must be kept in mind that the 'Gib-board' may be undergoing some collapse of structure as a result of the actions of both the groundwater and the overburden. I am not aware of any way of treating such a fill economically, i.e. in situ, and I would be very interested to hear from anyone who is.

J G Hawley (Aokautere Water and Soil Science Centre, MWD)

This situation (Mt Albert) would perhaps be one where the local body could require (at the building permit stage) that structures be designed to cope with the situation - either by driving poles (or piles) through the compressible materials or by allowing only wooden houses (e.g. weatherboard) to be built. It is usually a very simple and cheap matter to jack up a few of the bearers under a wooden house by a centimetre or two, and the weatherboard construction need scarcely suffer at all. Concrete framed, and in particular brick-veneered, houses are a different matter altogether.

It would be nice to know whether such 'Gib-board' materials dissolve in water over long periods and whether large settlements could accumulate in the longer term. Some groundwaters may be more dangerous than others in this regard.

J P Blakeley (University of Auckland, Applied Research Office)

I would like to speak to Mr Kayes' paper and in particular to the human side of the unfortunate events that we have been considering. Urban planning is surely not concerned only with roads and buildings but also with people's lives. Individual people suffer tremendously as a result of these misfortunes since their home is generally their main security and investment. Providing homes are adequately insured, when one of these misfortunes occurs the lucky people are often those whose homes are "written off" so that they can start life afresh. The unlucky people are those who have to live in a house which they cannot sell and which may be unsafe. They have to live with its deterioration while legal action takes its course, which may be many years.

With particular reference to the Mt Albert situation, I was asked to examine one of the home units owned by an elderly lady in the early 1970's soon after the problems became really evident. She showed me some of the damage to the other units in the same block and very soon I had a dozen people, mainly elderly ladies, all talking to me in a most animated way about the damage being suffered by their properties. As noted by Mr Kayes, that development was specifically designed for elderly retired people.

Nearly ten years have since elapsed and these elderly people have had to live with this problem with the buildings deteriorating further and to date they have been able to get no legal redress. They cannot sell at a reasonable price and find somewhere else to live. They have thus been forced to live in this situation by the decisions of other people. This shows how, when errors are made in making decisions about residential developments and the construction of houses, peoples lives can be greatly affected, even if they suffer no physical injury.

J C van Amerongen (Aokautere Water and Soil Science Centre, MWD)

In the last year in the Netherlands there have been about 30 former refuse tips which have been considered dangerous. All the houses either have to be broken down or all the soil has to be dug up and all the refuse from underneath. This is mainly because of dangerous chemicals being dumped there illegally by companies: after a few decades the drums and containers started to leak. Is there anything in New Zealand being done on that? We might get the same problem here?

J Griggs (Northland Catchment Commission)

This question of waste disposal has been a major issue in the Flaxmere situation in Hawkes Bay. The question of pollution of aquifers by the refuse tip on the plains has been a serious one.

Chairman Although the siting of rubbish tips is clearly a very real issue in urban planning and although there is undoubtedly a very real geotechnical dimension to the problem, I don't think that we can do justice to it in this discussion. This is a topic for another symposium.

B W Riddolls (Investigation Geology Ltd, Auckland)

Dr Crozier listed various planning options where slope instability could occur, ranging from avoidance, to acceptance of possible damage.

I would suggest another option which involves planning the layout of the various components of a subdivision once the existence of a particular hazard has been identified so that, should minor movement occur, it will not be aggravated by the way the area has been developed. For example, major sewerage or water supply systems should not be located close to potentially unstable ground, because any minor movement can readily lead to leakage thereby causing more serious problems. In other words, it is possible to live with some hazardous conditions by designing in relation to them, rather than avoiding them altogether.

J P Blakeley (University of Auckland, Applied Research Office)

Mr Gulliver states that his investigation showed that sampling and effective stress testing followed by stability analyses would not have defined the extent of the problem in the subdivision prior to development. This highlights a problem faced by the geotechnical engineer as to whether he can rely on his stability analyses carried out in accordance with accepted practice. Could Mr Gulliver or Mr Taylor state what the results of conventional stability analyses actually were, and what investigations and analyses prior to subdivision development may have shown up the stability problem?

Reply (Taylor D K - co author/investigator with Gulliver)

The point is that it would be necessary to get into something of the order of $20,000 worth of drilling, sampling, effective stress testing and slope stability analysis in order to do justice to the 9 or 10 sections involved, and even then you may not have detected the weakest surfaces or the weakest geometry of movement.

Quite apart from the cost, this business of pre-failure analysis is much more difficult than post-failure analysis when at least you do know the geometry of the failure.

In the case described we could see the outline of failure on the surface and we thought we could make a good guess as to where the bottom of the slip circle was - and we concentrated our efforts on "undisturbed" sampling in that zone. In spite of that we didn't manage to get samples which we could demonstrate to be weak enough to explain the failure. How we would have managed had we investigated beforehand, before the failure developed, I just don't know. It would have been a very expensive process or else the problem would have remained undetected.

The situation became more clear after we put in piezometers - sealed piezometers designed to show the pressures in confined aquifers. We also had (in the later work) the benefit of inclinometers which revealed the pattern of distortion within the soil. These gave a clear indication of the position of the failure surface.

The only other thing we could reasonably have done would have been residual strength tests - which involve even more expensive testing.

R High (MWD Auckland)

Although the effective stress tests and analyses did not indicate failure conditions, were your results and your knowledge of the soils such as would suggest that strain-softening had occurred and that residual strengths would have been relevant at the time of movement?

Reply (Taylor)

Our peak values for ϕ' were between about 31^0 and 37^0 and a back analysis indicated that a ϕ' of around 18^0 must have been prevailing in the ground. Yes, for these materials a residual value of 18^0 is quite possible. We did not go on to measure it because the tests we did were getting very expensive, as they were.

The real question here is - Is it worth spending all that money and effort when you could have got a good indication of the unstable nature of the ground from a study of old aerial photographs? I am asking the question. If people want to engage us to do that kind of work I guess we will do it. But it does become expensive and the results may prove to be inconclusive.

My theme is that we should take much more serious note of the surficial signs of instability and be prepared to make judgements on the basis of those signs. This may mean placing more reliance on the things which the geologists, engineering geologists and the pedologists can tell us and placing less reliance on laboratory strength testing.

J G Hawley (Aokautere Water and Soil Science Centre, MWD)

I see this as a key issue because I see courtroom situations arising in which the question will be asked "Did you take samples and do strength tests?" A professional witness who replied "No, - we simply examined the old (and the new) aerial photographs, conducted an examination of the ground surface and put in a few post holes", could sound as though he had failed to do the obvious thing i.e. sample the soil and measure its strength.

I feel that we should be very grateful to Messrs Taylor and Gulliver for providing us with this example of how inappropriate the laboratory strength testing approach can be in the urban development situation.

N S Luxford (Babbage Partners Ltd)

I agree with the last statement about the degree of testing appropriate in such situations.

I would like to ask however whether it is possible to know about the existence of artesian pressures (which the authors regard as having been very significant in the case described) without installing piezometers - i.e. just by looking at the air photos, the topography and so on?

I have looked at a number of situations where appreciable artesian pressures would have had to occur to cause the slope failures but where the stratigraphy had not given any obvious indication that that was the case.

Reply (D K Taylor)

Yes, in the case described our knowledge of the artesian pressures began with the installation of the piezometers. It was obvious when we first saw the site (after serious movements had begun) that there was a lot of water on the surface. As soon as we drilled holes for our piezometers water overflowed - out onto the surface.

We suspected the existence of high water pressures then but it was only after having had fairly sophisticated piezometers in for some time that we were able to put any numbers on them. Such pressure can vary seasonally of course and with the weather.

I agree that it would be difficult to gauge the likely significance of artesian pressures in a new area - you can only go on the surface conditions and on what the geologists and soil scientists can tell you about how that piece of the landscape ha been formed.

GEOMECHANICS IN URBAN PLANNING - PALMERSTON NORTH APRIL/MAY 1981
NEW ZEALAND PLANNING INSTITUTE : NEW ZEALAND GEOMECHANICS SOCIETY

DISPERSIVE LOESSIAL SOILS OF THE PORT HILLS, CHRISTCHURCH

D H BELL, UNIVERSITY OF CANTERBURY

1. INTRODUCTION

Expansion of urban Christchurch has led to the development of many steep erosion-prone sites on the Port Hills, the upper slopes of which are blanketed by wind-blown silty soils *(loess)* that accumulated during cold-climate episodes over the past million or so years. *Loess-colluvium* deposits characterise the lower slopes of the Port Hills, and have formed by the intermixture of eroded loess and weathered volcanic bedrock in layered fan-like aprons up to 20m thick (Fig 1A; Fig 2B). In common with many hillside areas *landslips,* involving sliding and/or flowage of soil and weathered rock, may be triggered during abnormally wet periods, or by occasional high-intensity rainstorms: such slope failures present obvious hazards to urban (and rural) land-users on the Port Hills. However, an equally serious problem for planners and land-users is *tunnel-gully* development, in which subsurface erosion forms pipe-like tunnels (or "under-runners") that enlarge until collapse of the bridging soil mass results in open gullies (Fig 1B and C; Fig 2C and D). Not only is engineering expertise required in developing sites that have already been badly gullied, but also the potential for tunnel-gully development in previously uneroded loessial soils *as a consequence of urbanisation* places considerable responsibility on the controlling local authorities. In this brief review I outline the nature of dispersive soils and methods for their identification; urban instability and planning problems on the Port Hills which result from dispersion and erosion in loessial soils; and remedial and construction practices which have been devised to allow safe development in these soils.

2. SOIL DISPERSION AND TUNNEL-GULLY DEVELOPMENT

Dispersion is a property of certain fine-grained clay mineral-bearing soils, in particular those which contain an excess of sodium ions in water held in void spaces between the soil particles. Such soils may consist predominantly of clay-size particles (which are by definition finer than 0.002mm), or the clay mineral aggregates may act as "binders" for the coarser (silt and/or sand) particles which provide the granular load-bearing skeleton of the soil mass. On immersion in water the soil structure breaks down as the clay minerals disperse into their ultimate particle sizes, and a cloudy suspension forms in which interparticle electrical repulsion prevents gravitational settling (Fig 4A). Dispersive soils are relatively widespread in New Zealand, as evidenced by tunnel-gully and/or sheet and rill erosion (Fig 2E) in hill country pastures developed on loess and loess-colluvium. Piping failures in earth dams constructed from dispersive soils, in which initial clay mineral dispersion may be followed by seepage path enlargement and physical erosion of the core materials, are an engineering problem of world-wide concern (Sherard et al. 1973; 1974).

In the loessial soils of the Port Hills *tunnel-gully* development in natural ground (Fig 1B and C) is a complex process involving *seepage waters* from either natural or "artificial" sources); *dispersion* of the clay mineral fraction (to form initial subsurface flow paths); tunnel enlargement by *slaking* (in which positive void air pressures cause collapse of the granular soil skeleton); physical *erosion* of collapsed debris within the tunnel (by intermittent water flows); progressive *growth* of a tunnel network and partial roof collapse along the tunnel alignment (causing subsidence of the ground surface); and ultimate *collapse* of the bridging soil mass to form open gullies. On bare ground in similar loessial soils *sheet* erosion by overland flow of water results in the formation of *rill* gullies by the same mechanisms (dispersion, slaking and physical erosion), and problems may be initiated by *cut-slope* development (Fig 1A) or "topsoil" stripping (Fig 2E). Since recompaction of soils does not alter their dispersive properties (although see Schafer 1978), *backfilling* with potentially erodible loess is likely to result in serious tunnel- or rill-gully problems (Figs 2C and F). It is not that loessial soils have inadequate strength as foundation materials, since suitably drained vertical cut batters stand safely to heights in excess of 10m: rather, dispersion is an inherent property of *only some* loessial soils, and their identification is necessary for sound urban development.

3. IDENTIFICATION OF DISPERSIVE SOILS

Field identification of dispersive loessial soils involves careful observation of natural slopes and exposed soil profiles (Fig 2A) for evidence such as the existence of open gullies (Fig 2B); the presence of shallow and/or deep tunnels; rill gully development on bare slopes (Fig 2E); and the presence in seepage or ponded waters of discolouration due to clay mineral particles in suspension. Commonly only one or two layers within the soil profile will show tunnel development, whilst erosion-resistant layers frequently provide a local base level to open- or rill-gully formation (Fig 2D). Site-specific geotechnical models (such as Fig 4C) can thus be formulated as a basis for development recommendations and construction practices.

Laboratory techniques to identify dispersive soils were originally developed for the prediction of potential piping failures in earth dams (Sherard et al. 1976a and b). The pinhole erosion test has since been adapted for use with Port Hills loessial soils (Evans 1977), and erodibility classification (Evans and Bell, in press) is based on observed flow rate and the nature of any sediment discharge at each test head (Fig 3A). Laboratory data can thus be integrated with field information on profile layering (such as standard penetration test results) to refine the geotechnical models for eroded sites (Fig 4C), and to predict future problems at previously uneroded sites (Fig 1A).

4. URBAN PROBLEMS AND LAND-USE PLANNING

Erosion problems caused by urban development practices on the Port Hills had become sufficiently serious that on 30 January 1976 *North Canterbury Catchment Board* invoked powers available under Section 34 of the Soil Conservation and Rivers Control Amendment Act (1959). This action was taken during a period of abnormally wet winters and associated *landslip* problems (Bell 1978), although one of its prime intentions was to control erosion (and siltation) caused by residential developments in *dispersive* loessial soils. These latter problems included gullying (both surface and subsurface) of stripped (i.e.*cut*) ground and compacted *fills* (Figs 2C, D and E): scour of backfilled *service trenches* (Fig 2F); house foundation instability and structural damage resulting from ground *subsidence* above active tunnel-gullies; discharge of *sediment* and water into basements, stormwater systems, etc; and the triggering of damaging *landslips* by the concentration of subsurface water flows into fills, etc (Fig 1A).

Since 1976 North Canterbury Catchment Board has prepared a 1:15840 *Relative Soil Stability Map* (Fig 3B) as a guide for urban development on the Port Hills, and has established the *Port Hills Erosion Committee* to advise on residential development practices in dispersive loessial soils. *Catchment Board consent* is still required for any excavation or filling likely to cause erosion or siltation of a natural watercourse on the Port Hills, although *Council byelaws* covering such development practices are now operative. Soil, regolith and erosion mapping at 1:10,000 has been completed by *NZ Soil Bureau* (Trangmar, in press), and relevant data is being incorporated into the various *District Schemes* as they come up for review. The *NZ Geomechanics Society* has been active in the organisation of seminars and public lectures on Port Hills erosion problems, and a major publication on the subject will shortly become available. Extensive research into *chemical stabilisation* of dispersive loessial soils has been carried out by Mr G L Evans, a consulting engineer formerly of Christchurch, and this work is continuing under my supervision at the University of Canterbury.

5. CHEMICAL STABILISATION OF DISPERSIVE SOILS

Engineering design and construction practices in dispersive loessial soils require particular attention to existing surface and subsurface drainage paths, and to the potential for tunnel-gully initiation as a consequence of excavation or filling (Fig 1A). Maintenance of adequate *vegetation* cover is necessary to minimise sheet and rill erosion, and to prevent deep shrinkage cracking and possible tunnel formation above or below the fragipan horizon. The development of many steep, erosion-prone sites on the Port Hills has become feasible with the use of *pole-frame houses* to minimise disturbance of the natural ground. However even with these precautions the properties of the loessial soils remain unchanged: there is always a potential for subsurface erosion if water gains entry to a dispersive soil layer.

Research completed to date (Evans and Bell, in press) has shown that additions as low as 0.5% by weight of *hydrated lime* [$Ca(OH)_2$] render dispersive loessial soils non-erodible (ND1 classification, Fig 3A), although a minimum of 2% is required to eliminate shrink/swell behaviour. A maximum dry strength about 10 times that of the untreated loess is achieved at 5% lime addition, whilst the saturated strength of the treated soil is 3 to 5 times that of the untreated loess, which itself collapses on immersion in water due to loss of shear strength (Fig 4A). Similar results have been achieved with *phosphoric acid* (H_3PO_4) additions to dispersive loessial soils, and both chemicals have been tested successfully in field situations (Evans and Bell, in press). Currently experimental backfilling of a sewer trench using excavated dispersive loess recompacted with hydrated lime is under evaluation (Fig 4B), and lime-stabilised loess is being used increasingly to prevent scour of cut-off drains in both natural and filled ground (Fig 4C). Maximum strength gain is achieved at or dry of the optimum moisture content for the untreated soil (usually about 14%), and this does present some practical problems in mixing and compaction: however, in situations where the only requirement is to prevent soil dispersion, the use of chemically-stabilised loess-slurries is likely to prove satisfactory.

6. CONCLUSIONS

1. Tunnel-gully formation in Port Hills loessial soils is a complex process involving clay mineral *dispersion, slaking* and physical *erosion:* sheet and rill erosion and tunnel-gully development can both be initiated in

natural ground or recompacted fills as a consequence of urban construction practices.

2. Potentially dispersive loessial soils can be identified by use of the *pinhole erosion test*, and site-specific geotechnical models thus determined by integrating field and laboratory data: design and construction practices should minimise interference with actively eroding or potentially erodible foundation materials.

3. *Zoning* of land on the Port Hills proposed *for urban development* must be based on detailed mapping of soil and regolith types, erosion features, and geotechnical characterisation: avoidance of major earthworks on steep badly-gullied slopes is to be preferred, whilst any residential subdivision in dispersive loessial soils requires careful control at all stages of planning and development.

4. *Chemical stabilisation* (especially the use of hydrated lime) can modify the erodibility characteristics of dispersive loessial soils, and remedy or prevent many of the past erosion problems on the Port Hills: suitable field techniques have been developed for backfilling of service trenches and cut-off drain construction, and the strength gain in chemically stabilised loess can also be utilised.

7. ACKNOWLEDGEMENTS

I gratefully acknowledge:-

1) Sources of unpublished information - North Canterbury Catchment Board (Fig 3B); Christchurch Drainage Board (Fig 4B); Corsair Bay Society (Fig 4C).

2) Photographs - G.L. Evans, Consulting Engineer (Figs 2D and F); W.F. Rennie, N.Z. Soil Bureau (Figs 2C and E); D.H. Saunders, North Canterbury Catchment Board (Figs 2A and B).

3) Additional photography by A. Downing and R.D. James; drafting by L.V. Leonard; typing by W. Nuthall.

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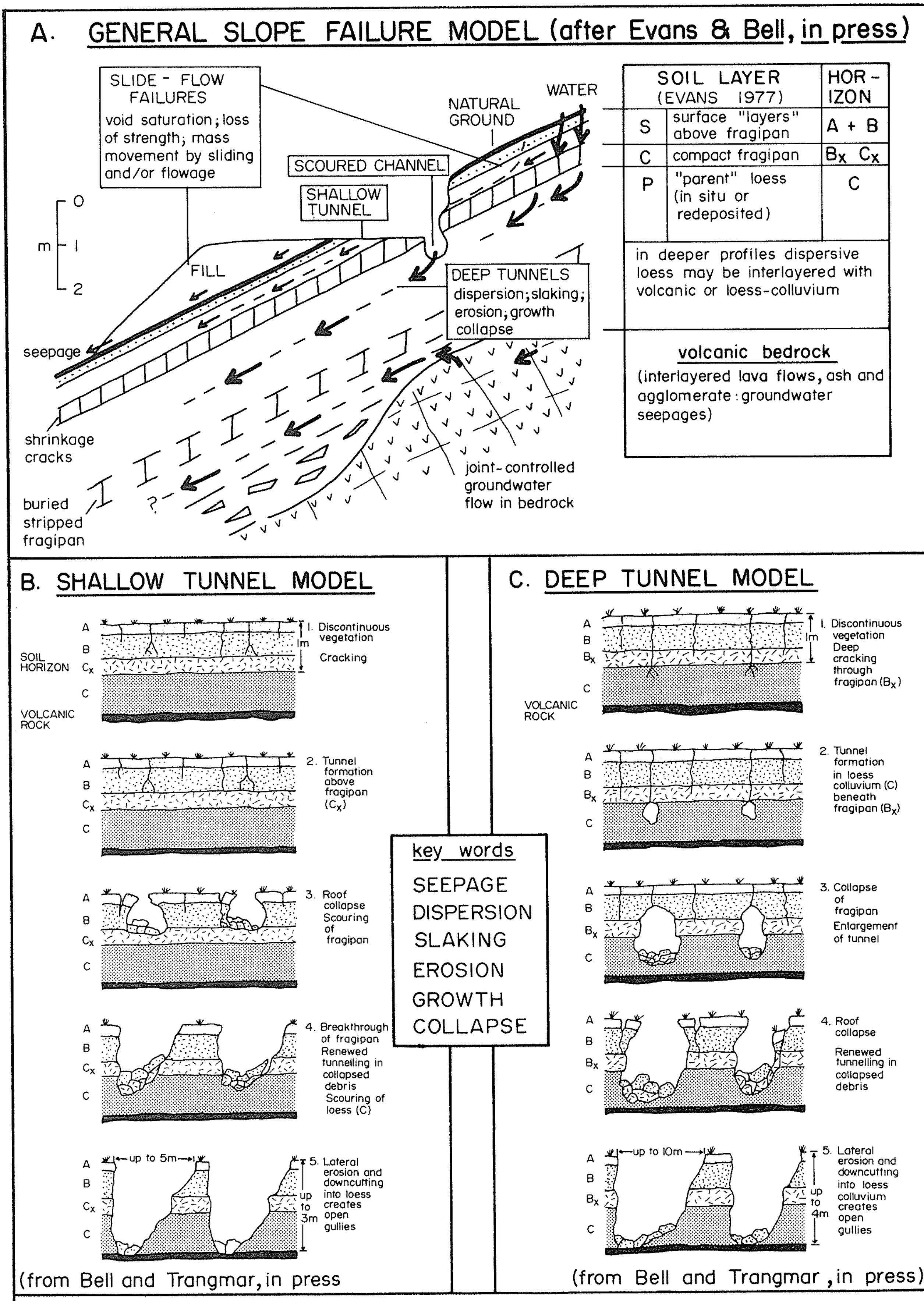
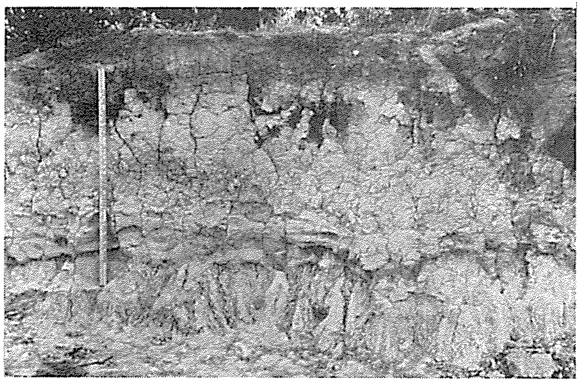
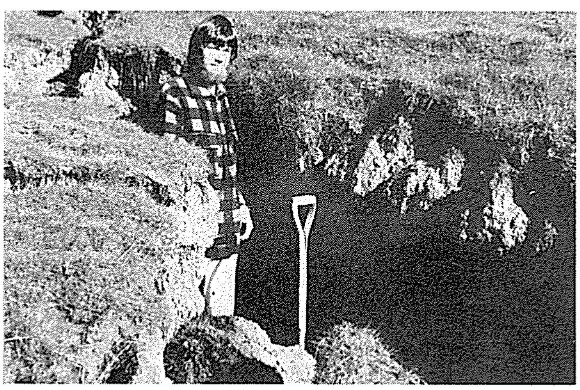


FIG. 1: TUNNEL-GULLY DEVELOPMENT MODELS

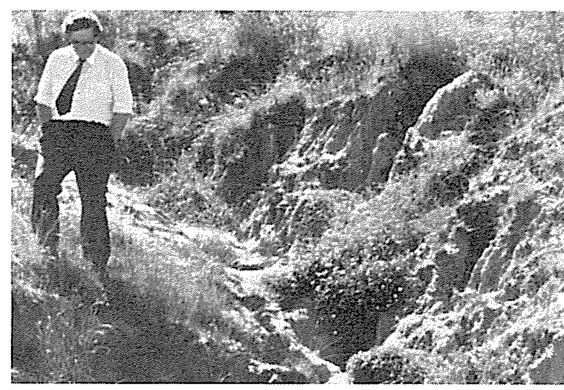


A. TYPICAL PROFILE IN LOESS
(note soil layering and shallow tunnel-gullies)

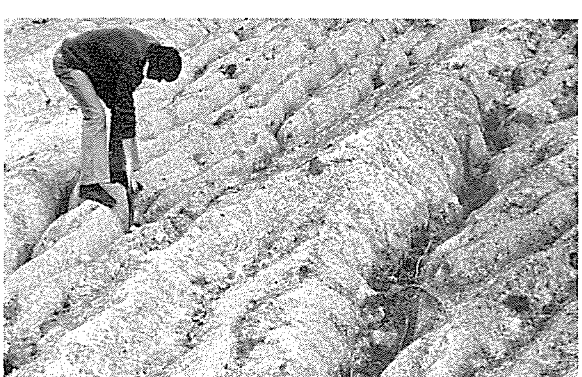
B. DEEPLY ERODED LOESS-COLLUVIUM SLOPES
(development limited to four sections in lower "fan" area)



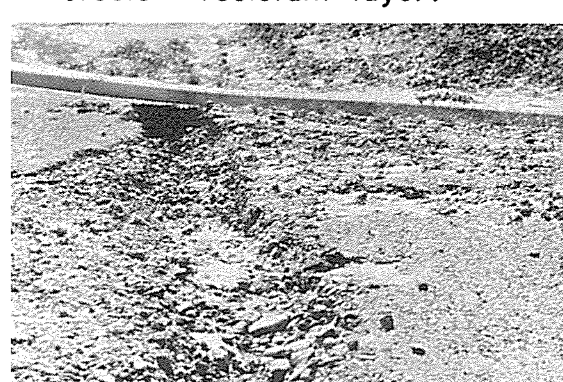
C. TUNNEL-GULLY COLLAPSE IN ERODIBLE LOESS
(used as fill during residential subdivision)



D. SCOURED CUT-OFF DRAIN IN ERODIBLE LOESS
(trench has gullied down to an erosion-resistant layer)



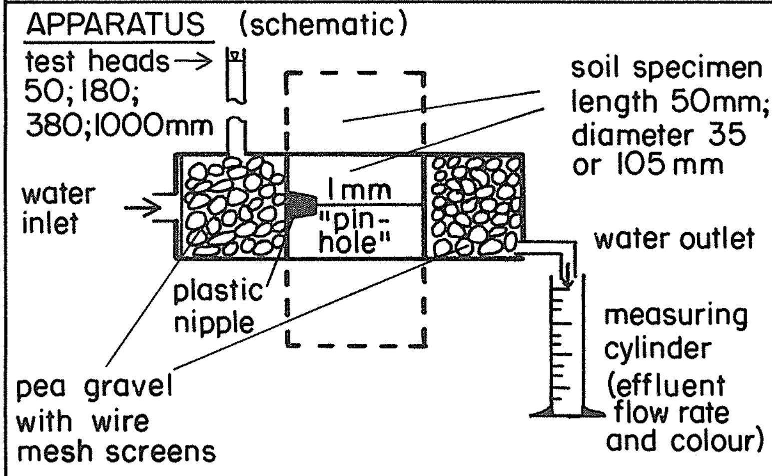
E. RILL EROSION OF 20° SLOPE AFTER STRIPPING
(rills up to 1·5 m wide and 0·8m deep)



F. SERVICE TRENCH FAILURE AFTER BACKFILLING WITH ERODIBLE LOESS (trench acts as channel-way for water flows)

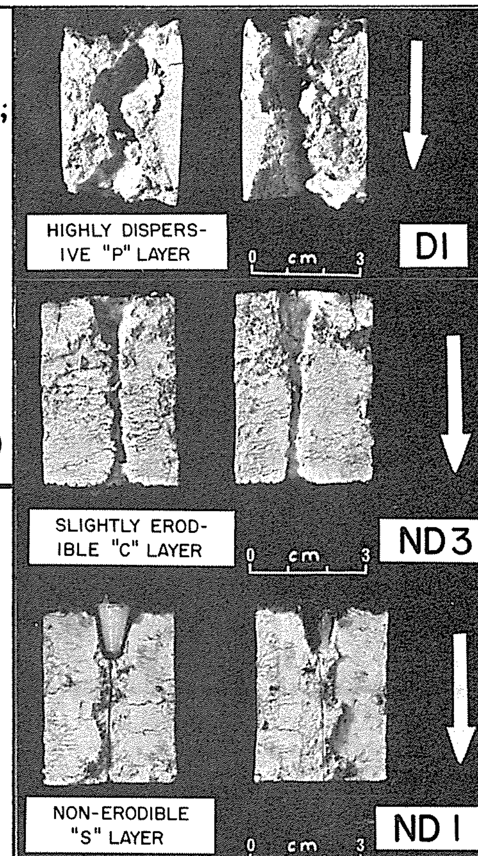
FIG. 2: TYPICAL EROSION PROBLEMS IN DISPERSIVE LOESSIAL SOILS

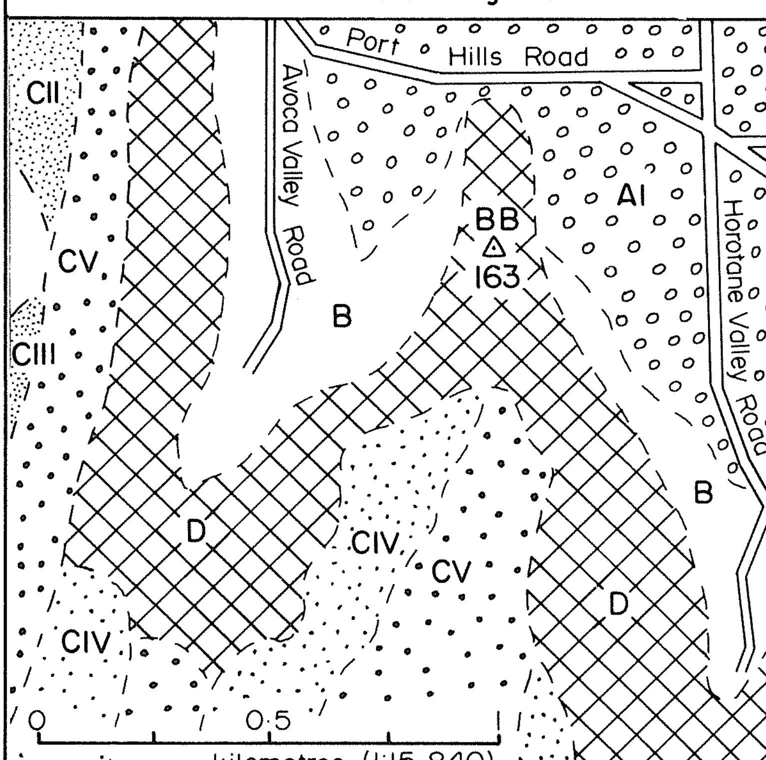
A. LABORATORY PINHOLE TEST FOR DISPERSIVE SOILS



CLASSIFICATION (Evans and Bell, in press)

- D1 rapid erosion and dispersion at 50mm head
- D2 erosion and dispersion to 180 mm head
- ND4 erosion but no dispersion – hole enlarges
- ND3 hole enlarges slowly – may stabilise
- ND2 slight erosion with increasing head
- ND1 no erosion with increasing head





B. RELATIVE SOIL STABILITY MAP

(NORTH CANTERBURY CATCHMENT BOARD)

PART OF LEGEND

Risk Category		Regolith Type	Slope	Erosion Problems
VERY SLIGHT	AI	alluvium	flat	F
	AII	alluvium	flat	W
SLIGHT	B	loess ± colluvium	7 – 13°	A
	BI BII	loess	3 – 13°	S + W
	BIII	bedrock	3 – 20°	——
MODERATE	CII	loess	13 – 20°	T ± S
	CIII	loess / bedrock	13 – 28°	L
	CIV	loess / bedrock	20–38°	T + L
	CV	colluvium / bedrock	20–38°	L + S
SEVERE	D	loess	18 – 28°	T + L

F = flooding
A = aggradation
L = landslip
W = wind erosion
S = sheet erosion
T = tunnel-gully erosion

FIG 3: LOESS ERODIBILITY AND LAND-USE PLANNING ON THE PORT HILLS

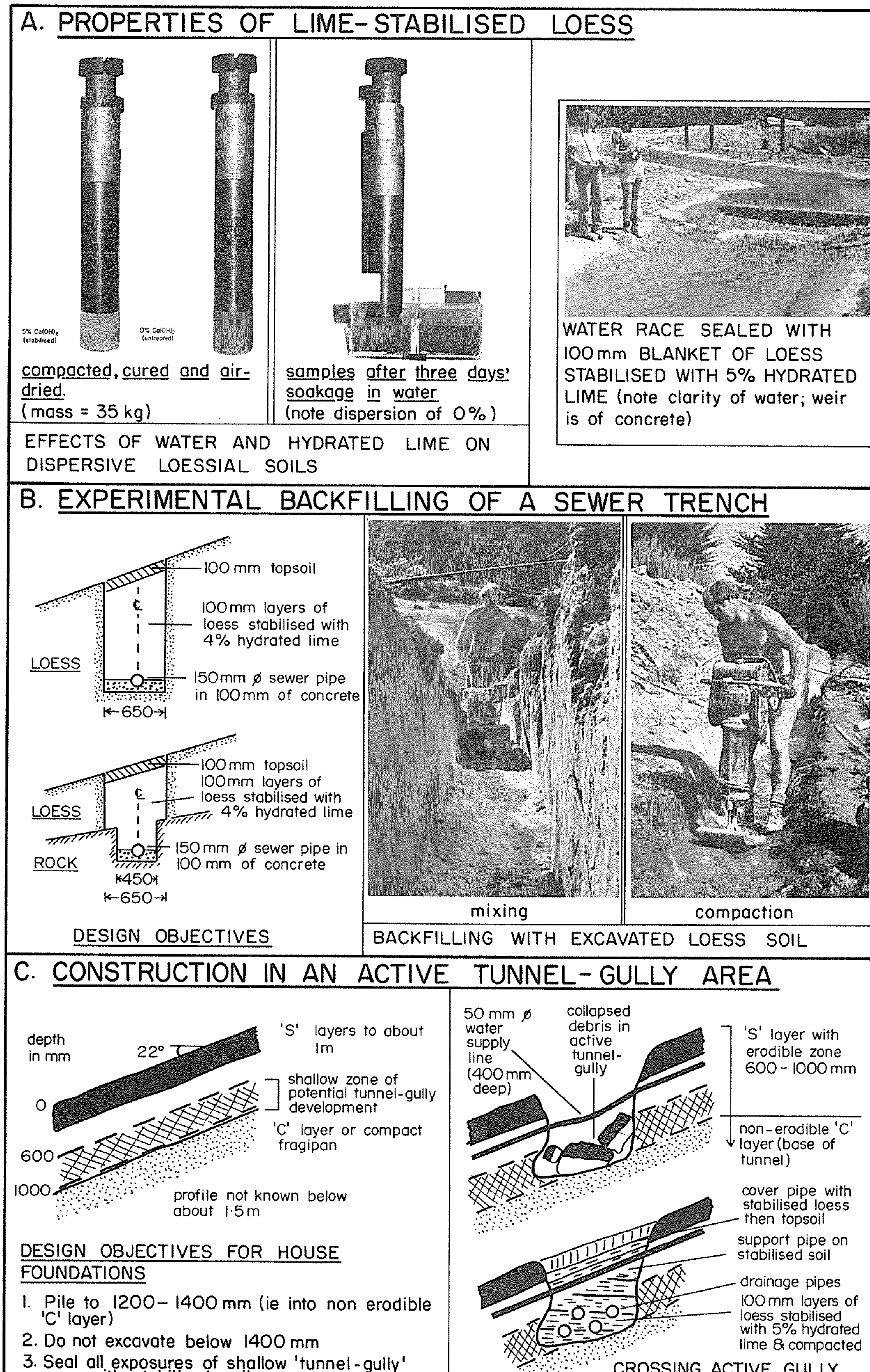


FIG. 4: CHEMICAL STABILISATION OF DISPERSIVE LOESSIAL SOILS

GEOMECHANICS IN URBAN PLANNING - PALMERSTON NORTH APRIL/MAY 1981
NEW ZEALAND PLANNING INSTITUTE : NEW ZEALAND GEOMECHANICS SOCIETY

SHRINKAGE AND SWELLING OF CLAYS

M A WESSELDINE, MANUKAU CITY COUNCIL

1. INTRODUCTION

The shrinkage and swelling of clay soils are important considerations in the design and construction of 'minor structures' within the urban environment. Such a classification would include one and two-storey residential dwellings, apartments, flats and motels. These structures account for approximately 75% of all building permit activity of local authorities in New Zealand.

The problems associated with buildings constructed on clay soils which are subject to seasonal volume changes relate predominantly to the interaction of the foundation of the structure and movements of the clay soil. This paper reviews the literature relating to factors which produce volume changes in shrinkable clays, the extent of such clays in Manukau City together with suggested design procedures for minimising the problem.

2. FOUNDATIONS

The British Standards Institute Code of Practice for Foundations[1] defines a foundation as ... "that part of the substructure in direct contact with and transmitting loads to the ground." When designing foundations, there are two criteria which must be considered and satisfied separately:-

(a) There must be an adequate factor of safety against a bearing capacity failure in the soil.

(b) The settlements, and particularly the differential settlements, must be kept within reasonable limits. Foundations for minor structures will generally be of the following types: pad, raft, slab, pile or continuous strip footing. In the Auckland region the most common form is the reinforced concrete strip footing having dimensions of 400 mm wide by 300 mm deep with (typically), four 12 mm diameter bars and 6 mm diameter stirrups at 600 mm centres.

The location and particularly the depth of the foundation transition structure is governed by a number of different and unrelated factors. These are given by Professor Leonards [2] and Winterkorn, [3] and include the following:

(a) Depth of soil subject to large volume changes due to seasonal moisture changes
(b) Depth of topsoil or other organic materials
(c) Location of water table
(d) Location of poor or better underlying soil strata
(e) Depth of frost action
(f) Adjacent structures, property lines, excavations, and future construction operations.

3. <u>SOIL MOVEMENTS</u>

Most soils are subject to wetting and drying cycles corresponding to seasonal changes. Some types of clay soil show marked swelling with increase of moisture content followed by shrinkage after drying out. In the Auckland region the clays showing this characteristic are mainly the plastic clays developed by the weathering of the Waitemata Series, sandstones and siltstones. Clays with shrinkage problems also occur in Pleistocene sediments and in clays overlying the Onerahi Chaos Breccia, North of Auckland.

Professor Leonards [2] describes the phenomena thus ...

"in regions which have well defined alternatively wet and dry seasons, susceptible soils shrink and swell in regular cycles. Beneath the centre of a building where the soil is protected from both the sun and rain, the moisture changes are small and the soil movements the least. Beneath the outside walls the movements are the greatest. The result is racking, differential movement and progressive damage.

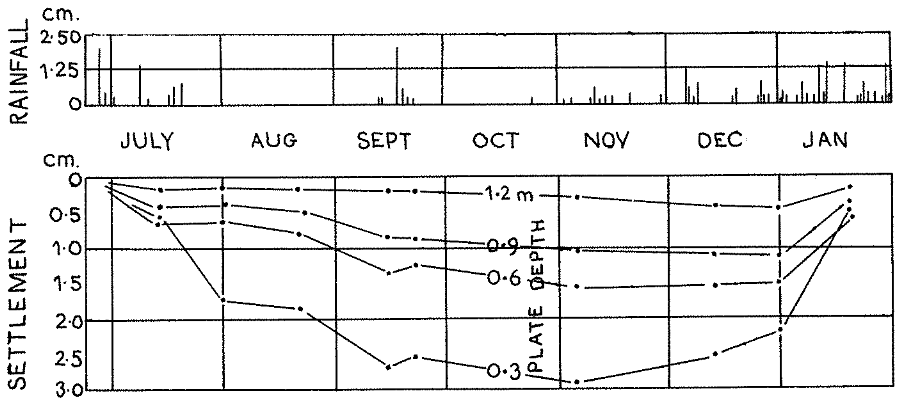
In arid regions where the soils are normally dry, the problem is somewhat different. Added moisture from leaking pipes and irrigation or the reduction of evaporation caused by the presence of a building or sealed pavement, can bring about swelling and heave. When the source of moisture is eliminated, the movement will reverse, causing the same racking of structures as the seasonal volume changes.

In humid regions where the soils are ordinarily moist, severe dessication may cause susceptible soils to shrink and bring about severe settlement of structures. Unusally prolonged periods of drought have produced settlements of structures which have stood for years without any sign of distress.

Accelerated dessication accompanied by rapid and irregular settlement can be caused by many local conditions such as by heat from boilers, oven and furnaces that are inadequately insulated from the ground. In numerous instances moisture used by vegetation has resulted in accelerated soil dessication. Large trees and even some shrubs and field crops are capable of removing sufficient amounts of moisture from soils to cause settlement of foundations placed above or adjacent to their major root systems."

The significance of high volume changes in susceptible soils can be best illustrated by reference to figures I and 2 below, taken from a research paper by Dr W H Ward [(4)]. Figure I shows the results of measurements made by the Building Research Station at Garston, Hertfordshire, on plates buried at various depths below the ground surface.

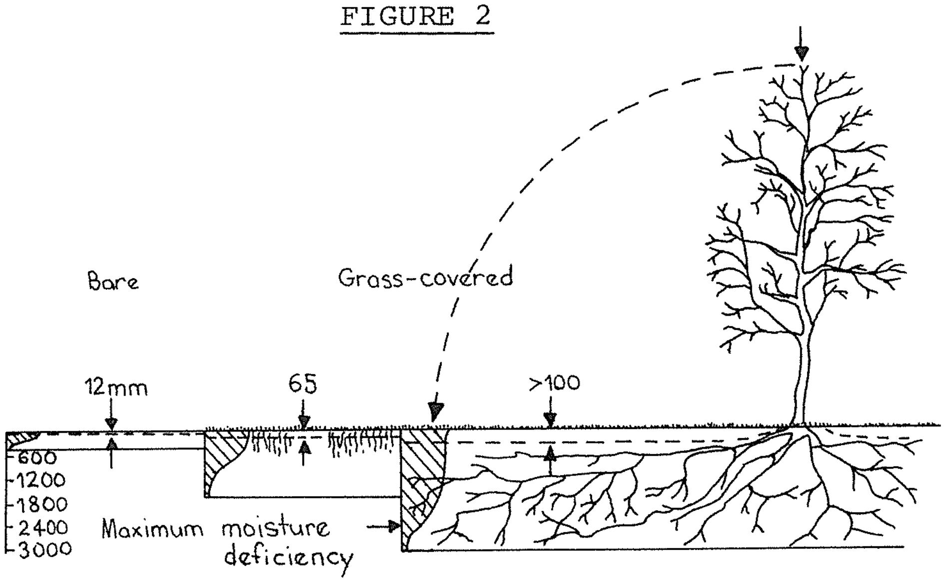
FIGURE I



VERTICAL MOVEMENTS OF BURIED PLATES

(adapted from reference (4))

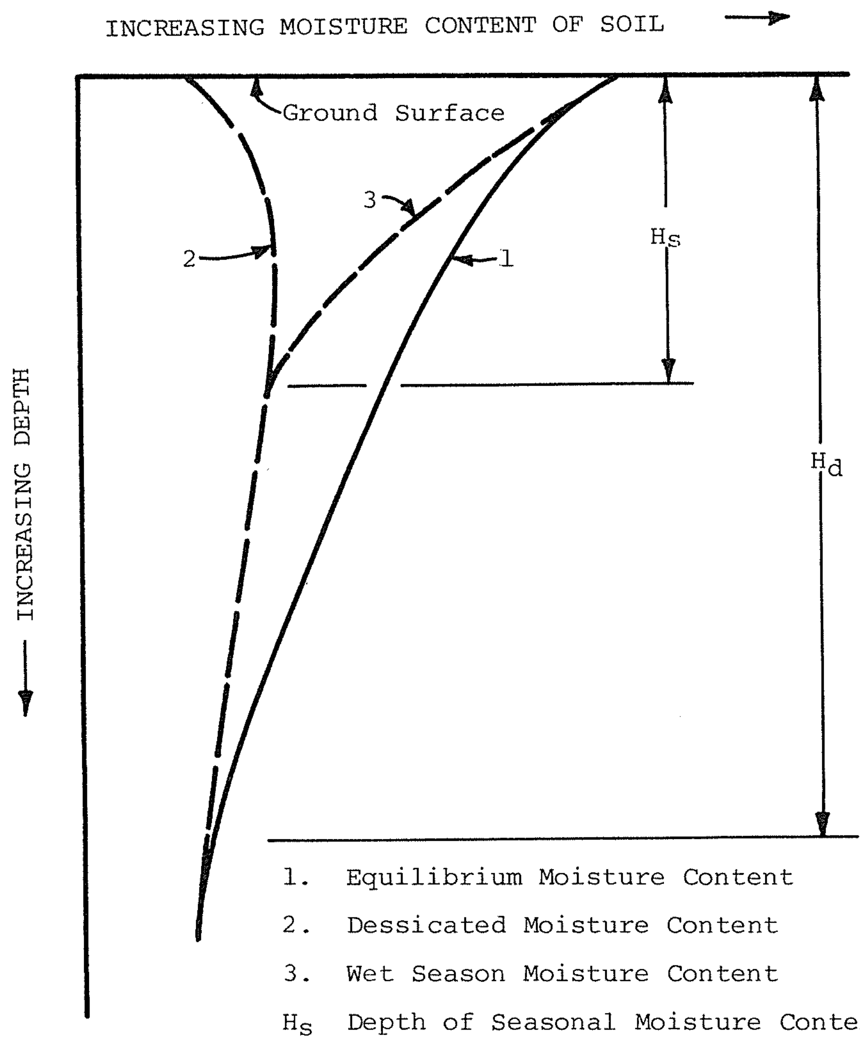
FIGURE 2



EFFECT OF VEGETATION ON MAXIMUM MOISTURE DEFICIENCY AND SURFACE MOVEMENTS OF HEAVY CLAY

(adapted from reference (4))

Figure 2 above "... conveniently summarises the depth and extent of ground movements and moisture deficiency in shrinkable ground, which is bare, covered with grass and adjacent to an isolated tree.



1. Equilibrium Moisture Content
2. Dessicated Moisture Content
3. Wet Season Moisture Content

H_s Depth of Seasonal Moisture Content Fluctuation

H_d Depth of Dessication

Figure 3: Moisture content variation with depth below ground level

Kraynski (5) explained the moisture content variation with depth in a homogeneous soil by figure 3. In a covered area, the moisture profile is shown by curve 1. There is no gain or loss of moisture to the atmosphere. The moisture content of the soil decreases with depth. Curve 2 indicates the moisture content variation with depth in the same area in uncovered natural conditions. Evaporation causes loss of moisture in the soil near the ground surface. However, the influence of evaporation decreases with depth and at some depth, H_d, the moisture content equilibrium remains the same as the covered condition. Kraynski referred to this depth as Depth of Desiccation. The value of H_d depends of the climate condition, the type of soil, and the location of the water table. This depth represents the total thickness of material which has a potential to expand because of water deficiency. It is impossible to determine the value of H_d. The hotter and drier the climate, the greater the depth of desiccation. The maximum depth of H_d is equal to the depth to the water table, and the minimum depth is equal to the depth of the seasonal moisture content fluctuation described below.

During wet months with heavier precipitation and higher humidity, the moisture content of near-surface soil increases and the moisture profile represented by curve 2 alters its shape to curve 3. The upper portion of curve 3 can extend beyond curve 1 in very wet seasons and behind curve 1 in dry seasons. The depth of seasonal moisture content fluctuation, H_s, indicated in figure 3 depends on the variation of surface moisture, permeability of the soils, and climatic conditions. In areas where precipitation and evaporation are fairly constant, the H_s depth may be less than 1 metre. When a long drought is followed by an intense rainfall, the H_s depth can reach 3 metres or more.

It should be noticed that in the above evaluation of the depth H_s no consideration has been given to the man-made environment. The watering of lawns, planting of trees and shrubs, discharge of roof drains, formation of drainage channels and swales, and the possibility of utility line leakage will all increase the value of H_s. It is not uncommon that H_s depth can reach as much as 8 metres.

4. CHARACTERISTICS OF SUSCEPTIBLE SOILS

It has been shown that the use of the term 'susceptible soil', relates predominantly to volume change. Volume change in a soil mass due both to natural and artificial causes introduces problems peculiar to soils that are not encountered with other construction materials. Volume decrease is caused by load; it is a function of time; it is associated with changes in water and air content; and it is produced by rolling or vibration. Volume increase is a function of load, density, water content and type of soil.

There are special terms used to describe each of these different volume change phenomena and these are listed below as given by the 'Earth Manual' (6)

Compression defines the volume change produced by application of a static external load.
Consolidation defines volume change that is achieved with the passage of time.
Shrinkage is the volume change produced by capillary stresses during drying of a soil.
Compaction is the volume change produced artificially by momentary load application such as rolling, tamping, or vibration.

The foregoing terms apply to reduction in volume. Corresponding terms that apply to increase in volume are:

Rebound as opposed to compression
Expansion as opposed to consolidation
Swell as opposed to shrinkage
Loosening, scarifying or similar terms describing the operation used in opposition to compaction
Heave is used to describe volume change produced by frost action or expansive soils.

In reviewing the literature on shrinkable clays, it has been noted that an equivalent discussion and attention has been focused by the various authors on, also, the mechanics of swelling. Indeed, the majority of papers researched on building damage were attributable to expansive clays. It has been claimed that shrinkage is the mirror reflection of expansion. The scope of such technical discussion is beyond the intention of this paper.

It will suffice to say that in relation to the mechanics causing building damage the recognition and properties of both expansive and shrinkable clays are similar.

Such clay soils are in the texts variously described as "shrinking" "plastic", "expansive", "active" or "heaving" clays. Their world-wide distribution includes the State of South Australia, South-east England, Texas, Cuba, South Africa, Canada, Burma, Nigeria and New Zealand.

Professor Teng [7] succinctly describes these soils by stating that both clay types are often characterised by high liquid limits and plasticity indices as a result of the more active clay minerals.

Probably the most intensive text on expansive soils is that of Fu Hua Chen [8]. This Consulting Soils Engineer documents three different methods of classifying potentially expansive clays. For completeness, a summary of Chen's tabulation (taken from his chapter on recognition of expansive soils) is given below.

(a) Mineralogical identification

In this method it is claimed that the swelling potential of any clay can be evaluated by identification of the constituent mineral of the clay. The five techniques which may be used are:

X-ray diffraction,
Differential thermal analysis,
Dye adsorption,
Chemical analysis, and
Electron microscope resolution

(b) Single index method

Simple soil property tests can be used for the evaluation of the swelling potential of expansive soils; such tests may include:

Atterberg limit tests,
Linear shrinkage tests,

Free swell tests, and
Colloid content tests

Relation between swelling potential of clays and plasticity index can be established as follows:*

Swelling Potential	Plasticity Index
Low	0 - 15
Medium	10 - 35
High	20 - 55
Very High	35 and above

While it is true that high swelling soil will manifest high index properties, the converse is not true.

The concept of swell potential is presumed to be related to the opposite property of linear shrinkage measured in a very simple test. In theory it appears that the shrinkage characteristics of clay should be a consistent and reliable index to the swelling potential.

(c) Classification method

By utilising routine laboratory tests such as Atterberg limits, colloid contents, shrinkage limits and others, the swelling potential can be evaluated without resorting to direct measurement. Some of these methods are listed below:

USBR method
Activity method
Indirect measurement
PVC metre
Soil suction, and
Direct measurement

* For comparison another tabulation (with nomenclature modified by the writer) given by Professor Leonards [9]

is given below:

Swelling Potential	Plasticity Index	Shrinkage Limit
Little	0 - 30	12 and above
Little to moderate	30 - 50	10 - 12
Moderate to severe	50 and above	10 and less

The writer considers that from his published house damage investigations in Manuaku City(9), the original soil consistancy tests of Atterberg (1911) are the best overall guide to identifying susceptible clays.

The Atterberg limits disclose 'engineering' properties of fine grained soils in which clay minerals predominate by giving measures of the water contents at which certain changes in the physical behaviour can be observed. The following definitions as given by Scott(10) are relevant:

The *shrinkage limit* (SL) is the water content below which no further shrinkage takes place as the soil is dried. If the water content is above the shrinkage limit, drying causes a loss of water without a corresponding increase in the air content of the voids, and the volume decreases. Further drying, at a water content below the shrinkage limit, causes no appreciable reduction in volume, the lost water being replaced by air drawn into the voids.

The *liquid limit* (LL) is the miminum water content at which the soil will flow under a specified small disturbing force. The disturbing force is defined by the conditions of the test. The soil sample is placed in the cup of the standard apparatus and a groove is cut with a standard tool. The cup is lifted and dropped 10 mm on to a block of rubber of specified hardness. The liquid limit is defined as the water content such that 25 blows will just close the groove for a length of 13 mm.

The *plastic limit* (PL) is the minimum water content at which the soil can be deformed plastically. It is defined as the minimum water content at which the soil can be rolled into a thread 3 mm thick.

The *plasticity index* (PI) is the range of water content over which the soil is in the plastic condition.

$$PI = LL - PL$$

The stages of consistency of the soil sample are shown in figure 4 below.

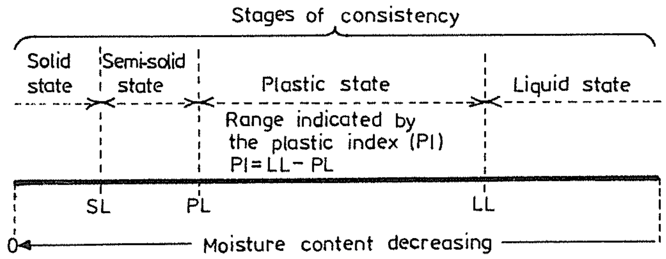


Figure 4: Consistency limits

4. <u>BUILDING CONSIDERATIONS</u>

This paper has previously described a susceptible soil as one subject to volume change. A most useful and practical description of the properties of such clays is that given in BRE Geotechnics Division technical information publication 43 (11) ... "Ground which is highly shrinkable will exhibit large cracks in the surface in dry weather and become very sticky in the winter. Such clay can shrink as much as 20 per cent in length when allowed to dry from its winter moisture content. The clay will be smooth and greasy to touch and when dry have considerable cohesive strength. The drying effect will be aggravated, especially in a dry summer, by vegetation and trees which withdraw large quantities of moisture from the ground to depths well below normal foundation level".

The writer considers that as a function of time, experience, selective soil testing and documentation of consulting engineers' subdivisional reports; most local authorities in New Zealand are capable of identifying areas of potential shrinkage and swell. A most useful background guide to assist in establishing these designated areas, is a 1963 Building Research Bureau publication (12). This bulletin provides an indication of the extent of expansive clays in New Zealand. On the basis of information supplied by the DSIR it designated for such Auckland districts as Remuera, Northcote and Manurewa a potential extent of hazard as "severe", to a maximum depth of 1.2 metres. Clearly, the intervening 18 years have shown to the author the accuracy of such guidance - unfortunately ignored, forgotten, or unheard of by the majority of building designers.

The main element to be considered in the design of structures on plastic clay is the foundation. Damage to a structure can be attributable to a number of causes such as foundation movement, material drying shrinkage, temperature contractions and expansions, structural deflections etc.

Foundation movement or settlement can originate from a multitude of causes. In the main, however, these would include consolidation of (uncompacted) fill, shear (bearing) failure of the soil, decomposition of organic layers, shrinkage or swelling of clay subsoils, consolidation settlement of clay, imposed load effects, reduction of volume of sands due to lowering of water table or vibration etc.

It is clear from the Building Research Bureau publication (12) that plastic clays exist in many centres throughout New Zealand - ranging from Kaikohe south to Invercargill and including (for example) such centres as Auckland, Rotorua, Napier, New Plymouth, Inglewood, Stratford, Hawera, Wellington, Oamaru and Dunedin.

In Manukau City the districts which have plastic clays include Pakuranga, Half Moon Bay, Manurewa and Mangere Central. The writer has studied over the past nine years the performance of numerous minor structures (mainly houses) founded on these clays. As a result the following points are recorded:-

(a) Brittle structures such as brick veneer cladding and/or concrete masonry can exhibit considerable distress under clay movements.

(b) Detailing of the structures is important.

Brick veneer or masonry dwellings adequately reinforced to resist ground movements performed better than un-reinforced structures.

(c) Buildings erected on timber or concrete piles or on stiffened raft foundations performed better than dwellings on continuous strip footings or isolated slabs.

(d) Lighter dwellings such as those sheathed in weatherboard or fibrolite and with lightweight roofs showed less damage than the heavier brick cladding houses with concrete tile roof. This point illustrates a 'fundamental' of structural theory in that load or forces are attracted to stiff points or elements in a structure and thrown off by yielding or more flexible members.

(e) Dwellings which had unusual features such as split-level or stepped internal basement (retaining) walls, concrete slab verandahs or porches showed a greater inclination to distress than similar dwellings without these "stiff" features.

(f) Specific detailing of (particularly) brittle type structures was important. For example, houses with running bond for blockwork courses performed infinitely superior than those constructed in stack bonded masonry.

(g) 'Housekeeping' measures undertaken by homeowners which can disturb the soil-moisture equilibrium or regime are also important. For example, dwellings which had extensive sealed areas or groups of fast growing aggressive trees (such as silver dollar gum trees) in close proximity to the foundations invariably suffered damage.

Wesseldine (13) has described case studies of building damage on shrinkable clays aggravated by the moisutre removal attributable to fast growing gum trees.

(h) Frequently the problems associated with clay shrinkage are only noticed after drought conditions, generally in late autumn. However, minor blast or earthquake forces, sudden drop in temperature or an extended period of low humidity can also trigger off the distress cracks and damage.

6. CONCLUSIONS

Areas of plastic clays subject to volume changes occur in numerous centres of New Zealand. It is essential that Local Authorities identify the specific districts where these clays occur - either at the subdivisional stage or by damage investigations. Once these areas are identified it is essential that designers of buildings be advised of these soil conditions.

Designers should, in areas of plastic clays, take specific structural design steps to provide foundations capable of accepting seasonal volume changes of clay; minimise where possible gravity loadings of the structure; pay specific attention to detailing of elements and specification of construction procedures; and attempt overall the design of buildings to accommodate unpredictible foundation movements without damage. The writer does not consider that a blanket requirement of deepening foundations would solve the problem - specific structural design is required.

Finally, home-owners should be reminded that in areas of clay shrinkage and swell it is essential to maintain the equilibrium soil-moisture regime. Because of this, extensive areas of impervious paving and/or saturation planting of aggressive trees or shrubs should be viewed with great caution. Of all the input variables which can lead to structural damage of buildings erected on plastic clays it is the "house-keeping" measures which ultimately can be "the straw that breaks the camels back".

7. ACKNOWLEDGEMENTS

The writer wishes to thank Mr R Wood, City Manager, Manukau City Council, for permission to publish this paper.

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GEOMECHANICS IN URBAN PLANNING - PALMERSTON NORTH APRIL/MAY 1981
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THE FLOODING HAZARD

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Any interference with natural land cover has hydrological consequences, but this reaches its extreme in urban areas where modification to the natural system is at its greatest. The vegetative cover, interposed as it is between erosive forces and weathered rock and soil, plays an especially important role in absorbing the impact of high intensity rains and in reducing and delaying its runoff. If vegetation cover is removed, various stream and basin adjustments follow (Gregory, 1977; Williams, 1980). These include changes on slopes, in channels, to channel networks, to water quality and to water quantity. Many problems result; the more extreme being hazards to life and property. Amongst these, flooding is the worst, although it is usually accompanied by major (head-water) erosion and (downstream) sedimentation problems.

Urban flooding problems are well known in Auckland, Christchurch, Nelson, Palmerston North and Wellington-Hutt. Some of the problems arise from flood-waters generated in largely rural catchments - thus rural management practices can impact upon downstream urban dwellers - but others arise from activities entirely within the urban area. The flooding experienced in Palmerston North is a good example of the first case, while that experienced in Auckland is a prime example of the latter. However, in both instances the hazard is only significant where building occurs on floodplains and particularly in natural floodwater channels.

Flooding is a natural phenomenon. Where there has been no human modification to the landscape, a river in our kind of climatic regime could be expected to overflow its banks on average once in every two or three years. Thus to build a settlement on a floodplain is to invite trouble. Nevertheless, in many cases in New Zealand and elsewhere, such building was done at a time when the natural role of a floodplain was not appreciated, and now the flooding problem has been compounded by other activities. The example of the Wairau Creek basin on the North Shore of Auckland illustrates the problem.

In its natural state, the 11.4 km^2 Wairau Catchment was vegetated by subtropical kauri forest, but by 1940 it was predominantly under grassland and scrub. By 1959 almost 75 per cent of the basin had this kind of vegetation cover, but only 16 years later, in 1975, about the same proportion had been transferred to urban uses. It has now increased to 80 per cent. With this land use change came a massive increase in flooding.

Bankfull discharge may be assumed to have occurred once every 1.5 to 2 years under the original forested conditions. However, in 1962 when hydrological records commenced and 30 per cent of the basin was urbanised, flooding of bankfull or higher stage was already occurring about 3 times per year. Flooding of this frequency continued until 50 per cent of the area was built-up (1968), when a noticeable steady increase in overbank flood discharges occurred. Thus by 1975, when almost three-quarters of the basin was in urban uses, discharges that would have been of bankfull or greater magnitude under natural conditions occurred 13 to 15 times more frequently than under the original forested conditions. Major channel works were required to cope with these frequent high flows, costing $2 million to-date - and the problem is by no means solved.

Associated with the considerably increased magnitude and frequency of high flows has been the problem of reduced warning of floods. The mean time of rise of floods has decreased by about 30 per cent since records began. Thus floods now strike more swiftly, rise higher and runoff more rapidly than they did before urbanisation commenced. Whereas extended rain was necessary to produce a flood of overbank magnitude, storms of much shorter duration can now produce significant flood events, although the expensive catchment works have so far largely contained them within the channel.

Thus the Wairau experience bears out many conclusions reached overseas, including for example, the fact that the mean annual to five year flood discharge is at least doubled by urbanisation, if about 15 per cent of the surface is sealed (Leopold, 1968). Nevertheless, very low frequency but high magnitude floods, such as the 150 year flood or greater, are not much affected by urbanisation (Hollis, 1975), because once a basin is fully saturated whether under forest or concrete, almost everything will run off.

It is clear that the phenomenon of flooding is a hazard, principally, because buildings are often constructed on floodplains. A choice exists not to build on such sites. Urban flooding is also made more frequent than necessary because of our development practices, and again we have the choice to alter the way we do things. Since we understand the mechanisms that exacerbate urban flooding, solutions to many stormwater problems are identifiable.

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GEOMECHANICS IN URBAN PLANNING - PALMERSTON NORTH APRIL/MAY 1981
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COASTAL HAZARDS AND URBAN PLANNING

J G GIBB MINISTRY OF WORKS AND DEVELOPMENT

INTRODUCTION

The coastlines of New Zealand total about 11,000 km in length (Gibb 1979a,b), and are prone to most if not all natural hazards. New Zealand is geologically young compared with other countries, has an active plate boundary passing through its continental mass, and lies in an area of the Pacific Ocean known to blue water mariners as the 'roaring forties'. Most, if not all the open exposed coastlines are subjected to high-energy sea conditions.

Each year heavy seas exceeding 5m in height are generated by westerly trade winds in the southern storm belt between latitudes 40^0S and 60^0S, and by deep depressions passing south-eastwards across the country (Pickrill and Mitchell 1979; Gibb 1981). During severe onshore storms, such as those in September 1976 (west coast) and July 1978 (east coast), maximum waves 10-15m high were observed. Such events caused widespread coastal erosion and flooding (Gibb 1978a, 1981; Reid 1979).

The rocks forming the coastlines of New Zealand range in hardness and strength so that their erosion susceptibility ranges from extreme to very low. For example, in the East Cape region the extensively deformed and disrupted Late Cretaceous-Early Tertiary sedimentary rocks are extremely susceptible to landsliding, and the moderately deformed Late Tertiary rocks are highly susceptible, especially along fault planes and where strata dip seaward. By contrast, the very hard and massive Matakaoa volcanic rocks have a very low landslide susceptibility (Gibb 1981).

Coastal hazards are commonly regarded as a problem only when they threaten property and improvements. The essence of the problem is not that the coastline erodes or is flooded, but that urban development has occurred within the hazard zone. Clearly, the way to avoid such threats is simply by the provision and management of an adequate width of land between the development and the beach. Such a width of land is defined as a *coastal hazard zone* (Gibb 1981) as it is highly vulnerable to natural hazards.

This paper lists some coastal hazards known to the author, discusses coastal erosion, probably the most widespread hazard at present, and describes a coastal hazard mapping technique that may be applied around the coastlines of New Zealand. The technique was endorsed by the Soil Conservation and Rivers Control Council at its 9 March 1981 meeting as a standardised method for nationwide application.

COASTAL HAZARDS

Coastal erosion, migrating river mouths and tidal inlets, flooding from the sea and blocked river mouths, wind erosion, and landslides are natural coastal hazards that occur around the sea coast and lake shores of New Zealand. Some trigger off others and most result from the interaction of many factors. For example, coastal erosion may trigger landslides by removing the lateral support of the land. Flooding from the sea may result from excessive storm wave run-up, tsunamis, sea level rise, tectonic movements, or differential consolidation of material triggered by earthquakes.

Coastal Erosion

Coastal erosion is the *process of removal* of material at the shore line, leading to a loss of land as the shore line retreats landward. Accretion is the *product of deposition* of material at the shore line, leading to a gain of land as the shore line advances seaward. Static shore lines are those where the erosion rate is *less than* 0.02 m/yr (Gibb 1979a; 1981).

Of New Zealand's 11,000 km of coastline about 80% is exposed to the open sea and the remainder is sheltered. For the exposed part, about 56% is static, 25% eroding, and 19% is accreting. History has shown that even the accreting sections of coastline may reverse to erosion, so that, in total, *almost half* of New Zealand's coastline has a *high susceptibility to erosion* (Gibb 1979b).

Although a long-term trend of coastal advance or retreat may be discerned in most places, the process is not regular along depositional coasts but takes place in a series of in-and-out movements of the order or 15-350 m (Gibb 1981). Such movements are episodic and unpredictable and are likely to occur within a period as short as one year. Erosion usually occurs during either one, or a cluster of severe onshore storms that are coupled with higher than normal sea levels and ground-water levels, whereas accretion normally occurs under conditions of low swell waves aided by offshore winds and low ground-water levels.

The distribution and net rates of eroding, accreting and static New Zealand coastlines is shown on Figure 1 (North Island) and Figure 2 (South Island). Both maps are an updated version of Gibb (1979a, figures 5.7, 5.8) and are based on detailed coastal observations, on comparative studies of plans and charts dating from 1842 and on aerial photographs dating from 1934. The data indicate that during the last century very slow net rates of erosion (0.02-0.5 m/yr) occurred most commonly, followed in order by slow (0.5-1.0 m/yr), by moderate (1.0-2.0 m/yr), by rapid (2.0-4.0 m/yr), by very rapid (4.0-8.0 m/yr) and finally by extreme net rates (>8.0 m/yr), maximum erosion of 9.5 m/yr being recorded at Ngapotiki, East Coast Wairarapa (Gibb 1978b, 1979a).

COASTAL HAZARD MAPPING

Coastal hazard mapping is a data-based technique that identifies and quantifies coastal hazards mainly from existing knowledge. The technique was developed from a study of natural hazards along the Waiapu County coastline, East Cape region, and is described in Water and Soil Technical Publication 21 (Gibb 1981).

The philosophy behind coastal hazard mapping is simple - *prevention is better than cure.* Combating any particular coastal hazard is usually very expensive, present-day costs for coastal protection works (sea walls, groynes, breakwaters) in New Zealand ranging

Figure 1. - Distribution and net rates of eroding, accreting and static coastline of the North Island, determined for approximately the last one hundred years. (ca. 1880 - 1980). Transverse Mercator projection. Each graticule of latitude equals 5 nautical miles.

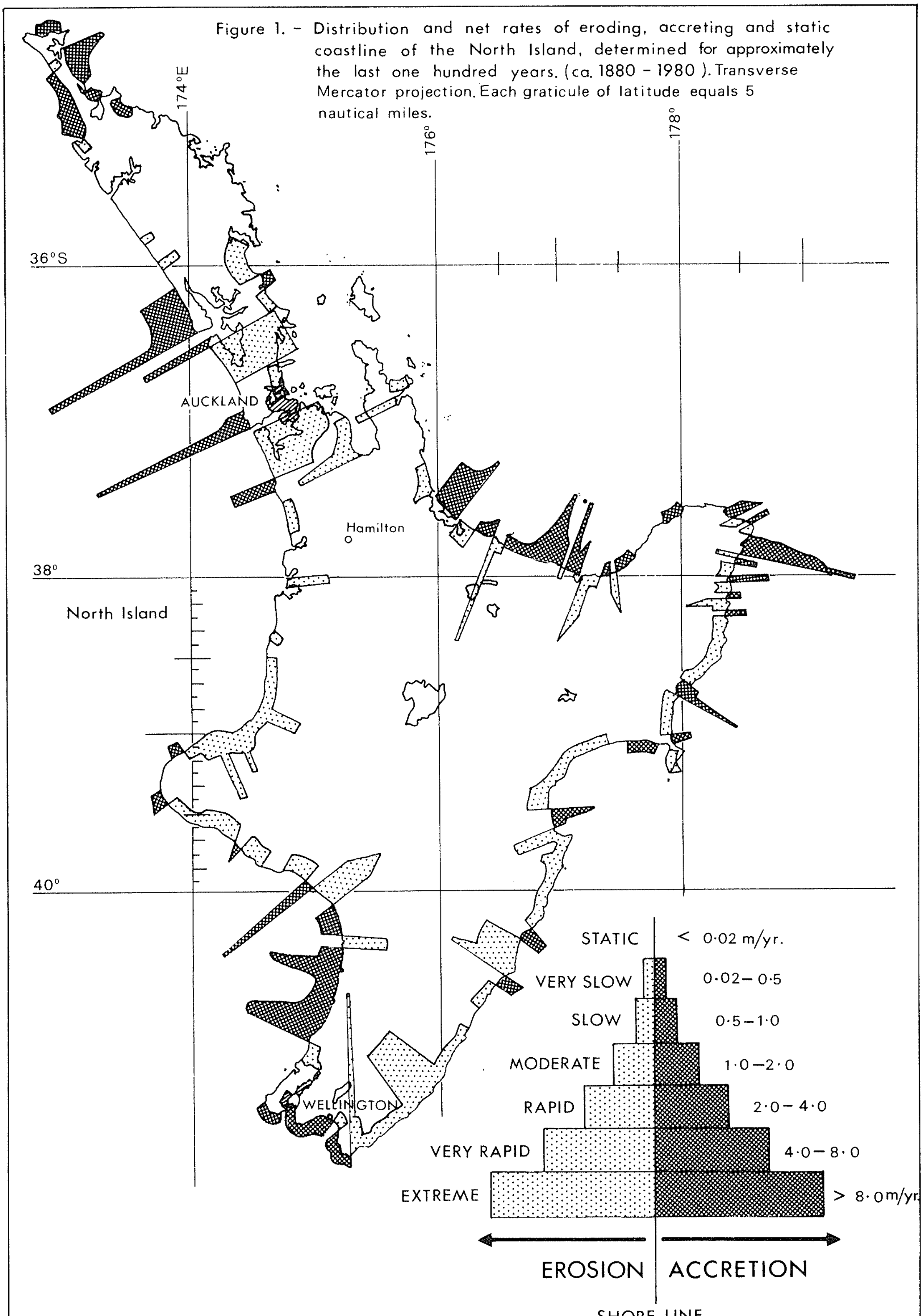
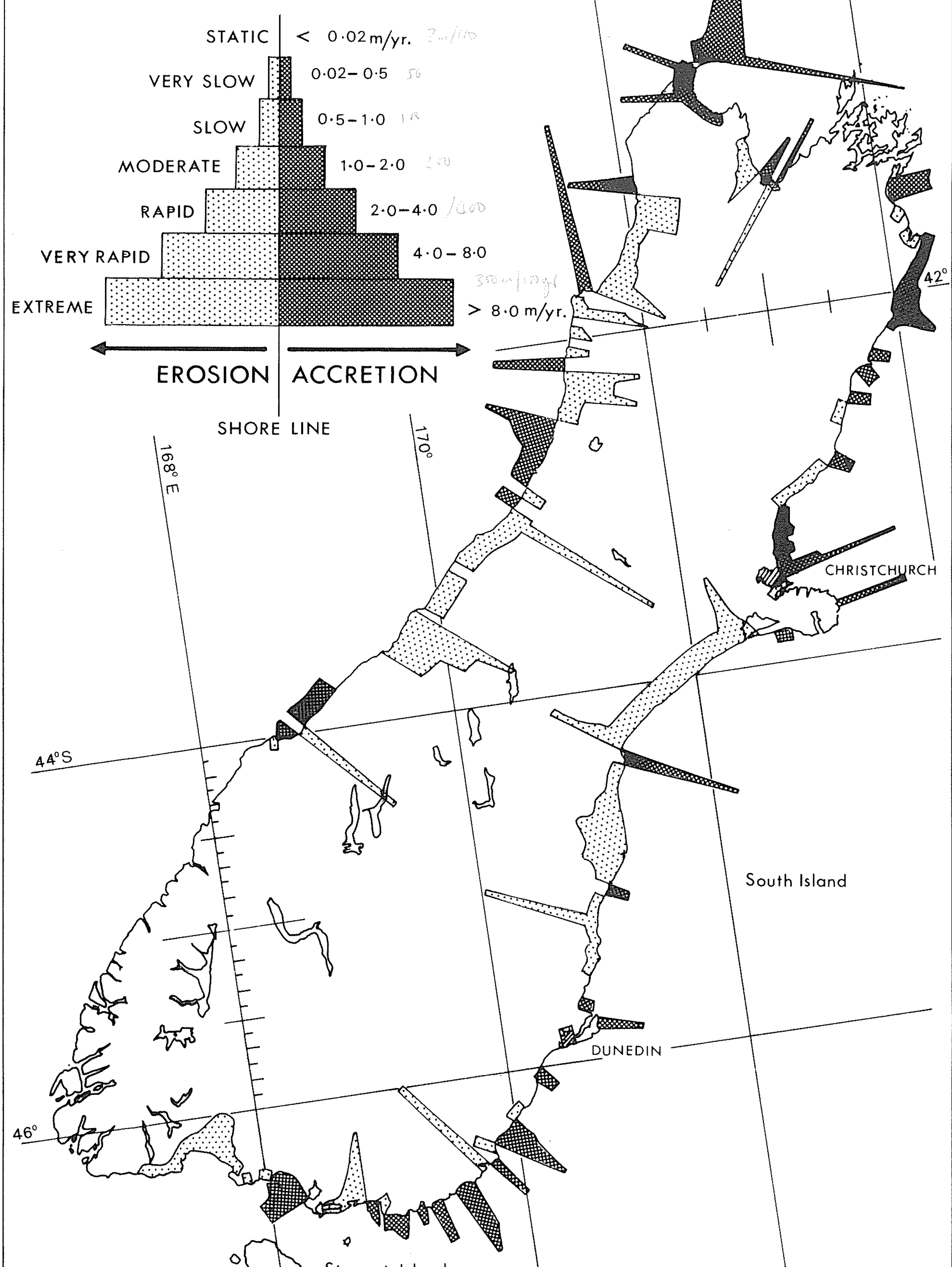


Figure 2. - South Island. Transverse Mercator projection. Each graticule of latitude equals 5 nautical miles.



from $150 to $2,000 per linear metre of coastline and beach replenishment from $1.50 to $15.0 per cubic metre of sand or gravel. In the case of urban development, such costs can be avoided simply by the provision and management of an adequate width of land *(coastal hazard zone)* between the development and the beach. The width of the zone is in proportion to the degree of hazard. Where there is an extreme risk the zone is wide, where there is a low risk the zone is narrow. Figure 3 illustrates the disastrous effects that will occur if a coastal hazard zone is not provided for between development and the beach.

FIGURE 3: Photograph showing one of two houses that fell into the sea at Ohiwa Spit (Bay of Plenty) during a severe onshore storm in Easter 1976, and unsuccessful attempts at curbing coastal erosion such as the dumping of unsightly car bodies. By April 1976, the railway irons placed at the toe of the foredune in 1969-70, had been outflanked 35-70 m (Gibb 1979c).

ASSESSMENT OF COASTAL HAZARD ZONES

Criteria for assessing the width of the coastal hazard zones are different for each section of coast because of the different factors involved. Such factors to be considered are:

1. Long-term (about 100 years) erosion or accretion rate based on survey and geologic data.
2. Short-term (a few tens of years) fluctuations in the position of shore line.
3. The likelihood of a reversal from net shore line advance to net retreat in the future.
4. Extent of river mouth migration.
5. Extent of flooding from the sea.
6. Susceptibility of sand dunes to wind erosion.
7. Preservation of the essential elements of the natural beach system such as the protective vegetation, dunes, beach ridges, and the beach profile.
8. Susceptibility of the coastal slopes to landsliding.

The hazard zone is measured as a horizontal distance inland, either from the toe of a seacliff or sea wall, or from the seaward limit of land vegetation or toe of the foredune, whichever reference line is the most clearly defined along each section of coast. The coastal hazard line is then fixed in terms of the existing cadastral survey system.

Sand Dune and Gravel Beach Ridges

For *accreting* sections of coast that are unlikely to reverse to net erosion in the foreseeable future, a *minimum hazard zone width* (S) is adopted to accommodate short-term shore line movements (15-350m) and for the protection of the essential elements of the natural beach system mentioned above. The foredunes function by protecting the beach in front and the land behind, acting as a natural buffer against wave attack and a source of sand for the beach during periods of erosion. Dune vegetation traps wind-blown sand, aiding dune build-up and preventing sand transgressing inland where it is lost from the beach-dune system. Hence, it is essential that they are set aside from future development. Therefore, for accreting coastlines the hazard zone width will range between the width of the foredune and 350 m inland from the beach.

For the Waiapu County coastline a minimum hazard zone width of 50m was adopted for the accreting sections of coast (Gibb 1981). Here, the width of the primary beach ridge and foredune, both essential elements of the natural beach system, is of the order of 50 m.

For *eroding* sand dunes and gravel beach ridges, the width is calculated by multiplying the *long-term erosion rate by 100 years and adding the factor for short-term movements* so that:

Hazard zone width (m) = (R x 100) + S

where R = long-term erosion rate (m/yr)

100 = assessment period (in years)

S = extent of short-term movements (in mretres)

The 100-year period is adopted to accommodate the practical life of new buildings and services.

Based on the above method, the landward extent of the hazard-zone represents the line beyond which the shore line (seaward limit of land vegetation) is not expected to lie in the next 100 years.

In New Zealand, long-term coastal erosion rates for dunes and beach ridges range from 0.10 m/yr up to 9.5 m/yr (Gibb 1978b). Therefore, hazard zone widths (including short-term movements) for such coastlines, will range between about 25 m and 1000 m. Any development placed within the hazard zone during the next 100 years may be destroyed by coastal erosion.

Seacliffs

For eroding seacliffs, the width of the *coastal hazard zone* is calculated by multiplying the maximum long-term erosion (back-cutting) rate at, or close to, the site by 100 years and adding a safety factor (F) so that:

Hazard zone width (m) = (R x 100) + F

For the eroding seacliffs in the Waiapu County, F was deemed to be 2/3 (R x 100) to allow for landslides and unknown structural weaknesses in the rocks which will cause variations in erosion rates. Where there is evidence of past or present coastal land-slides, the hazard zone is calculated from the top edge of the landslide scarp (crown), extending inland to include the landslide-prone area between the coast and the position predicted for the crown in 100 years' time.

Long-term backcutting rates for seacliffs in New Zealand range from 0.05 m/yr up to 3.5 m/yr (Gibb 1978b). Therefore, taking the

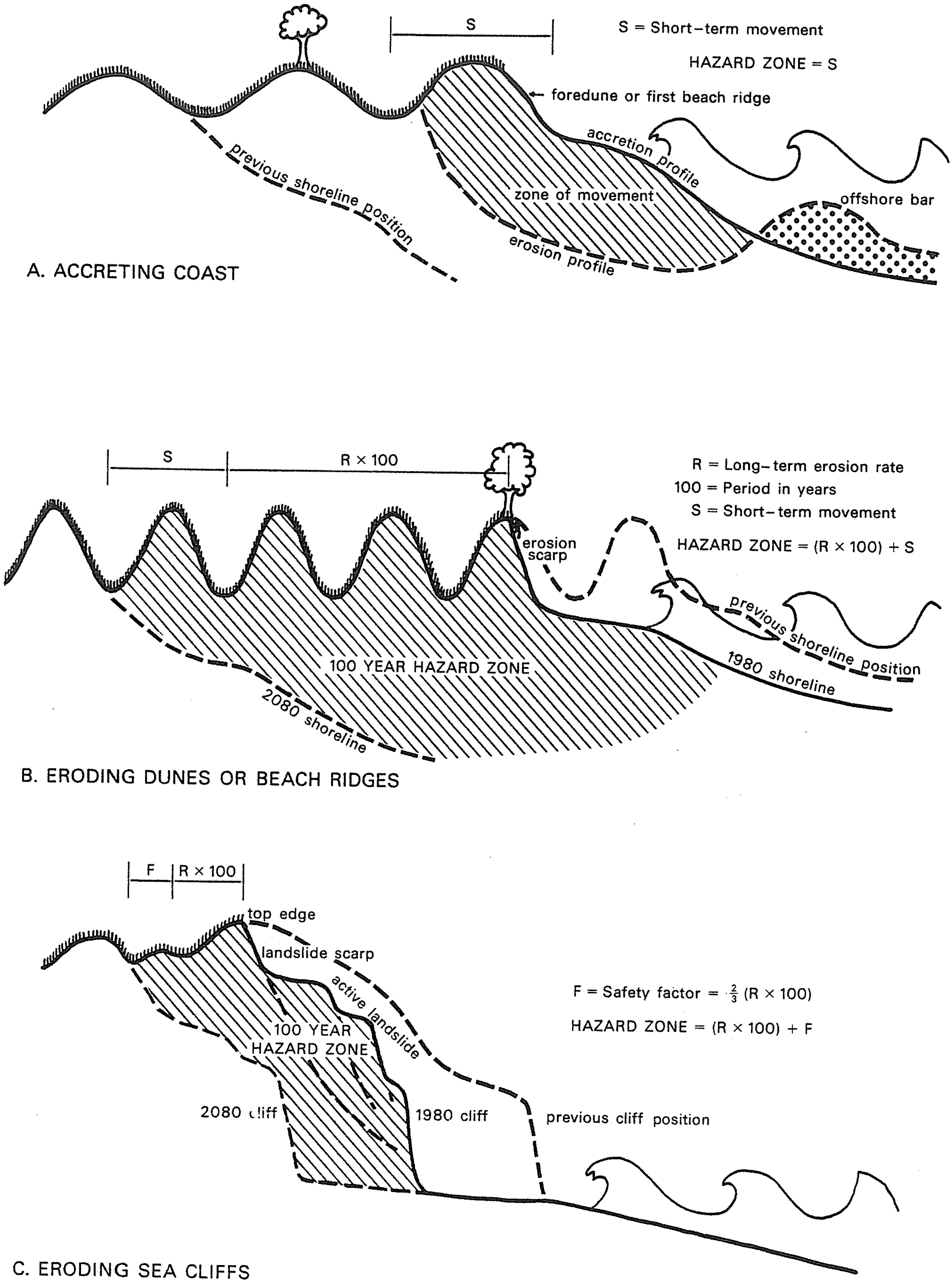


Figure 4: Diagrams showing the methods used to assess coastal hazard zone widths along the Waiapu coastline for accreting coastlines (**A**); eroding sand dune and gravel beach ridges (**B**); and eroding sea cliffs (**C**).

Adapted from Gibb 1981 (figure 20)

safety factor into account, hazard zone widths will extend from about 9 m to 580 m inland from the landslide crown plus the width of landslide-prone land between the crown and the coast. Any development placed within the hazard zone may be destroyed by landsliding and coastal erosion. Figure 4 shows the methods for assessing the width of the hazard zones.

REASSESSMENT OF COASTAL HAZARD ZONES

Because the coastline is dynamically balanced between advance and retreat the extent of the coastal hazard zones must be periodically reassessed. As coastal hazard zones are now being shown on district planning maps within some District Planning Schemes, the most logical period for reassessment is at the time of each district scheme review - *every five years*. In order to provide an adequate data-base for the five-yearly reassessment, fluctuations in the position of the shore line should be monitored once or twice a year in urban areas, or areas likely to be developed. Such a monitoring programme is currently being carried out by the Waiapu County Council in its priority areas.

NWASCO POLICY ON RECOGNITION OF NATURAL HAZARDS

At its 7 July 1981 meeting the National Water and Soil Conservation Authority adopted the following as National Water and Soil Conservation Organisation (NWASCO) policy:

1. The general identification of lands subject to hazards such as erosion, flooding and landslip and the promotion of the inclusion of such information in the relevant Regional Planning Schemes.

2. The promotion of the inclusion in District Planning Schemes of maps and information describing the location, type and extent of each hazard.

3. The promotion of the inclusion in Regional and District Planning Schemes of provisions for land uses compatible with the type and extent of the hazards identified.

The data-based standardised technique of coastal hazard mapping is seen as a method that implements NWASCO policy and satisfies the provisions of both the Town and Country Planning Act 1977, and Local Government Amendment Act 1979.

CONCLUSIONS

(a) Coastal erosion, migrating river mouths and tidal inlets, flooding from the sea and blocked river mouths, wind erosion, and landslides are natural hazards that may be identified and quantified around the New Zealand coastline. Under the provisions of the Town and Country Planning Act 1977, such hazards can easily be provided for in regional and district planning schemes.

(b) The provision of adequate *coastal hazard zones* and the preservation of the natural character of the coastal environment within them by careful management, is clearly the best way of protecting both the beaches and nearby urban development in New Zealand.

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THIRD DISCUSSION

- of papers by Bell; Wesseldine; Williams; and Gibb

J G Hawley (Aokautere Water and Soil Science Centre, Aokautere)

We tend to think of this dispersion problem as being limited to the Port Hills. I suggest that this may be because those are the only hills with very dispersive soils which have been urbanised so far.

Dispersive soils under pasture suffer from 'tunnel gully erosion' and the incidence and severity of this has been mapped on the New Zealand Land Resource Inventory. It is clear that a lot is to be found in Northland, Hawkes Bay and the Wairarapa, the Wither Hills near Blenheim and in North Canterbury (see Figs. on pages 294 and 295). The problem of controlling soil dispersion, particularly around urban service lines (pipes) and roads, could arise in any of these places if they were developed.

G J Lensen (NZ Geological Survey, DSIR, Lower Hutt)

To what extent is the 'tunnel gully erosion' shown on these maps due to deforestation and/or overgrazing? Is it a man-made problem?

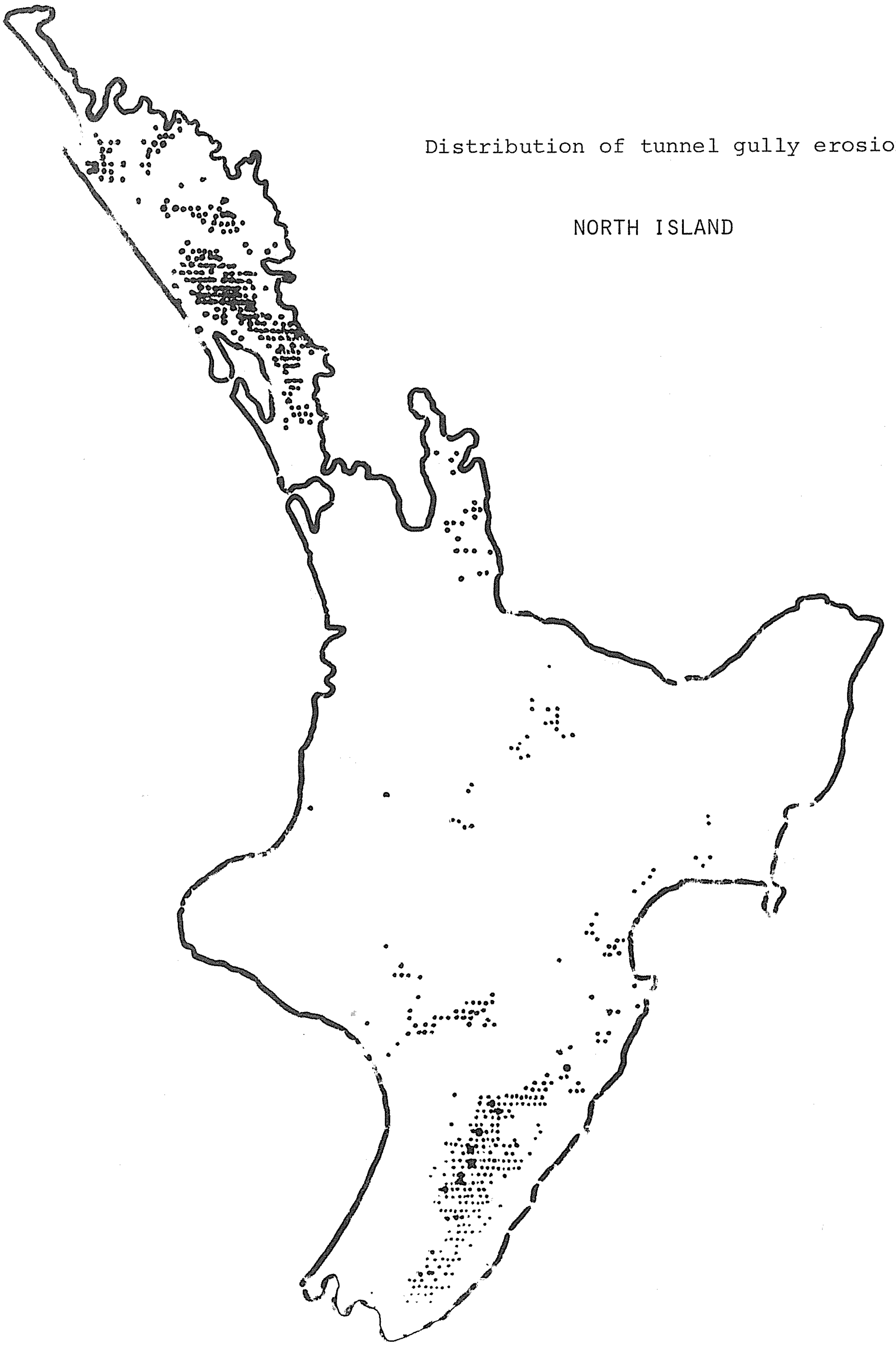
Reply (Hawley)

Certainly the rates of loss of soil are currently several orders of magnitude greater than the rates of accumulation. Even more to the point is that the current rates of loss are in many areas so great that had they been going on for the last few thousand years there would be no soil there at all now. It appears that the tunnel gullying phase begins when the soil gets very dry and cracks open. The soil can (and does) get much drier under pasture than it ever did under scrub or forest.

Getting some trees back may be part of the answer. The possibility that the wrong trees in the wrong places could make the soil even drier and make things worse is not to my knowledge supported by field observation. In the urban setting the right trees should at least have a remedial if not a preventative action: tree roots do block drains and these tunnel gullies are, in their early stages, just like drains. Yes, it is a man-made problem.

Reply (Bell)

I agree that it is largely a man-made problem.

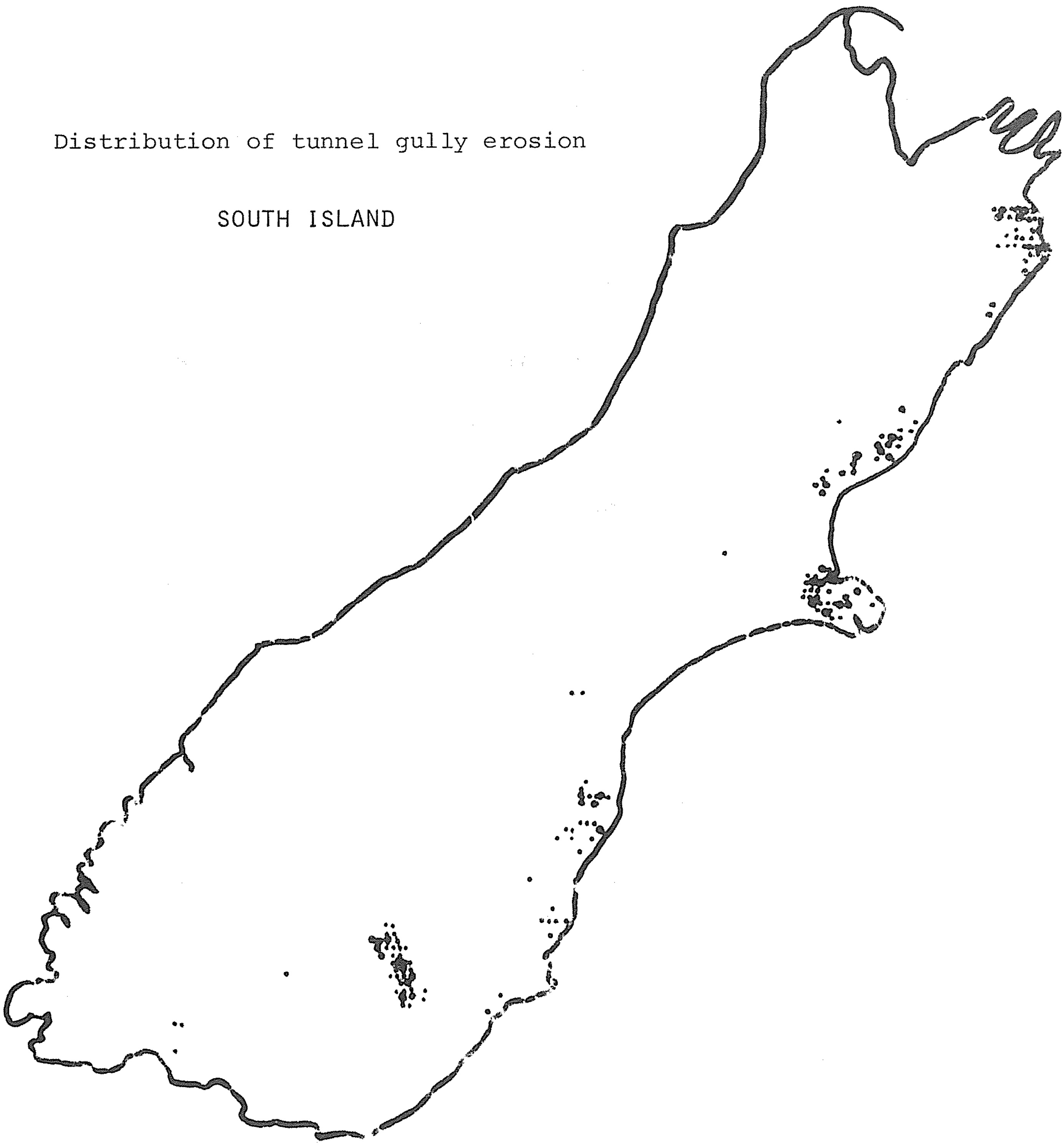


Distribution of tunnel gully erosion

NORTH ISLAND

Distribution of tunnel gully erosion

SOUTH ISLAND



I have noticed also how erodible (dispersive) some of the infilled gullies are. These are areas which were gullied and later infilled in previous erosion cycles - perhaps after early European or Polynesian fires, or just after major storms. The re-worked, redeposited loessial soils are more easily dispersed than the undisturbed soils. This is also clear in laboratory tests: all samples become more dispersible when remoulded than they were in the "undisturbed" state.

Reply (Hawley)

Mr G J Schafer of Soil Bureau has done a lot of work on developing the pinhole test so that it may give an indication of dispersion susceptibility. This is a cheap test, cheap enough to be included in urban capability surveys - not nearly as expensive as strength testing for example.

It was interesting to note in one of Mr Bell's slides a situation where dispersion was a problem and yet the soil had plenty of strength. It was standing in vertical cut 10 or 20 metres high. This illustrates how clear we must be about making distinctions between the different failure mechanisms. Susceptibility to dispersion is not directly related to low strength.

D S Wilshere (MWD Wellington)

The Wairarapa Catchment Board has been very successful in using trees to plug up tunnel gullies, - in the pastoral setting. It does seem likely that in the urban setting with careful planning and sensible planting this soil dispersion problem could be overcome.

Reply (Bell)

Yes, I agree. In one of the subdivisions I referred to earlier there are highly dispersive soils - with erodibility classifications of D1-D2. We are planting up the badly gullied area above the subdivision and we are mixing lime in when trenches are backfilled and so on. As a result we are confident that the problem will be kept under control.

C Collins (Water & Soil Division MWD, Head Office)

Mr Wesseldine has pointed out the sorts of problems which can arise in some soils when the wrong trees or too many trees are planted too near to houses, roads etc. What is the Manakau City Council doing to acquaint its citizens with this problem?

Reply (Wesseldine)

We have basically an in-house monitoring system and I have been very pleased with the response we have had from some of the soils consultants. In some instances, where there have been very plastic clays, house foundations have been deepened to 600 mm for surprisingly little extra cost, and in some cases they have designed basement walls to be, in effect, very deep beams - 2.4m deep. That sort of stiffness, that sort of lever arm, will be able to handle the stresses caused by differential shrinking.

Fortunately our structural section has close rapport with our planning department and with our building inspectors.

We have a map with the areas known to have very plastic (high shrinking) clays marked in yellow. When a building permit comes in for a house on such an area it goes automatically to our structural section for checking.

What we are doing then is in effect giving the applicant the benefit of our experience, i.e. the experience of all the other people who have built in the "yellow" areas. It saves them money in the long run and they know what they are in for when they begin - before they get their building permit.

J H Lawrence (Water & Soil Division MWD, Head Office)

It is pleasing to hear that owners are told what they are in for at the building permit stage. It would be even better if they could know what the problems were before they bought the site.

Are the owners given any guidance as to what sort of care and maintenance they should invest in?

Reply (Wesseldine)

Care and maintenance after the structure is up are certainly key issues. We are talking about all the other things people might do to a section - rather than to the building itself. Like putting down large areas of impermeable sealed driveway and parking areas and planting trees next to them.

This is more difficult to control and is a matter of educating the public - a very big task!

K J Tremaine (Planner, Palmerston North City Corporation)

One of the options for development identified in the Manawatu Urban Growth Study was an area which would have had to be protected from flooding. There was a tendancy by the local authorities to talk only about who would pay for this protection - rather than to evaluate the various alternatives.

D S Wilshere (MWD Wellington)

We must acknowledge that large areas of New Zealand have been farmed as a result of flooding - over many thousands of years. Our floodplains are generally our best agricultural land. So we must distinguish between the natural floods and the floods which are caused or worsened by land use changes - from forest to pasture and from pasture to urban.

Reply (Williams)

We must be very careful to distinguish between the two kinds of floodplain: geomorphic floodplain and the 50 year (or whatever) floodplain. The geomorphic floodplain is relatively easy to map.

B J Forde (DSIR - and Palmerston North City Councillor)

I would like to compliment Prof. Williams and Dr Gibb on the work which they have outlined. I would also like to emphasise the need for educating the local authorities and their staff. I have been on the Planning Committee here in Palmerston North since 1971. There have been 12 members on that committee and I am the only one that is still there. We have had two City Engineers since 1971, we have had three City Planners, four Deputy City Engineers - and staff turnovers of 30% or more.

Coming along once and explaining coastal hazard zones of probabilities of flooding is not going to have a permanent effect. We need to have our staff and our councils addressed by the experts regularly.

The problem with the adversary process is that the one who wins is often simply the one who puts his case most powerfully. He is not always the person who represents the best ideas. Only if a Planning Committee is well informed can it make sound decisions in these circumstances.

M E Jones (Murray North Partners, Whangarei)

I act for two county councils in the far north where there are many sandspit areas that we would wish to protect or draw attention to. Who should we turn to for advice in the drawing of the "black line"? It is obviously a fairly expensive job. Can you tell us why or how Waiapu county came to be surveyed?

Reply (Gibb)

Waiapu county just happened to be the first regional planning scheme with a need for a coastal hazard input to come across our table. It was immediately clear that some sort of national standards had to be set for identifying coastal hazards and showing them on a map so that planners could operate sensibly in this regard.

In this case 70% of the coast was in Maori ownership so we had to speak on maraes and at other public meetings. In this way we got the benefit of the knowledge the local people had of the coastal hazards: we were able to check our ideas against their experience.

Because this type of work can have major effects on property values you have to be able to justify all your decisions as to just how far back the coastal hazard zone extends.

This is a very new technique. Who would pay for it to be carried out in other areas we don't yet know. It is possible that the catchment authorities will play a key role.

There is one thing to be said in favour of defining the coastal hazard zone at the regional scheme stage rather than at the district scheme stage and that is that the catchment authorities must then become involved.

V E Neall (Massey University, Soil Science Dept.)

You define the limits of coastal hazard zone with a sharp line. Would it not be true that in many places the boundary is very gradational?

Reply (Gibb)

Yes. We could acknowledge this by making the line broad or grey or spotty in some places and leaving it to the planners and the local councils to make a final judgement on where the zoning boundary was to be. (We like to have things grey in New Zealand - it promotes indecision.)

I think that the gradational aspect is covered by showing the line as a 100 year line. This acknowledges that we are dealing with probabilities rather than certainties. So I prefer to see a clear sharp line drawn. The local authority and its advisors can then work around that line as best they see fit, taking many other factors into consideration.

J H Lawrence (MWD Head Office)

I understand that the Wanganui-Rangitikei Catchment Board regard such lines on maps as guides only and that they expect to have to carry out more detailed investigations - in some places - on each side of the line before finally positioning it.

GEOMECHANICS IN URBAN PLANNING - PALMERSTON NORTH APRIL/MAY 1981
NEW ZEALAND PLANNING INSTITUTE : NEW ZEALAND GEOMECHANICS SOCIETY

AN ASSESSMENT OF PRESENT STATUTORY POWERS AND RESPONSIBILITIES

JUDGE D F G SHEPPARD
DEPARTMENT OF JUSTICE, AUCKLAND

A. INTRODUCTION

The statutory powers and responsibilities which are relevant to the subject of the symposium are mainly to be found in the Town and Country Planning Act 1977 and the Local Government Act 1974. There are some powers in the water control legislation - the Soil Conservation and Rivers Control Act 1941 and the Water and Soil Conservation Act 1967. But they have less direct effect on urban planning, and in any event those Acts are long overdue for review.

Sections 3 and 4 of the Town and Country Planning Act contain some statements of general principle which are a guide to the way in which it is envisaged the statutory powers and responsibilities conferred by the Act are to be exercised. Section 3(1)(a) emphasises the national importance of the conservation of the physical environment, and section 3(1)(b) the wise use and management of resources. The latter goal is also expressly a purpose of regional and district planning (s.4(1)), as is the direction and control of the development of a region or district. Section 4(3) directs that in statutory planning, regard is to be had to the principles of the water control legislation, and the title to the Water and Soil Conservation Act includes in the purposes of that legislation promoting soil conservation and preventing damage by flood and erosion.

Against those general statements of principle, one can examine individual statutory powers and responsibilities.

B. REGIONAL PLANNING

The function of regional planning is the responsibility of every united and regional council - Town and Country Planning Act 1977, section 5. The general purposes of regional planning are the wise use and management of the resources, and the direction and control of the development of the region in such a way as will most effectively promote and safeguard the health, safety , convenience, and the economic, cultural, social, and general welfare of the people, and the amenities of every part of the region - section 4(1). The general objectives of regional schemes are to achieve those purposes - section 4(2).

The regional scheme is to include a statement of objectives and policies for the future development of the region and the means by which they can be implemented having regard to national, regional and local interests and to the resources available. The scheme is to make provision for such of the matters referred to in the First Schedule to the Act as are appropriate to the circumstances and to the needs of the region - section 11(2).

The First Schedule lists the matters to be dealt with in regional schemes. Clause 4 has the heading 'Type and General Location of Development'. Subclause (c) under that heading refers to 'General identification of areas to be excluded from future urban development, including ... land subject to hazards such as flooding and earth movement ...' The combined effect of those provisions is to impose a clear statutory responsibility on every united and regional council to prepare a regional planning scheme, and in it to identify generally the areas in its region which come within the various categories referred to in clause 4(c) of the First Schedule.

It may be that the identification need not be fully detailed, in the sense that it may be confined to areas of regional significance.

With the responsibility to make that identification, the subclause clearly also contemplates that the regional planning scheme contain provision to exclude such areas from future urban development.

A regional planning scheme, when approved, is a potent instrument. By section 17 of the Act, the Crown and every local authority and public authority is required to adhere to its provisions and every district scheme is required to give effect to its provisions. In the event of a conflict between the provisions of an approved regional planning scheme and those of an operative district scheme the provisions of the regional planning scheme generally are to prevail. See section 17(3).

Even the provisions of a draft or proposed regional planning scheme have some effect. By section 22 they are to be taken into account in determining any matter arising in the course of preparing implementing and administering a district scheme.

So the powers of a united or regional council are far-reaching indeed; and consequently the community and the law will be entitled to expect that those duties are performed carefully and the powers exercised responsibly within the regional context. In particular district councils will be entitled to look to the regional planning scheme for guidance as to areas which should be excluded from future urban development because land is subject to hazards, such as flooding and earth movement.

C. DISTRICT GOVERNMENT

Under this heading the statutory powers and responsibilities of territorial authorities are considered.

i. Land Use Planning

The pattern of the Town and Country Planning Act is to confer at the local level powers and responsibilities of a more detailed kind corresponding with those conferred on united and regional councils at the regional level.

Every territorial authority is obliged to provide and maintain an operative district scheme in respect of its district - Town and Country Planning Act, section 38(1).

The general purposes of district planning and the general objectives of district schemes correspond with those of regional planning schemes already referred to. District Schemes are to make provision for such of the matters referred to in the Second Schedule to the Act as are appropriate to the circumstances or as are necessary to promote the purposes and objectives of district planning set out section 4 of the Act - section 36(1).

The various matters to be dealt with in district schemes that are set out in the Second Schedule include clause 8 which is quite specific as to the hazards listed and as to the provision to be made in district schemes in respect of them. The district scheme is expressly required to contain provision for the avoidance or reduction of danger, damage or nuisance caused by the various phenomena listed. And although the territorial authority may be entitled to look to the regional planning scheme for a general identification of areas to be excluded from future urban development being land subject to hazards such as flooding and earth movement, the provision which it is the territorial authority's responsibility to make in its district scheme is much more specific and detailed. A district scheme has the force of law as a regulation. It is at the district level of government that planning can effectively control use and development of land. Territorial authorities can therefore expect to be held accountable for carefully exercising the responsibilities conferred on them by these provisions.

Planning Consent

Territorial authorities have responsibility for deciding applications for planning consent for specific uses and development of land. Depending on the circumstances the applications might be made under sections 33, 72, 74 or 75. Regardless of whichever section is appropriate, the council will have a discretion to refuse consent where a grant of consent would be contrary to the intent and purposes of the Town and Country Planning Act; and in each case the provisions of section 3 of the Act relating to matters of national importance will be required to be taken into account. The discretion must be exercised judicially, and having regard to the circumstances of each individual case. But in nearly every case it will be required to consider the application of the provisions of sections 3 and 4 of the Act and the provisions of the regional planning scheme and the district scheme. Depending on the individual circumstances, correct exercise of the council's discretion may well require it to refuse planning consent to a use of development of land which would involve danger from earth movement or flooding or erosion or the like.

ii. Control of Land Subdivision

Territorial authorities also have the responsibility of control of the subdivision of land under Part XX of the Local Government Act 1974. Section 313 makes new provision concerning the council's responsibility to provide a code of urban subdivision. The contents of such a code are likely to include passages concerning the stability of land, and its suitability for subdivision for building purposes; and also relating to excavations and fillings and the control of erosion during earth works. A draft standard currently under consideration by the Standards Association of New Zealand (which acknowledges substantial assistance from the Auckland branch of the NZ Institution of Engineers) contains sections dealing with those topics.

Approval of Scheme Plan

Whether or not a council has adopted a code of urban subdivision which contains such provisions, it has in relation to a scheme plan of subdivision submitted to it certain statutory powers and responsibilities. It should be noted that subsection (1) of section 274 is mandatory. It is the council's duty to refuse to approve in any of the circumstances set out in that subsection. Paragraphs (b)(i) and (d) provide a link between subdivision control and the Town and Country Planning Act. They are another means by which the provisions of that Act as to matters of national importance, and the provisions of the district scheme, are to be given effect to by the Council.

Paragraph (f) expressly obliges the council to refuse approval of a scheme plan where the land in the subdivision, or part of it, is subject to erosion or subsidence or slipping or flooding; and also where the subdivision is likely to accelerate or worsen or result in erosion or subsidence or slipping or flooding of other land; except where satisfactory provision is made for the protection of the land.

Consequently it is the council's duty to consider, in respect of every scheme plan submitted to it for consideration, whether or not any of the circumstances are applicable. That is a responsibility which it is required to exercise with care, and one which may involve requiring a report from those with specialist skills. It is a responsibility which the council owes to its future citizens - those who will own property in, or reside in the land being subdivided.

Attention is also drawn to the council's duty under section 277 in respect of a concept plan. Such a plan may be required in any major subdivision involving more than 50 lots. The council is required to send a copy of a concept plan to the regional council or united council for comments; and if it considers that the subdivision will affect soil conservation or erosion, it is also required to send a copy to the Regional Water Board - see section 277.

Where the council approves a scheme plan of subdivision, it has power to impose conditions in certain classes of case. Those referred to in paragraphs (f), (g), (h) and (i) of subsection (2) of section 279 may be relevant. It can stipulate the height of floor levels (presumably to minimise damage from flooding) paragraph (f). It can require provision for protection against subsidence, slipping, erosion or flooding (presumably in the form of physical works) - paragraph (g). It can impose a condition that filling and compaction of the land and earthworks be carried out to its satisfaction (paragraph (h)), and it can exclude any allotment from the subdivision (paragraph (i)). By subsection (4), the council may have regard to the siting of each allotment in order to provide suitable building sites, and can exclude allotments which would not produce suitable building sites.

iii. By-law Control

1) Buildings

Territorial authorities are empowered by section 684(1) paragraph (22) of the Local Government Act 1974 to make by-laws regulating and controlling the construction, alteration and repair of buildings. In exercise of that power most councils have adopted the NZ Standard model Building By-laws (NZS 1900), with or without local modifications. This power to make by-laws would be regarded as a power coupled with a duty: that is to say it is the duty of territorial authorities to make such a by-law.

By-laws regulating the construction of buildings, to be complete, would need to contain provision concerning the adequacy of foundations of buildings as well as the integrity of the structure.

The provisions of Chapter 2 of NZS 1900 are an example.

2. Building Sites

The responsibility of territorial authorities in respect of the adequacy of building sites is even more clearly defined by section 641 of the Local Government Act. That section, which prevails over anything in any building by-law, casts a duty upon a council to refuse a building permit in respect of a site which is not suitable or subject to erosion or subsidence or slippage or flooding or where the building work is likely to accelerate worsen or result in erosion or subsidence or slipping or flooding, unless the council is satisfied that provision is being made for protection of the land from erosion or subsidence or slippage or flooding. Where a condition of a building permit is imposed, the council is entitled to require a bond, with or without security, to ensure performance of the condition. A decision refusing a building permit or granting it subject to conditions may be the subject of an objection to the council, and if that is unsuccessful, to an appeal to the Planning Tribunal.

These provisions demonstrate the importance of the responsibility cast on territorial authorities in this area. Not only do they have a duty to future occupants of buildings and their owners, they also owe a duty to take proper care but not to be over-cautious without proper justification.

3. Landslip, earthworks and topsoil removal

By section 684(1) of the Local Government Act, councils have power to make by-laws prescribing conditions for control or prevention of slippage of land in any specified urban part of the district, or the protection of such land from slippage of other land (paragraph (25)); regulating or prohibiting the construction of earthworks (paragraph (26)); and regulating or prohibiting the removal of topsoil from private land (paragraph (27)).

D. EXERCISE OF STATUTORY POWERS AND RESPONSIBILITIES - THE REQUIREMENTS OF THE COMMON LAW

Whenever Parliament grants powers to a public body there are certain duties implicit in the grant of the power. They are implicit in the sense that they are often not expressed fully, or at all, in the Act of Parliament. But the community expects that public bodies entrusted with statutory powers will use them when the occasion requires, and will use them responsibly. The duties which the Courts will imply are only a development of those propositions.

Generally what is required of a public body in respect of its statutory powers is well known. The duties fall under three headings:

1) It should use its powers when the circumstances call for it;
2) It must not exceed its powers;
3) It must not abuse its powers.

These can be explained by reference to the statutory powers already mentioned.

1. If a building permit is sought in respect of a site which is subject to erosion or subsidence or slippage or flooding, then it is the council's duty to exercise its power under s.641 and refuse the permit (unless and until it is satisfied that provision for protection of the building is being made). To overlook the condition of the site so as to avoid a confrontation, and perhaps litigation, with an irate developer is readily seen as a breach of its duty.

   Likewise where a scheme plan of subdivision is submitted for approval, the council is obliged to consider whether it must refuse to approve it because of subsection (1) of section 274.

   So, too, where a council has power to make by-laws to control various activities. Where the circumstances in its district make control of that kind relevant, then it has a duty to make a by-law imposing appropriate control.

With the power to make by-laws, if it is exercised, comes the duty to administer the by-laws and enforce them. Thus it is the responsibility of territorial authorities to employ inspectors to ensure that the provisions of the by-law are complied with. Reference should also be made to the power of dispensation from the provisions of a by-law which is found in most by-laws. It should be noted that this power is not conferred on the engineer or any other officer of the council, but must be exercised by the elected council itself. Like all the other statutory decisions and discretions to be made by councils, a decision whether or not to grant a dispensation from the requirements of the building by-law concerning the foundations of a building would need to be exercised with care, and in appropriate cases after receiving a report from an officer or consultant having the appropriate qualifications. It should also be recognised that by-laws frequently leave matters of a technical nature to the judgement of the engineer, and in practice are often left to the judgement of an inspector. The officers concerned, of course, have responsibility for using care and skill in exercising judgement on these matters. In turn the council has responsibility to ensure that the people it employs in these posts possess the necessary skill and experience, and carry out their tasks to the necessary standard of care.

2. The principle that a public body must not exceed its powers is usually straightfoward. What is called for is a careful examination of the words of the statute conferring the particular power, and a comparison with the circumstances of the particular case to see that it fits. For example, section 641(2) sets out the circumstances in which a building permit is to be refused. It is only if the case falls within one of the three categories described in that sub-section that a council can lawfully refuse a building permit under that section. If it refuses for some other reason, e.g., because it considers the appearance of the building will be so unsightly that it will depreciate the value of other buildings in the vicinity, that would be exceeding its powers under s.641.

Another example could arise from the power to impose conditions on approving a scheme plan (s.279(2)). If a council omitted to impose a condition on approving a scheme plan later sought to impose it as a condition of sealing the survey plan, that would not be valid at law. It would be exceeding its power to impose conditions which is expressly related to approval of the scheme plan.

A different kind of excess of power would arise if a council sought to impose a condition of a kind which is not authorised by the statute at all, e.g., that no houses below a certain cost be erected on the lots; or that the subdivider be required to contribute to the cost of developing a car park at the nearest shopping centre.

3. There are many ways in which statutory powers can be abused. In general they relate to circumstances where a public body is biased, or fails to give fair consideration to the position of the person who will suffer as a result of its exercise of power.

There is less scope for abuse of power where a public body is involved in making legislation, such as a district scheme or a by-law. But where it is exercising a power affecting an individual, such as imposing a condition of scheme plan approval or refusing a building permit, the community expects very high standards of fairness. In some cases the law expressly requires that the person affected be given an oral hearing - as in the case of applications for planning consent. That is not always done, at least in the first instance, in imposing subdivision conditions or refusing a building permit, though it would be done in the case of an objection under s.299.

But where the person affected is not being given an oral hearing, it is important that he be sent any reports being made to the council or committee and in sufficient time that he can examine them and contradict or comment on anything in them.

The council must, of course, genuinely apply its mind to the particular case and not just rubber stamp the recommendations of its officers. If its decision is not made in good faith and on the merit of the case, it would be an abuse of power.

Even where it is not expressly required by statute, a public body should, as a matter of sound and fair administration, always give its reasons for any decision which is adverse to the interests of any individual.

E. APPEALS TO THE PLANNING TRIBUNAL

Appeals lie to the Planning Tribunal against decisions of public bodies in exercise of many of these statutory powers. For the purpose of deciding the appeal, the Tribunal has the same powers as the body appealed from, so it can substitute its own decision for that of the public body concerned.

The Tribunal will usually expect the council to justify its decision with appropriate expert evidence, and not merely to take the passive role of leaving it to the appellant to make out its case for the urban zoning, or the building permit. At the least, the council is likely to be called upon to demonstrate that it had reasonable cause for its decision.

The Tribunal will expect councils to act responsibly in these matters, and is unlikely to look kindly on a council which is unjustifiably cautious - i.e., without having obtained appropriate technical advice; or on a council which is suspected of leaving the responsibility of a true decision to the Tribunal so as to avoid the possibility of legal liability.

In preparing for the presentation of a case to the Tribunal, it will usually be helpful to all concerned if the expert technical witnesses for the contesting parties have met together to isolate their areas of difference.

Issues of primary fact are seldom in dispute and it will assist all concerned if an agreed statement of them can be submitted. The evidence (including cross-examination) can then be concentrated on the matters which are truly in issue.

The expert witnesses should also be given the opportunity of seeing each others report or evidence in advance of the hearing. Where questions of fact prove to be in issue they can then be checked. And where differences of professional opinion arise, no real advantage can be gained by surprise. The Tribunal will be assisted more by witnesses who have had the opportunity to reflect on the differing conclusions reached by their colleagues and the reasons expressed for them.

F. ASSESSMENT

Most of the statutory powers and responsibilities have been enacted during the last five years and it is probably too early to judge their adequacy in performance.

The water control legislation is said to have been under review for several years but only piecemeal amendments have been seen. It is to that area and the Mining legislation that we might look for new developments in the immediate future. One feature of Part XX of the Local Government Act which is said to leave room for improvement is the absence of provision for councils to have noted on the titles to land restrictions on its future development or use. The Commission of Inquiry into the Abbotsford Landslip Disaster considered this question carefully and recommended that the Act be amended to provide for it. The same issue was raised at the 1981 Municipal Conference, and a remit was passed requesting an amendment to the Act. Both the Commission of Inquiry and the Conference had been informed that the Registrar General of Lands did not consider the proposed amendment appropriate, but neither was dissuaded by the views of that officer. Evidently some opposition was expressed at the Municipal Conference because of the risk that an inference would be drawn that sections whose titles are not noted may be presumed to be sound building sites.

This is a live issue at present, and those who are professionally involved may wish to express their views and their reasons for them to the Government to assist it to reach a decision.

Setting aside that issue and the review of the water control and mining legislation, the present statutory powers and responsibil-ities provide a basis for informed decision-making at each stage of the urbanisation process, from regional planning to building permit. At most stages there is opportunity for participation by those who may not be directly involved, but whose skills and knowledge make their contribution particularly valuable.

Jeremy Gibb

Manawatu Evening Standard

Ministry of Works and Development

FOURTH DISCUSSION

- on the Abbotsford failure. Discussion leader Dr R D Northey; Soil Bureau, DSIR, Lower Hutt.

D H Saunders (North Canterbury Catchment Board)

Are there any other areas around Abbotsford where you can predict that a similar thing could occur?

Reply (Northey)

I am not an engineering geologist with precise local knowledge of the whole area - but certainly not in the immediate vicinity. That is not to say that that same piece may not move again: the underlying positions are still essentially the same. You would be looking for other areas where the dip is about 8^0 and the boundary between the Green Island Sand and the Abbotsford formation is buried at some depth with some sort of open face at the end of it. Personally I know of no such specific area.

G T Hancox (engineering geologist - NZ Geological Survey)

I have been working on that area with one of my colleagues and we have not yet found another area which is similarly at risk.

K J Tremaine (Palmerston North City Planner)

(a) What was the cost of your investigations, and
(b) Have some parts of the area been re-established.

Reply (Northey)

(a) It is always difficult to know what costs to include when investigations are carried out by a branch of government. In this case there were several people involved for several months - say one man-year. With allowance for overheads this sounds like about $100,000.

(b) Landscaped but not built on.

I M Grierson (Harrison and Grierson & Partners, Auckland)

You referred to a report which provided some warning about the area but was lost. Presumably the writers of that report would not have known about the subtle nature of the Abbotsford formation at a depth of 30 metres at this site. In fact it would appear that further geotechnical checking - limited to shallower depths and much less expensive than the $100,000 investigation you did - would have given the area a clean bill of health.

Reply (Northey)

Yes, this is a case where the surficial signs spoke more loudly than conventional soil strength tests would have done. The earlier workers must have taken note, very wisely, of the neighbouring slide - the one known as the "sunclub" slide.

J H Lawrence (MWD Head Office)

I think that if we had been looking at the Green Island borough from an urban capability point of view, there would have been a lot of other areas which we would have regarded as being at greater risk.

Anonymous

I am concerned that the earlier report was lost sight of. We have a long way to go to persuade councils of the seriousness of geotechnical issues. I recall that when Whangarei City announced its reviewed district scheme about three years ago (and it was the first to zone for flooding and landslip in one package) the Chamber of Commerce quickly rose to its feet and said what a load of nonsense it all was. At that stage it would have been very easy for the Council to have backed down. Many of the councillors were tempted to back down and it required a lot of resilience on the part of the City Engineer to make the thing stick. The Ministry of Works Water and Soil Division also helped to carry the day by supporting the view that landslip does need to be taken into account in district scheme preparation.

Reply (Northey)

I was concerned many years ago with the landslide at Tahunanui in Nelson. An interesting thing turned up when we looked at the title deeds on that piece of landscape. The district land registrar of the time had allowed to be registered on the title - quite beyond his power - the words "site of old landslide". There were also some details recording how far pegs had moved over certain periods of time. Things stayed that way for as long as that man remained the registrar or perhaps there was a change of city engineer. When he (or they) retired that piece of landscape was re-subdivided and plans were re-presented back through the system with no indications on them of the instability. The subdivisions went ahead, the area was developed and then it failed with many houses being seriously damaged.

M A Wesseldine (Manukau City)

I understand that financial loss at Abbotsford and elsewhere could have been lessened if the Earthquake and War Damage Commission had been allowed to spend money to prevent damage - e.g. to move houses which were obviously at risk. Did the Abbotsford Commission of Enquiry make any recommendations on this?

Reply (Northey)

Yes, a recommendation was made that the powers of the EWD be extended to allow it to minimise damage (i.e. to minimise its own losses) by repairing retaining walls, moving houses and so on.

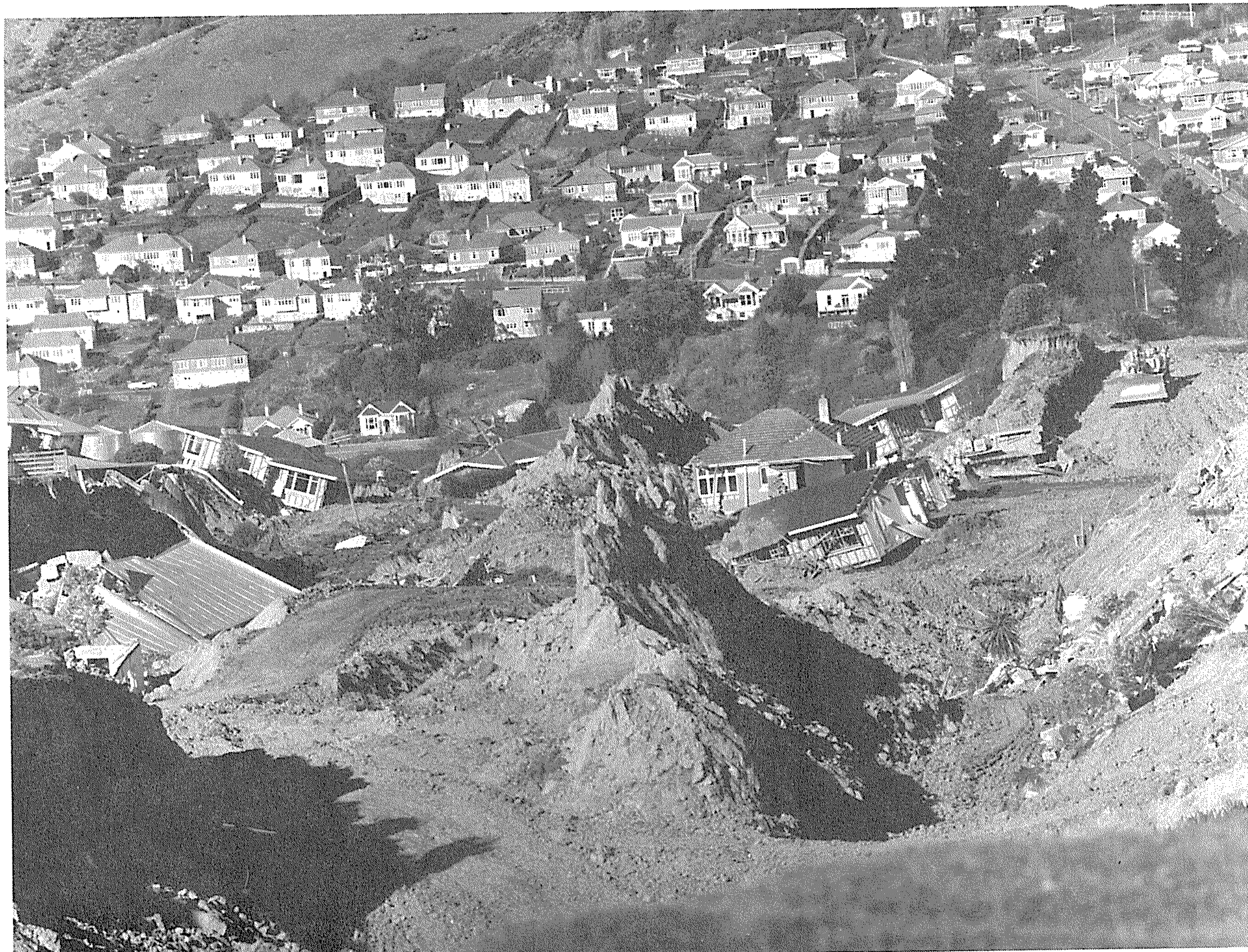
Anonymous

The weak layers of material in the Abbotsford formation had presumably been there for millions of years and I cannot believe that there have not been many periods of wetter weather there than occurred just before the failure. I believe that we must look at recent changes in order to explain why the failure occurred and I feel that the significance of the excavation at the toe of the slide - Harrison's Pit - has been underestimated. You have said that the effect of Harrison's Pit was small, but when a system is almost at the point of failure a small thing can be large enough to trigger movement.

Reply (Northey)

The influence of Harrisons Pit I see as being one of influence on the time of failure, rather than on whether failure occurred or not. The excavation of Harrisons Pit almost certainly hurried things along.

One final point I believe deserves emphasis. The Abbotsford situation illustrated that it is the defects, the weakest layers in a system, which control things - not the properties of the mass as a whole. There is a very big geotechnical lesson to be learnt here. The piece of material which did not survive the sampling procedure may very often be the most significant piece of all.



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GEOMECHANICS IN URBAN PLANNING - PALMERSTON NORTH APRIL/MAY 1981
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PLANNING TO PREVENT GEOTECHNICAL PROBLEMS IN URBAN DEVELOPMENT - AN ENGINEERING GEOLOGICAL VIEW

G T HANCOX, NZ GEOLOGICAL SURVEY, LOWER HUTT

1. INTRODUCTION

The preceeding papers have discussed in some detail the range of geological hazards that affect urban areas and described some typical examples of problems that have arisen in the past.

Following on from this, the objective of this paper is to examine the role of geology in planning future urban development. For convenience this will be done in two stages:

(i) An outline of present sources of geological information and discussion on the adequacy of this information for urban planning.

(ii) Discussion on the possible future role of geology in urban development, including methods of improving the range, quality, and presentation of engineering geological and hazard related data for planning purposes.

In the interests of brevity, methods of data collection, planning implications, and the complex problem of "who provides the information" will not be discussed.

2. SOURCES AND LIMITATIONS OF EXISTING GEOLOGICAL INFORMATION

Geological information is available in a variety of forms, including maps, reports, and scientific papers and bulletins. Although a great deal of valuable data are contained in the latter three, in NZ Geological Survey experience, this source is less used by planners, who usually do not know how and where to look for it, often because the practical value of some of the information is obscured by the form in which it is published.

The main map types presenting geology-related data are listed in Table I, and those presenting basic geology are discussed more fully below.

2.1 Geological Maps

Published geological maps are the most widely used source of geological data for planning as they most effectively provide land area related information.

2.1.1 Small scale basic geological maps

For basic geological information, national coverage is available in the Geological Map of NZ, 1:250 000 series, published between 1960-68. These maps show time - stratigraphic rock units (rock deposited during a specific period of time) rather than rock - type (lithological) units. Apart from the younger beach, stream, and swamp deposits, most surficial deposits (soils, colluvium, etc.) and landslide features are generally not shown. Other important field characteristics (lithology, hardness, strength, weathering, defects, particle size, etc.) also are not indicated. Essentially these are small-scale reconnaissance maps, suitable only for broad planning. In the past however, they have been widely used for planning at all levels as they were the only readily available source of information.

2.1.2 Medium scale basic geological maps

Larger scale maps (Geological Map of NZ 1:63 360 and 1:50 000 modern, post 1950 series) cover about 20% of the country, but at present only some of the large urban areas have been mapped (Auckland, Hamilton, Taupo, Napier, Hastings, New Plymouth, Nelson and Greymouth). These maps present in greater detail the same type of data as the 1:250 000 maps. Many of the earlier maps use time - stratigraphic (rock-type) units but most post 1950 maps use lithological units. The larger scale and the rock type data make them better for general planning, and they offer the best base for the production of special purpose and interpretative maps and assessments. Suitability for planning is lessened by limited coverage and the same lack of relevant data as described above.

TABLE 1

MAJOR MAP SERIES PRESENTING GEOLOGICAL AND GEOTECHNICALLY RELATED DATA APPLICABLE TO URBAN PLANNING

MAP SERIES TITLE	PRODUCTION AGENCY	TYPE OF DATA SHOWN	% NATIONAL COVERAGE PUBLISHED	COMPIL. SCALE	PUB. SCALE	PUBLICATION DATE Start	PUBLICATION DATE Comp.	COMMENTS
Geological Map of NZ 1:250 000	NZ Geol.[a] Survey, DSIR	basic geology	100	1: 63 360	1:250 000	1960	1968	Show time stratigraphic units, not designed for, and of limited value for detailed urban planning
Geological Map[b] of NZ 1:63 360 (and recent 1:50 000 maps)	" "	basic geology	20	1: 15 840	1: 63 360	1950	-	Same as above; best basis for special purpose and interpretative maps at present
Late Quaternary Tectonic maps	" "	Active faults, folds	(c) (selected areas only)	various	1: 63 360 1: 50 000	1969	-	Indicate possible faulting hazard areas; some Quaternary geology in later maps; some have larger scale map inserts
Geological Map of NZ Industrial Series	" "	basic geology and geol. hazards	(c)	1: 15 840 & various	1: 25 000	1966	-	Show basic (1:63 360) geology; geol. hazard and some eng. geol. data provided. Limited coverage; good for preliminary local planning
Geological Map of NZ Urban Series Maps	" "	basic geology, instability data	(c) (Nelson only at present)	1: 15 840	1: 25 000	1979	-	Some eng. geol and hazard (slope instability) data; best basis for special purpose on interpretative maps; good for local and site planning. 1 published sheet at present, 2 others in prep.
NZ Geol Survey Miscellaneous Series	" "	basic geology	(c)	various	various	1969	-	Mainly basic geology, catering for miscellaneous areas and topics
Soil Maps of NZ - several map series 1:1 000 to 1:250 000	Soil Bureau DSIR (a)	basic soil sets, series, types and phases	100 (1:250 000; others incomplete)	various	various	-	-	Data varied, applicable for broad assessments mainly; some valuable eng. prop data on some maps, but generally too shallow for detailed planning of eng or urban works
Detailed Regolith, Geomorph. Maps	" "	loess, tephra, surface deposits	50	various	1: 30 000 1:250 000	1972	-	25 maps; show regolith and landform features
National Resource Surveys (Pub. by MWD, T & C Planning and Lands & Survey)	NZ Geological Survey	simplified basic geology	47	1:500 000	1:500 000	1959	1973	Limited factors incorporated, compiled from existing data (eg. 1:250 000 Geol. Maps); suitable only for broad planning
Land Inventory Map Series (NZMS 237)	(Interdepartmental preparation, published by Lands & Survey)							
"Rock Type and Resources" maps	NZ Geological Survey	basic geology, rock types	7		1: 31 680 1:126 720	1965	1976	Comments as immediately above
NZ Land Inventory "Rock Types and Surface Deposits" NZMS 290 (new metric series)	Published by L & S, compiled by NZ Geol. Survey	rock types & resources; faults, rock hardness (compilation, little new data)	3 sheets (11 of Northland in prep.)	1:250 000	1:100 000	1979	-	Map emphasis rock type and hardness, with data on geol. resources, active faults. Limitations due to lack of data, (eg slope instability), scale enlargement. Suitable only for broad planning. Despite title, surficial deposits not shown
NZ Land Resource Inventory	Water & Soil Division, MWD* (a)	Multifactor on one map (rock type, soil, slope angle, erosion type & degree, vegetation classes)	100	various; geology at 1:250 000	1: 63 360	1975	1979	Limited factors, size of land units (60 ha), scale enlargement, and limited range of physical and geological factors (lack of hardness, structural, economic and geol. hazard data) limits use to broad planning; not suitable for foundation, resource, or detailed hazard evaluation.

(a) These agencies produce maps of many scales for different purposes. Only the major series are listed here.

(b) Maps in process of being replaced by metric 1:50 000 Series; text and notes refer also to bulletin maps at 1:63 360 published since 1950. Maps of variable quality and content at same scale accompany older bulletins (1906-1950) and cover c. 25% of the NZ land area.

(c) National coverage not intended. [Note: Data from various sources, including Molloy et al. 1980]

Late Quaternary Tectonic Maps

Late Quaternary Tectonic maps show earth deformation features (active faults, folds) at various scales, mainly 1:50 000 or 1:63 360, with large scale map insets. Maps of only a few areas are available at present. In these maps, areas of faulting hazard are delineated, providing planners with valuable data in a form that is of immediate use for regional, district, or subdivisional planning.

2.1.3 Large scale special purpose geological maps

(a) Industrial Series Maps

NZ Geological Survey Industrial Series maps (1:25 000) are available for Hamilton and most of Auckland City. These maps have an aerial mosaic base and show basic geology in litho-stratigraphic (rock-type formations) units. Map notes include sections on geological hazards (volcanic risk, landslides, earthquakes) and engineering aspects (foundations, excavations). A table is included, listing main features of the various map units (rock and soil types, hardness, weathering, thickness) and subjective assessments of their general engineering characteristics (bearing capacity, stability, ease of excavation, construction material potential, etc.). During the 15-year period of their preparation these maps have evolved in concept and content. The most recent one, Cornwallis (N42/7) which is being draughted, also emphasises the relative strength of materials. Such maps have proved valuable for general local and site planning in the Auckland area, but they are not intended as an alternative to site investigations.

(b) Urban Maps

A recent advance has been the introduction by NZ Geological Survey of Urban Series maps, a development from the Industrial maps and designed to cover urban or potential urban areas, at a scale of 1:25 000 or larger. Compared to Industrial maps data presentation is substantially improved by colour reproduction and contour base. Basic geology is presented in litho-stratigraphic units, and legend notes give greater emphasis to lithologic descriptions. Potential geological hazards such as active faults and various landslide features are shown, and an extended legend gives general engineering properties of the map units. Only the Nelson Urban map is available at present, but one of southern Dunedin (including

Abbotsford) is nearing completion, and a third, Whangarei, is in preparation.

The Urban maps are seen as a significant advance from basic geologic maps, but from a geotechnical point of view they are by no means ideal. NZ Geological Survey plan a more extensive coverage of similar or improved maps in the future. It should be stressed however that preparation of such derivative maps is a slow process, and dependent on the availability of large-scale basic geology maps. Also, the maps are not intended to cater for site-specific situations; they should, however, prove to be of great value in preliminary planning, and serve as a guide to those areas requiring more detailed site investigations.

Many other special purpose or interpretative maps are also available, such as soil maps, Resource Surveys, Land inventory Rock Type and Resources Maps, Miscellaneous Series maps, Land Resources Inventory maps, etc. (Table I), to mention but a few. Unfortunately, space does not permit further discussion here, however, in most of these maps, scale enlargement and lack of basic data limit their use to broad planning.

2.2 Town and Country Planning

At present two DSIR divisions (NZ Geological Survey and Soil Bureau) have major input of geotechnical data into Town and Country Planning District and Regional schemes. NZ Geological Survey comment is made by District Offices, and by the Economic Geology, Earth Deformation and Engineering Geology Sections in Lower Hutt, and other staff as appropriate.

For Town and Country planning, NZGS contributions are based mainly on office studies (of reports, papers, bulletins, files and published maps) of the areas concerned. Data provided usually includes a geological summary and general assessments of groundwater, mineral resources, geological hazards (earthquakes, landslides, faulting, volcanic activity) and engineering geological problems. Comment is seldom site-specific and field checking is not generally carried out. In 1979 NZ Geological Survey made 33 assessments for borough, city, county, and regional schemes, and in 1980 34 assessments were made.

Problems encountered in providing meaningful geological advice include:

(a) Lack of large scale geological maps for rapid appraisal of areas nominated.
(b) Inadequacy of existing geological data on resources, hazards, surficial deposits, and engineering properties of map units.
(c) Staff shortages and lack of time to collect data, carry out field checks, and prepare reports and special purpose and interpretative maps.
(d) Lack of suitable (large scale, metric) base maps and aerial photos.

3. GEOLOGICAL INFORMATION REQUIRED FOR URBAN PLANNING

The need for geological information in urban planning, and the limitations of existing sources of data in meeting this need, have been apparent for many years, and it was vividly demonstrated by the recent Abbotsford Disaster and the subsequent inquiry. Most planners and developers have recognised the need for more geological information, and most would also agree that it must be the right kind of information.

The range of geological information likely to be needed in urban planning in the future, and some methods of data presentation are summarised in Table 2 and discussed briefly below.
Geological data listed in the "Information Required" column of Table 2, includes:

(a) Basic information (B), shown on basic geological maps (e.g. rock types, unconsolidated alluvial and beach deposits, faults, volcanic features, and geological structures etc. as shown on recent 1:50 000 maps).
(b) Basic and some specialised data, usually shown only on special topic maps such as the NZ Geological Survey Urban, Industrial, Tectonic, and Land Inventory maps.
(c) Specialised engineering geological and geotechnical data (strength, atterberg limits, density, grading, defects etc.), and instability, geomorphic, and geological hazard data not shown on existing geological maps.

TABLE 2

GEOLOGICAL INFORMATION REQUIRED FOR URBAN PLANNING

INFORMATION REQUIRED(1) Basic	Specialised	DATA PRESENTATION Special Purpose Maps	Interpretative Maps
1. Rock types (B) 2. Unconsolidated materials (B) (eg Quaternary stream and beach deposits) 3. Surficial deposits	Lithology (B), distribution (B), composition (mineral, chemical) (B); *particle size; thickness; hardness and/or relative strength (including *consistency and compactness of soils); origin (eg. colluvium, loess, tephra); rock defects *(spacing, persistence and nature of joints, bedding, schistocity, clay seams/beds, gouge and crush zones); *lab. geotechnical data (density, moisture content, shear strength, slake durability, atterberg limits etc.)	- Rock type (lithologic) maps - Rock hardness and weathering maps - Surficial deposits maps - Soil maps Maps with a more comprehensive range of basic and specialised data include: - Engineering geological maps and plans; geotechnical maps, Urban and Industrial maps (eg. basic geology; rock type, surficial deposits, eng. parameters, geological hazards, slope processes etc.)	- Ease of Excavation maps - Foundation Suitability maps
4. Geological Structures (B) - faults, folds (attitude of bedding, schistocity)	Active, potentially active, inactive Faults; *Fault displacements; nature and width of fault zones	- Late Quaternary Tectonic maps (faulting hazard maps)	- Erosion Potential maps
5. Mineral, groundwater, and aggregate resources	*distribution, quantity, grade	- Mineral resource maps - Construction material resource maps	- Geologic Hazard maps (landslides, earthquakes, faulting, volcanic activity, lahars, flood induced mass movements (mud and debris flows etc.)
6. Volcanic features (B)	active vents; old craters; geothermal areas (hot ground, pools, stream vents etc.); *lahar courses and deposits; *high ashfall areas; sources of acid waters	- Volcanic and geothermal maps - Volcanic hazard maps	- Earthquake (seismic) Microzoning maps - Relative Stability maps
7. Landslide and mass movement features	**Active landslides; old landslide areas; landslide debris; actual or suspected unstable ground (hummocky ground, creep, subsidence, minor slumping); deformation features (tension cracks, compression rolls); ponded water, springs; seepages; erosion features (gullying, sheet erosion, scree slopes, debris fans); mass movements due to flooding (mud and debris flowprone areas)	- Landslide maps (types, activity and landslide deposits) - Landslide morphology maps (large scale) - Erosion maps	eg. RELATIVE STABILITY MAPS - Determined by subjective assessment, or by multi-factor overlay method of factors such as: - rock type (including fault zones) - surficial deposits - slope angle - evidence of past or present instability These factors can be classed numerically and combined to produce a coded stability classification
8. Topographic features	Relief, *slope angle, slope aspect; *topographic lineaments; drainage; springs; cliffs, scarps; *major road cuts and excavations	- Landform maps - Slope angle maps - Topographic (structural) lineament maps	

(1) Includes data shown on basic geology maps (B); basic and specialised data usually only shown on miscellaneous special topic geological maps (eg. Urban, Industrial, Tectonic, and Land Inventory maps), and some detailed geotechnical, geomorphic and hazard data not shown on current geological maps (*). ** Some features shown on recent Urban Series Map I (Nelson).

TABLE 3

POSSIBLE USE OF MULTIFACTOR ASSESSMENT OF RELATIVE STABILITY IN THE WELLINGTON AREA

GEOLOGICAL FACTORS	SLOPE ANGLES - RANGE APPROPRIATE TO REGION 0 - 15°	15° - 30°	30° - 40°
GREYWACKE BEDROCK (no landslide deposits, thin surficial deposits, < 1 m thick)	STABLE 1		GENERALLY STABLE 2
SUSCEPTIBLE BEDROCK (Crushed, highly weathered)	STABLE 1	GEN-MOD STABLE 2 & 3	MODERATELY UNSTABLE 4
THICK (>2 m), SUSCEPTIBLE SURFICIAL DEPOSITS	GENERALLY STABLE 2	MODERATELY STABLE 3	MODERATELY UNSTABLE 4
LANDSLIDE DEPOSITS	UNSTABLE 5		

NOTE: This table is intended to illustrate one method of multifactor assessment of relative slope stability. The details shown are thought to be reasonable for the Wellington area, but have not been field checked and should not be used for urban planning or stability assessment.

If the above information is available, any number of special purpose or interpretative maps (Table 2) can be produced, including one designed for urban planning. As a result of varying geology and topography, the range of geological hazards (and hence the data required) will differ considerably throughout New Zealand (see Appendix). An engineering geologist should be able to identify the type of information that will be of most relevance in any area under study.

Generally both the basic geological maps and special purpose maps with a comprehensive range of data will be of most value in urban planning and development. For example, large scale (1:5 000 to 1:25 000) engineering geological maps showing basic geology, lithologic descriptions and engineering properties of rock and soil (engineering) types, and geological hazards (landslide features, active faults, active volcanic areas etc.). The present industrial and urban series maps show only some of these data, but for planning purposes they are the best currently available in New Zealand.

The special purpose and interpretative maps (Table 2), designed essentially for urban or industrial planning, have been extensively described in overseas literature (see References). Interpretative maps of most value for the urban areas are those showing geologic hazards. A relative stability map, for example, can be prepared by subjective assessment of each map unit (shown in table form on the Nelson Urban map), or by a multifactor overlay method, taking into account rock types, surficial materials, slope angle, and evidence of past instability. These factors can be classed numerically (with or without allowance for ground-water conditions) and combined to produce a coded stability classification. Due to varying geologic and topographic conditions, the appropriate range of geologic factors and slope angles used should be determined separately for particular areas or for particular rock types. An example of one possible method of multifactor assessment of relative stability in the Wellington area is shown in Table 3.

4. CONCLUSION

This paper outlines the main sources and limitations of geological information, lists an "ideal" range of geological and geotechnical data required for urban development in the future, and mentions some methods of data presentation.

The main conclusions drawn from this appraisal are:

(1) Most geological maps available at present are inadequate for detailed urban planning because of scale limitations, lack of relevent data, or limited coverage.

(2) There is an obvious lack of medium scale (1:50 000 and 1:63 360) basic geological maps. About 20% of the country has been covered at these scales but only some of the major urban centres have been mapped.

(3) Medium scale geological maps currently available do not present important data on surficial deposits, geological hazards, engineering properties of materials, and mineral resources.

(4) The additional engineering and slope instability data shown on the large scale (1:25 000) Nelson Urban map, although far from ideal, is seen as a significant improvement for planning purposes.

(5) The inclusion of a similar or improved range of engineering geological data on future NZ Geological Survey Urban maps and 1:50 000 geological maps, possibly with large scale map inserts of major urban centres (e.g. Greymouth map), would be a major advance.

(6) Improved coverage in medium and large scale basic geologic maps is seen as a major prerequisite for the development of engineering geological maps and geologic hazard maps. Such maps, however, would not be an alternative to site investigations, but would mainly be used for detailed preliminary planning and serve as a guide to areas requiring more detailed work.

(7) The future role of geology in urban planning and development rests with the geologists, the engineering geologists, and most importantly, with the policy makers who must ensure that the right decisions are made and adequate resources provided so that the appropriate data are made available.

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APPENDIX

Regional occurrence of major recurring hazards and mineral resources in some urban areas.

Type of hazard or mineral resource	WHANGAREI	AUCKLAND	HUNTLY	HAMILTON	ROTORUA	GISBORNE	NEW PLYMOUTH	NAPIER-HAST.	WANGANUI	PALMERSTON NTH	MASTERTON	WELLINGTON[1] URBAN REGION	NELSON	GREYMOUTH	CHRISTCHURCH	TIMARU	DUNEDIN	INVERCARGILL
HAZARDS																		
FLOODING																		
lakes, rivers,			o		o			o		o		o	o	o	o			o
sea		o				o						o			o			
EROSION and SEDIMENTATION																		
slopes					o							o			o	o	o	
coasts		o										o						
dunes												o						
SLOPE INSTABILITY (excl. above)	o	o				o	o	o	o	o		o	o	o	o		o	
SEISMICITY					o	o	o	o	o	o	o	o	o	o	o	o	o	o
ACTIVE FAULTING, FOLDING											o	o	o					
VOLCANIC ACTIVITY																		
eruption		o			o		o											
geothermal					o													
WEAK FOUNDATION MATERIALS																		
landfill		o		o	o			o				o	o		o		o	o
expansive soils[2]		o																
liquefaction[3]					o	o		o	o			o	o				o	o
subsidence[4]			o												o		o	
organic rich materials[5]		o			o		o		o	o	o	o			o			o
WIND							o			o		o			o		o	
WATER CONTAMINATION[6]			o	o				o				o			o			
MINERAL RESOURCES																		
ENERGY																		
coal			o															
geothermal					o													
natural gas/oil							o											
NON-METALLIC																		
aggregate		o						o		o	o	o	o		o	o	o	
clay		o										o			o			
dimension stone		o										o						
limestone	o							o									o[7]	
sand				o								o					o	

[1] Includes Raumati coast so as to list examples of coastal and dune erosion.

[2] Expansive soil is one that expands when its pressure is reduced and/or its water content is increased.

[3] Liquefaction is the transformation of a material into a fluid mass.

[4] Subsidence is the local downward settling or sinking of the earth's surface with little or no horizontal movement. Often due to underground excavation or solution.

[5] Organic rich materials include peat and lagoonal deposits.

[6] Either surface and groundwater.

[7] Marl quarried for cement.

(From Molloy et.al., 1980)

GEOMECHANICS IN URBAN PLANNING - PALMERSTON NORTH APRIL/MAY 1981
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URBAN CAPABILITY SURVEYS AS PART OF LAND USE PLANNING

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The need for identification of physical hazards to urban land-use has largely arisen from the responsibilities and liabilities imposed on local authorities by the Town and Country Planning Act 1977 and the Local Government Amendment Acts 1978 and 1979.

Local authorities are empowered to identify in regional schemes areas to be excluded from future urban development, including land subject to flooding and earthmovement.

Local authorities may through district scheme planning avoid or reduce danger, damage or nuisance caused by flooding, erosion, landslip, subsidence, silting and wind.

The purposes of regional and district planning (to use and manage resources wisely and control development so as to promote the safety, general welfare, and amenities of the region or district) reinforce the theme of avoidance of physical hazards. Local authorities are also empowered to have regard to the principles of the water and soil legislation, which are to promote soil conservation, prevent and mitigate soil erosion, prevent damage by floods and utilise land in a manner to attain these objectives.

Local authorities have the power and responsibility to refuse subdivision plans and building permits if the land or any part of it is subject to erosion, subsidence, slippage or inundation, or if subdividing or building exacerbates or causes these hazards.

Local authorities clearly have the planning and management responsibilities to avoid physical hazards so as to minimise the dangers, costs and impacts of the hazards on the community.

Before planning can begin to prevent problems from arising, some assessment is required to identify the hazards, and to order them in terms of the degree of risk involved for various types of urban development.

It is within this context and arising from local authority requests that NWASCO has developed techniques to identify some of the physical hazards to urban land uses.

Assessment methods have largely developed from the NSW Soil Conservation Service's technique of Urban Capability Assessment. This is based on a physical inventory of data including geology, soils, slope, land form and surface drainage. From this information, urban capability classes are derived and expressed as homogeneous unit areas according to a scale of increasing physical limitation to urban use. Each class is assessed as to its suitability to the particular level of urban development that it can sustain, without causing excessive erosion and sedimentation e.g. extensive building complexes, residential, strategic development, reserve and recreation.

Urban capability assessments can be undertaken at various scales depending on the planning and development requirements of the requesting local authority and the size of the area involved. NSW surveys are carried out at 4 levels; regional strategy plans, district plans, project and subdivision plans, and site plans. At the first two levels the indicative urban capability survey identifying physical limitations and land suited to various uses is used. At the latter two levels detailed geotechnical data is also included along with detailed erosion and sediment control plans.

Many urban capability assessments have now been carried out in New Zealand at a variety of scales (1:25,000-1:4,000) and for a variety of purposes.

All except one (Eastbourne) have adapted the homogeneous unit area approach to map physical limitations to urban uses, an approach used widely for geotechnical, geomorphological and rural land use capability mapping. The inventory factors mapped and the limitations identified reflect the type of physical problems which confront urban use of that land. For instance, full account is taken of the position of the land unit in relation to the catchment within which it is located, by recording a terrain component in the inventory, detail of the catchment hydrology (both surface and underground), and by identifying off=site runoff effects and topographic location limitations. Detailed information is also given on soil conservation and water management to reduce erosion, sedimentation, and flooding during and after development, and to identify areas where site specific ground engineering investigations are necessary.

INVENTORY FACTORS:

The following inventory factors are mapped.

1) Geology - Lithological classifications for each survey using Geological Survey information.

2) Soils - Best available classifications from Soil Bureau.

3) Slope - Standard slope categories developed from LUC surveys modified where necessary to suit urban situations.

4) Terrain - The following terrain types have been used where appropriate:- ridge top, side slope, foot slope, basin, valley bottom/flood plain, gully, plain, terrace, scarp, fan, swamp, ephemeral waterway, beach ridge, dune, coastal cliff, disturbed terrain (man made and natural).

   NB: Irrespective of whether or not development involves major earthworks, an indication of terrain helps determine the limitations to development, be they onsite, offsite, or in terms of site development techniques.

6) Erosion - past, present and potential erosion have been mapped using standard LUC survey types and rankings.

7) Drainage - The following drainage conditions have been recorded where appropriate; ponding, high water table, overland flow from rivers and adjacent elevated areas, marine inundation, springs.

Each drainage condition has been given a severity ranking in terms of difficulty of mitigation for the urban situation on a 0-3 scale of negligible, slight, moderate/severe, extreme.

8) Landuse and vegetation - recorded using standard LUC survey classification and modified according to the scale and purposes of the survey.

URBAN CAPABILITY CLASSIFICATION:

1) 3, 4 and 5 class capability systems have been used according to physical limitations to urban use.

3 class (Eastbourne Borough)	*Favourable* - no hazards to further development other than those catered for by good subdivision and building practice. *Restricted, suitability 1* - only one hazard or a combination or minor hazards. *Restricted, suitability 2* - one severe hazard or a combination of 2 or more hazards.

4 class (Hawkes Bay area and Upper Waitemata Harbour Catchment)	A	Negligible limitations
	B	Minor limitations
	C	Moderate-severe limitations
	D	Physical limitations to urban use so severe that while technically feasible to overcome they preclude high density urban use.

5 class	A	Well suited to urban use
(other surveys)	B	Slight limitations
	C	Moderate limitations
	D	Severe limitations
	E	Unsuited to urban use.

NB: The 4 class system has been used in both cases for broadscale mapping at 1:25,000 scale for regional planning exercises where there was an unwillingness, given the level of geotechnical data, to state categorically that land was not suited to any form of urban development.

2) Limitations have included the following physical conditions; flooding, drainage/soakage, stability, erosion (sediment generation), foundation (settlement and bearing capacity, topography (dissection and slope length), aquifer, ground properties (rock outcrops), locational (with respect to other hazards).

One study, Eastbourne, identified hazardous situations with the hazards listed for each situation e.g. base of steep slope >15^0 - landslips, rock and tree fall, stormwater from above; large dead and dying trees on steep slope >15^0 - landslip, tree and debris avalanche, root wedging in rock. This approach was used to guide the Council in the absence of sufficient data to allow mapping of homogeneous unit areas.

NB: Some studies have incorporated highly productive soils as a descriptive qualification which does not affect the overall limitation to urban use i.e. the capability class.

All urban capability studies carried out to date fall within the category of indicative studies, that is, they identify physical hazards generally (1:25,000-1:4,000) so that local authorities can:

1) Derive a general impression of where development is best avoided because of the degree of hazard.

2) Request site specific ground engineering investigations from the developer, and depending on the results avoid or mitigate the hazards.

Indicative urban capability studies can, therefore, direct attention to particularly hazardous areas, obviating the need to carry out detailed surveys over large areas, some of which may never be developed for urban purposes. The cost effectiveness of such an approach is obvious. Many local authorities have adopted this approach and used hazard information for the following three purposes.

1) In the Hawkes Bay area a group of local authorities are using the urban capability information (1:25,000) to identify areas within a region that have the least physical impediments to urban growth.

2) Eastbourne Borough, and Manukau and Waitemata Cities are using hazard survey information to identify where site specific ground engineering investigations are necessary before considering subdivision and building permits, refusing some, and putting conditions on others to mitigate or avoid the hazards. Suspect areas are shown on the planning maps, and the scheme statement clearly states that not all sites or parts of sites in the areas indicated as hazardous are necessarily hazardous; and that physical limitations for urban use may not be confined to those areas indicated on the maps.

3) Hikurangi Town has used hazard information (1:4,000) from an urban capability survey to avoid the hazardous areas altogether by zoning them rural.

SUMMARY

The objective of the urban capability survey is to assist local authorities to identify and control development in hazardous areas by:

1) Describing the physical factors contributing to the hazardous situation - inventory.

2) Assessing the type and degree of physical hazards - urban capability assessment.

3) Indicating the <u>degree</u> of urban development that can be sustained in particular areas.

4) Describing the <u>consequences</u> of developing in hazardous situations.

5) Describing measures to <u>mitigate</u> problems that already exist and <u>avoiding</u> those that may occur through landowner action.

The urban capability study can do no more than indicate and advise on the physical capability of the land, that is, its ability to physically sustain urban use, and idenfity the type and degree of hazards. It is the local authority that must decide on the most appropriate land use, considering <u>all</u> factors affecting the suitability of land for urban use, and then control development by zoning land and issuing or refusing subdivision and building permits.

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PLANNING TO PREVENT PROBLEMS: THE CASE OF THE UPPER WAITEMATA HARBOUR CATCHMENT STUDY

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Everyone recognises the value of preventive medicine: that prevention is much more desirable, is less disruptive or troublesome, as well as being cheaper and more effective than attempted cure. The Upper Waitemata Harbour Catchment Study (UWHCS) is such a project, aiming to identify and head off problems before they arise, as well as to solve a few existing problems en route.

The UWHCS is jointly sponsored by the Auckland Regional Water Board and the Water Resources Council. It arose because of the concern that major land development in the 200 km^2 catchment draining to the Upper Waitemata Harbour could have a very serious and perhaps irreversible impact on the Waitemata Harbour, one of Auckland's greatest natural resources, quite apart from the damage that simultaneously could be done to contributing streams and adjacent soil resources. Rational land development is required to conserve all the values of the area and, at the present time, guidelines to ensure this are in an embryonic state. If a coherent set of guidelines for minimum impact development of land and water resources can be produced for the Upper Waitemata Harbour Catchment, then the general principles should be applicable to many other areas in New Zealand, even though calibration for local conditions would obviously be required. Hence the Study has national as well as regional significance.

After clearly establishing terms of reference and general objectives, detailed problems requiring study were identified and teams were established to take responsibility for each problem area. Research in each case is directed strictly towards providing information for water and soil management purposes (Guidelines Development).

The UWHCS therefore has six sections:

1. <u>Land Resources</u> (Coordinator: Dr J. Hawley, Aokautere Science Centre) Objectives are to map land resources, to identify actual and potential hazards in the way of development, and to assess the best use and

management of the land, from a soil and water point of view.

2. Water Quantity (Coordinator: Mr J. Waugh, Christchurch Science Centre) Objectives are to measure stream flows from rainfall over land having different uses, and to predict stream flows resulting from various patterns of development.

3. Water Quality (Coordinator: Mrs M. Van Roon, Auckland Regional Water Board) Objectives are to measure the water quality of streams draining from areas of different land use, to predict the changes in water quality that might occur when land use patterns change, and to assess the sensitivity of the Harbour to pollution, as well as its present condition.

4. Estuarine Hydrology and Sedimentology (Coordinator: Mr B. Williams, Hamilton Science Centre) Objectives are to measure the physical characteristics of the Upper Harbour, to estimate the flushing action of the tides and residence times and paths of pollution dispersion, and to measure sedimentation rates and assess its relation to adjacent land uses.

5. Biological Studies (Coordinator: Professor G. Knox, Canterbury University) Objectives are to survey the existing flora and fauna in the Upper Harbour and its contributing streams, and to predict the effects of different patterns and styles of land development on the biota.

6. Guidelines Development (UWHCS Director and Manager, Professor P. Williams, Auckland University, and Mr D. Brickell, Auckland Regional Water Board) Objectives are to estimate from all studies done what would be the pollutant load on the Upper Harbour and its contributing streams from both different patterns and different practices of development in the catchment, and on the basis of local and overseas data to prepare guidelines for wise management of the land and water (both policy and planning guidelines and technical standards and procedures).

Thus sections 1 to 5 are working along common flow paths: (i) reviewing relevant literature, (ii) measuring baseline conditions, (iii) explaining existing conditions and drawing conclusions about present levels of degradation, (iv) predicting consequences of future land use changes on soil and water resources, (v) assessing the maximum level of environmental change that is acceptable, and (vi) suggesting measures to achieve water and soil management objectives.

Section 6, Guidelines Development, is at present working on the Albany basin, a sub-catchment of the study area, treating it as a test case because it is the area currently experiencing the greatest development pressure. The approach being taken is, firstly, to accept a minimum impact, 'design with nature' philosophy and, secondly, to model processes and through that to estimate impacts and formulate control measures. Land development aspirations, as presented in the proposed revised District Scheme, are taken as a starting point for application of the guidelines, and the relative impact of alternative land development techniques are to be assessed. The study will be concluded by the end of next year.

GEOMECHANICS IN URBAN PLANNING - PALMERSTON NORTH APRIL/MAY 1981
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MAKING USE OF SURVEY INFORMATION IN THE PREPARATION OF DISTRICT SCHEMES

K J TREMAINE, CITY PLANNER, PALMERSTON NORTH CITY CORPORATION

1.0 INTRODUCTION:

As we assume greater individual responsibility for shaping our urban environment, the tools that we have to work with come under increasing scrutiny. One such tool is the District Planning Scheme, more commonly known as the Town Plan. Many plans made under the 1953 Town and Country Planning Act were little more than catalogues of petty restrictions. Dissatisfaction with this approach led to major legislative changes in the early 1970's. As local government responded to these changes, town plans which identified important local issues were prepared. The 1977 Act has provided the statutory backing for extending this approach.

This paper will discuss the preparation of a town plan, which identifies urban hazards. Its aim is to highlight the difficulties a planner currently faces in identifying these hazards, reconciling conflicting data, generalising from broad data down to site specific situations, and then defending this approach against a barrage of opposition from land owners who find that their development expectations have been restricted and who threaten to invoke the compensation provisions of the Town and Country Planning Act, 1977. The general good or public interest must be proven beyond reasonable doubt if private rights are to be restricted. It is frequently claimed that we live in a property owning democracy. These tenets are often tested to the limit as land-owners exercise their rights under the Town and Country Planning Act.

While the major emphasis of this paper is on District Scheme preparation, I also comment on the identification of urban hazards in relation to the control of development, especially urban subdivision. Development control is an important part of district scheme administration. The challenge we all face is how to identify hazard limitations on particular pieces of land and, having done this, how we ensure that the limitations imposed by such hazards are recognised through the various stages of development, from proposed urban zoning through subdivision, to the completion or prevention of buildings on a particular site. How can we achieve continuity of information and consistency of interpretation given the number of participants in the development process? What solutions can the town plan offer? What are its limitations?

A Council's minimum statutory obligations are set out in the Town and Country Planning Act, 1977. Since a town plan must recognise factors raised in a regional scheme, Clause 4 (c) of the First Schedule to the Act is of importance. It requires a -

> *"general identification of areas to be excluded from future urban development including .... land subject to hazards such as flooding and earth movement ....."*

The Second Schedule of the Act, in Clause 8A, specifies that town plans must consider -

> *"the avoidance or reduction of danger, damage or nuisance caused by :*
>
> *(a) earthquake, geothermal and volcanic activity, flooding erosion, landslip, subsidence, silting and wind."*

How these statutory requirements are dealt with is entirely dependent on the information, skill and imagination available to a particular local authority. Although we have a uniform set of requirements for New Zealand planning, the standard of practice varies considerably between authorities. This standard of practice is influenced by how much information is available, whether there are sufficient staff available to accurately interpret the information, and whether the local Mayor is also the Council's de facto engineer!!

Irrespective of competence, our obligations are quite clear. As the Abbotsford Landslip Disaster Report States in paragraph 5.3.2.26 :

"The Green Island Borough, having been advised of problems relating to instability in the Abbotsford area, was under an obligation to the people it represented, that is, the residents of Green Island, both present and future, to advise of possible difficulties. That obligation was formalised in the town plan. An ordinary citizen contemplating the erection or purchase of a house in the area identified as unstable could reasonably have expected to have learned from the Borough plan that there were possible problems associated with the area. The loss of the report and changes to the plan have meant that intending purchasers or builders have been deprived of the opportunity of learning that some concern had been expressed as to the development of the area. ..... The plan would have provided a warning for intending home owners and had it been administered as was required, the loss occasioned by the landslip might have been less."

2.0 PREPARATION OF THE DISTRICT SCHEME:

The objective of the urban hazards section of the town plan is to identify the type and location of hazards, set limits on (and promote styles of) development, prevent local authority liability and avoid personal stress to a property owner. The planning technique that should be used is survey analysis plan, a very orthodox technique which, in some quarters, has fallen into disrepute through a feeling that too much planning in the 1970's lacked clear objectives and was wallowing in data without direction.

Clearly, it is important to identify the range of possible urban hazards from those contained in the Schedules to the Planning Act. The Pre-review Statement required by Section 60 of the Planning Act directs a local authority to embark on hazard identification well before the preparation of a town plan. The Act states :

"The Council shall, not later than 1 year before its

> *district scheme is due for review or if the Council decides to review its scheme at an earlier date, as soon as that decision has been made prepare a statement setting out the planning objectives that the Council responsible for the scheme proposes at that time to incorporate in the review of the scheme and the policy to be pursued to achieve those objectives and such plans as may be necessary or desirable to illustrate those objectives and that policy."*

In the seven years that pre-review statements have been required, they have, in most cases, developed from cryptic statements of platitude into worthwhile corner stones for the preparation of a town plan. A well prepared urban hazards' section in a pre-review statement would list the known hazards, identify their locations, state what information was known about them. It would also state the type of information required before the plan was prepared in final form, together with a possible list of sources. A local authority could then approach the various government departments for further assistance as well as advising the owners of potentially affected land.

In 1980, the D.S.I.R. published a comprehensive inventory on Land Use and the Role of Research[(1)]. Chapter 13 deals with the use of urban land. It gives consideration to natural and man-induced hazards, lists these by cities and towns, and spells out those agencies undertaking research into natural hazards. Given that there are 13 agencies listed, the pre-review statement has an over-riding responsibility to try and get a common data base for a particular problem.

On specific problems such as slope stability, the joint publication of the Geomechanics Society and the D.S.I.R.[(2)] provides clear

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(1) Land alone endures", D.S.I.R. discussion paper, No. 3, Eds. Molloy, Forde and Others, Wellington, 1980.

(2) D.S.I.R. Information Series No. 122. Taylor, Hawley & Riddolls, Wellington, 1977.

guidance, particularly if the planning scheme is for the Auckland, Wellington, Nelson or Christchurch urban areas.

There is also a further difficulty that very little information will be available for land which is already subdivided and requires no further council approval prior to a building permit being issued. Here I refer to the four "prime" sites which have never been built on since those in the know remember them as an old sawmill site. But the rates are rising and they cannot remain vacant forever or, alternatively, the privately owned gully filled with refuse many years ago and covered with a thin layer of topsoil. Where is the local authority going to get information that will verify that these sites have severe limitations for development? There is likely to be a strong reaction from the landowner. Who will pay for the test bores? The Council or the landowner? What are the likely political pressures? Most agencies collect urban hazard information which is not site specific. Most agencies, because of resources and cost, also take a broad brush approach to hazard identification. Yet the planner is dealing with individual properties and must be able to be site specific in identifying hazards.

Molloy, Forde and Others[(3)] make seven general points which sum up the planner's dilemma when approaching the gathering of data. These are :

> *"(a) First, the multiple sources of basic information. Many Government and other agencies produce similar or closely related information. Compilation, integration and evaluation of information from many sources takes time, even if the user knows where to go."*

While this sort of problem is able to be tackled by the larger local authorities, it is quite daunting to the majority of New Zealand councils. While the pre-review statement is an excellent opportunity to set up an inter-agency project team, it is my belief that most authorities

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(3) ibid, page 249.

will continue to take decisions from imperfect data.

"(b) *Second, the diverse forms of storage.*

(c) *Third, the form of information often makes it unsuitable for immediate use by the enquirer, and compounds inaccessibility.*

(d) *Fourth, variation in accuracy, detail, quantity or coverage of data on a map or in a report may not be understood, noticed or taken into account.*

(e) *Fifth, there is often a basic incompatibility between the time in which a planning decision has to be made and the time required for a collection, compilation and evaluation of scientific information.*

(f) *Sixth, lack of awareness of the types of information required by users also contributes to confusion.*

(g) *Seventh, is the problem of where to go for information."*

The difficulty that the urban planner faces is how to obtain integrated information and how to get it checked in the field. Within the works departments of larger local authorities, some resources are available but councils are still heavily dependent on help from outside agencies.

The land use assessment procedure discussed by Molloy, Forde and others[4], and the Land Resource Inventory Work Sheets reviewed by Neville Lewthwaite in People and Planning[5] are examples of integrated approaches to data gathering. The Eastbourne Survey[6]

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(4) ibid, page 234.

(5) People and Planning, No. 12, December, 1979, Ministry of Works and Development, Wellington.

(6) Landslip and Flooding Hazards in Eastbourne Borough - a guide for Planning, Lawrence Depledge and others, Ministry of Works & Development, Wellington, August, 1978.

provides a very good example of a team approach to urban hazard identification. It culminated in a specific change to the district scheme, which is now operative. The change is well supported by survey data of a form able to withstand litigation.

3.0 CURRENT PRACTICE IN DISTRICT SCHEME HAZARD IDENTIFICATION:

Regrettably, the high standard of presentation adopted by the Eastbourne Borough Council is far from typical in District Scheme planning.

District Schemes take a variety of approaches to hazard identification. Only a few have specific clauses on urban hazards and these are usually buried in the section on subdivision of land. The "standard town plan", which had its origins in the 1960 Town and Country Planning Regulations, contained two specific clauses relating to subdivision and building on unstable land. These state :

> *(a) "The council shall not approve the proposed subdivision if the site is not suitable ... provided that in determining whether a site is suitable, regard shall be had to the liability to flooding, erosion and landslip; to stability of foundations;" and*
>
> *(b) "No buildings shall be erected or placed on land which is not suitable .... and for the purpose of determining whether land is suitable, regard shall be had .... to liability of flooding, erosion or landslip, stability ...."*

These two clauses have found their way into most district schemes in New Zealand. While well intentioned, without specific territorial analysis and identification of urban hazards, they can remain no more than pious hopes among a general morass of planning ordinances. Few local authorities responded with the necessary work to make their implementation possible. If the response rate had been enthusiastic, then few government departments would have been able to cope with the demand for information.

Molloy, Forde and others summarise the current situation in a section on scientific information and urban planning, when they state :(7)

> *"At least 10 of the major and provincial centres need such studies, but this need is likely to face problems of finance and manpower if simultaneous large scale (1:10,000 or larger) mapping of all these centres were to be attempted. One alternative would be to set priorities. Another, itself a strain on resources if the time scale is short, would be to produce standard, medium scale (e.g., 1:25,000 1 cm equals 250 metres) geology soils and hydrology maps with tables or extended legends which emphasise engineering and physical characteristics of land use as for geology in Nelson City. High risk or problem areas identified by this work could then be avoided until studied in more detail."*

In 1976, the Earthquake and War Damage Commission wrote to local authorities with suggested Council policy on land stability which was subsequently revised by a joint sub-committee working on behalf of the Territorial Local Government Council. The Territorial Council adopted a recommendation that member councils indicate on planning maps, areas of known, potential or suspected land instability. It also recommended formats for obtaining a proper opinion from a registered engineer experienced in soils engineering before subdivision or building takes place in such areas. These recommendations have been adopted as part of Change No. 14 to the Eastbourne Borough District Scheme.

How have other authorities reacted? Several have adopted building line restrictions, which can be imposed in any zone. A well documented example is that of Kapiti Borough, which has included a building line restriction on beach frontages liable to be eroded by the sea. The properties affected are clearly denoted in the

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(7) ibid, pages 233, 234.

planning maps. Jeremy Gibb[8] has undertaken an extensive study of Waiapu County, which will no doubt become an important part of the County's planning scheme. Clearly, the techniques developed by Gibb can be applied elsewhere in New Zealand.

Some local authorities have expanded the two hazard clauses from the 1960 Regulations. Appendix I contains a section from the recently notified Third Review of the Nelson District Scheme, which demonstrated this point. It is unfortunate that the map illustrating specified areas of hillside land is only available at the Council, since many decisions to develop land are taken outside the Council environment. Such maps should be attached to the planning scheme for general consultation.

Tauranga County[9] has recently notified a Scheme Change which includes two new planning maps denoting land on a site by site basis which is vulnerable to long term landslip risk. The Change is in response to a number of slips which occurred along the western foreshore of the Omokoroa Peninsula in August, 1979. The Variation and one planning map are included as Appendix II. Within the land areas identified, any building permit application must be supported by a comprehensive report covering stability aspects. The report is to be prepared by a registered engineer experienced in soil mechanics. This is similar to the approach of Eastbourne Borough.

In Palmerston North, the Planning Map has been used in a similar manner. The 1978 Review specified an area in which minimum floor levels apply. Clause 23.15 of the Scheme states :

> *"23.15 Objective: Control of Development in Areas Likely to be Affected by Flood:*
>
> *To minimise the effects of flooding in the City.*
>
> *23.15.1 Policy: Minimum Floor Level:*
>
> *In low-lying areas to require buildings to be constructed with a minimum floor level.*

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(8) Coastal Hazard Mapping as a Planning Technique for Waiapu County, N.W.A.S.C.O., Wellington, 1981.

(9) Tauranga County Council, Variation No. 1, March, 1981.

023.15.2 *Upon subdivision of low-lying land, Council will define minimum floor levels designed to provide a reasonable degree of protection to houses from flood damage. The map on page ... shows areas where Council has found it necessary or anticipates that it may be necessary to make such a requirement. However, Council reserves the right to impose such restrictions elsewhere if it considers it necessary.*

The minimum floor levels will not normally preclude ordinary types of building construction. There is no doubt of the suitability of the land concerned for urban development. Not all sites in these areas will require a minimum floor level. Information on any particular site is available from the City Engineer's Department.

23.15.3 *Explanation:*
Complete protection from flooding is not possible in Palmerston North, where a large proportion of the City lies below peak flood levels in the stopbanked river and stream channels. Council has established ponding areas throughout the City to deal with excessive stormwater, but it is desirable that in low-lying areas of the City, minimum floor levels for buildings be established."

A copy of the relevant Planning Map is included as Appendix III.

A third approach is the identification of hazards through zoning. For example, watershed protection, flood channel protection, coastal protection zones or the residential hills protection zone of the Christchurch City District Scheme. Within these zones, it is common for buildings not to be permitted in areas which are liable to floods or erosion. Also, where building is permitted, it is often subject to a report by the relevant drainage board or Catchment authority. Apart from Christchurch, examples of schemes which have included zones of this type include Pohangina County, Tauranga County, Patea County, Egmont County, Blenheim Borough, Lower Hutt City, Manukau City in its current review, Upper Hutt City, Ashburton County and Waimate County.(10)

In addition, the Ministry of Works and Development has recently objected to the Wanganui County Review stating that the scheme contains "*no policy on areas of water and soil sensitivity*" asking for these to be identified on the planning maps and supported by relevant policies.

The final and most comprehensive approach is that of putting together a relevant "information system" for a particular area. Rodney County, in a 1981 scheme change, is the first local authority to adopt this approach.

All the information relating to unstable land, flooding and other hazards will be put together in such a way that it is generally available to the public. Given that such information is often amended and added to as further work is undertaken, Rodney County has decided to keep this information separate from the District Scheme. Change No. 46 to the County's Plan undertakes to provide advice on the availability of information about the known incidence of land instability, dangers of flooding, erosion and inundation in the County. It is attached as Appendix IV.

This method of providing information has considerable potential. It would be possible for Rodney County's information to be published in a booklet form similar to the Palmerston North City Council Design Guide Series.(11)

It is clear from this section that many local authorities are undertaking hazard identification in spite of a lack of basic data.

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(10) The assistance of Mr. J. Harland, Planner, Ministry of Works & Development, Wellington, is gratefully acknowledged.

(11) Palmerston North City Corporation, City Planning Department, 1980, Design Guide No. 1, Adding to or Altering Your House; Design Guide No. 2, Garages and Carports.

4.0 TYING THE SYSTEM OF LOCAL AUTHORITY ADMINISTRATION TOGETHER:

Some form of design guide, or road code-type information booklet, identifying specific hazards in particular local authorities is probably the only way of spanning the administrative gaps which exist between autonomous departments, particularly in the larger local authorities. There is a general problem on how to get consistent administration from the time a piece of land is selected for subdivision through to placing the paths and retaining walls on the finished site. Separate staff handle the subdivision approval, the planning permission to build, the building permit, and the plumbing and drainage permission. Often, the job is then taken over by an inspector who knows little of the background and whose only role is to make sure that minimum requirements are enforced.

Clearly those of us in local government have a clear responsibility to put together a Rodney Council-type of resource kit. If this were done, it would not be necessary to tag titles through the Lands and Deeds Office. Given the tremendous difficulty of setting acceptable parameters for title tagging, I believe that local government should be given the opportunity to improve current practice. Producing further regulations steeped in legal liability will do little to improve current approaches to this planning problem.

Clearly there will be considerable debate on this subject, since the report of the Commission of Inquiry into the Abbotsford Landslip Disaster leaves its views in no doubt when it says, in paragraph 6.6.13 :

> *"We therefore recommend that the Local Government Act be amended to require a local authority when imposing conditions in respect of approving a plan or scheme plan of subdivision or in the issue of building permits to advise the district land registry of the imposition of such conditions and that the Land Transfer Act be amended to require the District Land Registrar in any such case to note on certificates of title affected by such notice, a memorandum to the effect that conditions have been imposed."*

5.0 CONCLUSIONS:

The way that survey information is used in the preparation of District Schemes will clearly depend on the nature of hazards which have been identified in the district, on the quality of the information available, and the extent of possible trade-offs between them. Section 3 of this paper identifies a wide variety of approaches.

Given the conflict between an adequate data base and the need to inform the public of possible hazards, the approaches of Rodney County, Eastbourne Borough and Tauranga County are interesting ways of finding solutions.

The importance of the pre-review statement and the interdisciplinary team approach to hazard identification should not be overlooked. In the ultimate, however, the achievements of local government will still be heavily dependent on the quality of the staff providing advice, and on the political climate in which they are working.

APPENDIX I

CITY OF NELSON PROVISIONAL THIRD REVIEW OF DISTRICT SCHEME

"PART 9.

90.0 LAND SUBDIVISION AND DEVELOPMENT:

91.1 GENERAL:

91.11 Interpretation: Within this Ordinance the terms "Subdivision" and "Development" have the meanings given in the Local Government Act, 1974.

91.12 Subdivision and Development to Conform with Planning Principles:

Notwithstanding that a scheme of subdivision or proposed development may comply with the requirements of the district scheme in respect of frontage, shape factor, area, use or bulk and location, the Council shall not approve the scheme of subdivision or development if the site is not suitable or if the use proposed or the arrangement of sites or shape of any proposed site is not in conformity with the principles of Town and Country Planning.

Provided that in determining whether a site is suitable, regard shall be had to best use of the land and its economic servicing and development, to earthquake fault lines and to liability to flooding erosion and landslips, to stability of foundations, and to safety, health and amenities.

91.13 Land Stability:

Instability of natural hill slopes in Nelson is common. Subdividers and developers must assume that certificates as to the suitability of the land for its intended use in the Council's standard form from registered engineers experienced in the field of soil engineering, and more particularly landslope and foundation stability, will be required in most cases before the scheme plan or development plan will be considered. In cases where earthworks are involved a certificate may be required before the final plan of subdivision is approved. In such cases the Council will reserve the right of imposing further conditions before the final plan is approved. Similar requirements will apply to areas of flat land in the City where foundations are suspect and where land has been filled or reclaimed.

In any case where, in respect to any land within a proposed subdivision or development, certificates acceptable to the Council cannot be given, subdivision or development will not be permitted unless satisfactory conditions can be imposed that unsuitable areas are not to be used for building

APPENDIX I (Continued):

development. In subdivisions this may require that unsuitable areas are incorporated with other allotments in the subdivision and the unsatisfactory areas be excluded from building development.

Note: Specified areas on hillside land (zoned residential or residential deferred in the District Scheme) are subject to the requirements of Section 34 of the Soil Conservation and Rivers Control Amendment Act, 1959. In the specified areas (which are shown on a map displayed at the City Planning Division offices) the written consent of the Nelson Catchment Board is required before any work is carried out on land involving :

(i) the exposure of soil by removal or burning of vegetation cover;

(ii) the exposure of subsoil by the removal of soil; or

(ii) the execution of earthworks.

Intending developers or subdividers should also note that where a subdivision or development is proposed, Sections 275 and 293 of the Local Government Act, 1974, impose requirements that limit any work to be undertaken on land (including clearing of vegetation, disturbance of the land surface or excavation) prior to the approval of the subdivision or development.

91.14 Provision of Services:

In parts of the City, capacity of existing water supply, stormwater and sewage disposal services are not adequate to permit additional subdivision or development unless service capacity is increased.

Specific problems relating to these services and the effect on zoning, subdivision and development are dealt with in Part 7 of the Scheme Statement. Notwithstanding the details given therein, relating to main trunk services, there are many localised areas where service capacities are limited to the needs of existing development.

The Local Government Act, 1974, empowers the Council to obtain monetary contributions from subdividers and developers in cases where services and roading beyond the subdivision or development require upgrading to serve that subdivision or development.

In such cases the Council will require contribution (up to limits permissible under the Local Government Act) towards the cost of providing adequate services to any particular subdivision or development.

91.15 Special Subdivision Areas:

(Refer to Paragraph 5.29 of the Scheme Statement for further

APPENDIX I (Continued):

detail, page 20.)

Where land has been included in an area delineated as a "special subdivisional area" on the Planning Map the Council will consent to a subdivision of such land only when it is satisfied that :

(i) The proposed subdivision is planned to achieve efficient and practical use of other land included in that "special subdivisional area", whether the land is held in single ownership or not; and that

(ii) The ability to provide practical street access to other land in that Special Subdivisional Area is not impaired by the proposed subdivision.

Note: Where the land involved in a special subdivisional area has a deferred zoning the additional requirements of Ordinances 92.30 or 93 apply."

APPENDIX II

COUNTY OF TAURANGA

SECOND REVIEW OF THE DISTRICT PLANNING SCHEME

"Pursuant to the provisions of Section 47 (2) of the Town and Country Planning Act, 1977, the Tauranga County Council proposes the following variations to the Second Review of the District Planning Scheme.

Proposed Variation No. 1 - Land Stability - Omokoroa.

A. To add the following clause to the Scheme Statement :

Clause 21.1.9 Land Stability Omokoroa:

During August, 1979, a number of landslips occurred along the western foreshore of the Omokoroa Peninsula damaging and endangering several properties. To advise what action should be taken in that area the Council engaged a firm of consulting soils engineers to investigate land stability in the affected area. Their report contained a number of recommendations including the siting of future buildings and the disposal of stormwater and septic tank effluent.

A copy of the report "Omokoroa Point Land Stability Investigation" by Tonkin and Taylor, Consulting Engineers, Auckland is available for perusal at the County Office.

Acting on the report, the Council has adopted the following policies:

Areas identified in the report as being "vulnerable to long term landslip risk" have been shown on planning maps 23 and 24. In these areas buildings or extensions to buildings will not generally be permitted.

In the areas identified as such on the planning maps and in areas in proximity thereto applications for building permits must be supported by a comprehensive report covering stability aspects, prepared by a registered engineer experienced in Soil Mechanics. The Council shall refuse to issue a building permit unless the provisions of Section 641 (2) of the Local Government Act, 1974, are satisfied.

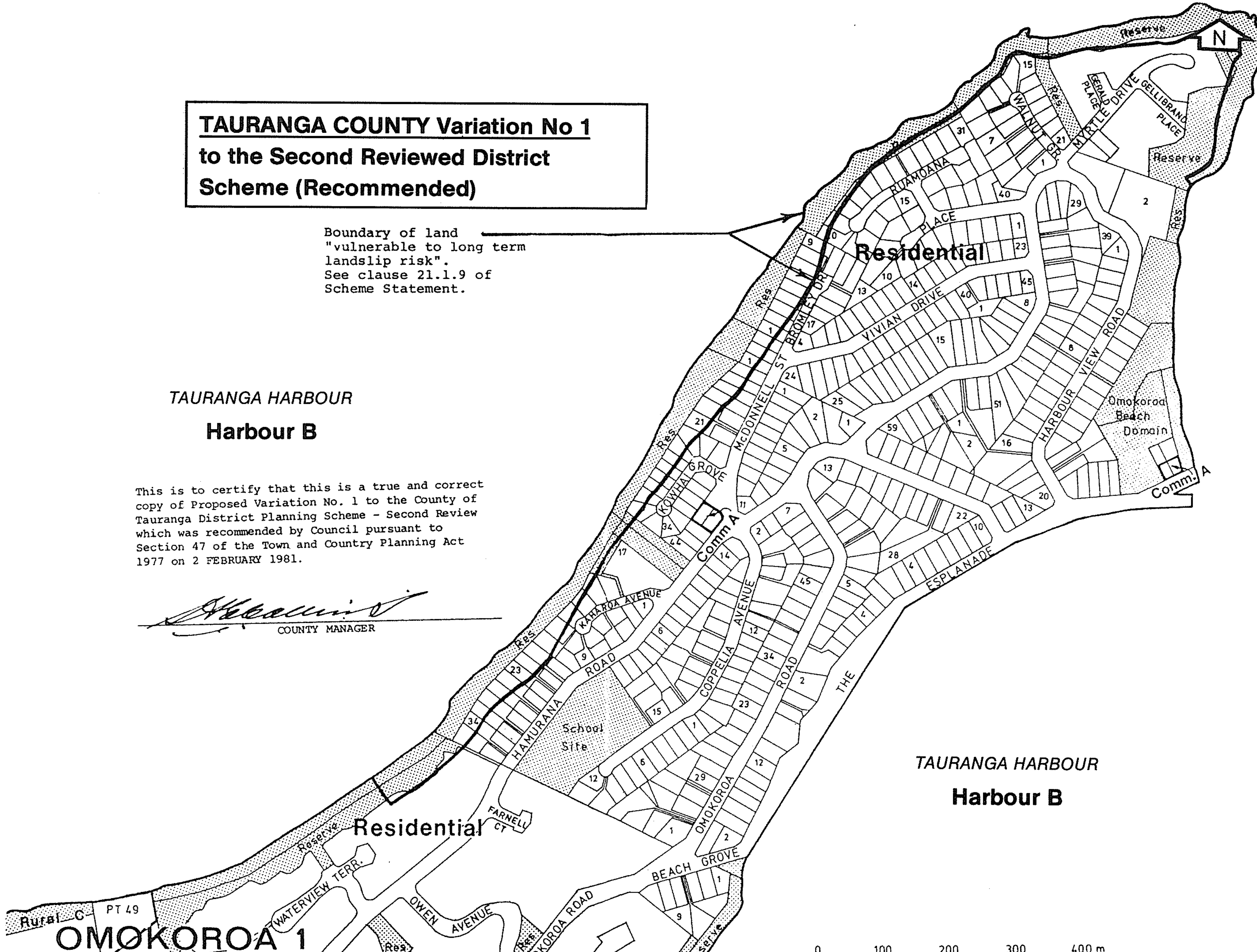
Minor alterations and repairs to existing buildings and the construction of accessory buildings may be permitted provided the County Engineer is satisfied that the probability of any damage from potential landslips, and the likely extent of such damage is not increased by doing so.

Earthworks and development, including significant planting of trees or shrubs will only be permitted subject to the prior approval of the County Engineer and any application for such approval may have to be supported by a report prepared by a registered engineer experienced in Soil Mechanics.

B. To show on planning maps 23 and 24 the areas defined as "vulnerable to long term landslip risk". (See plans attached.)

TAURANGA COUNTY Variation No 1 to the Second Reviewed District Scheme (Recommended)

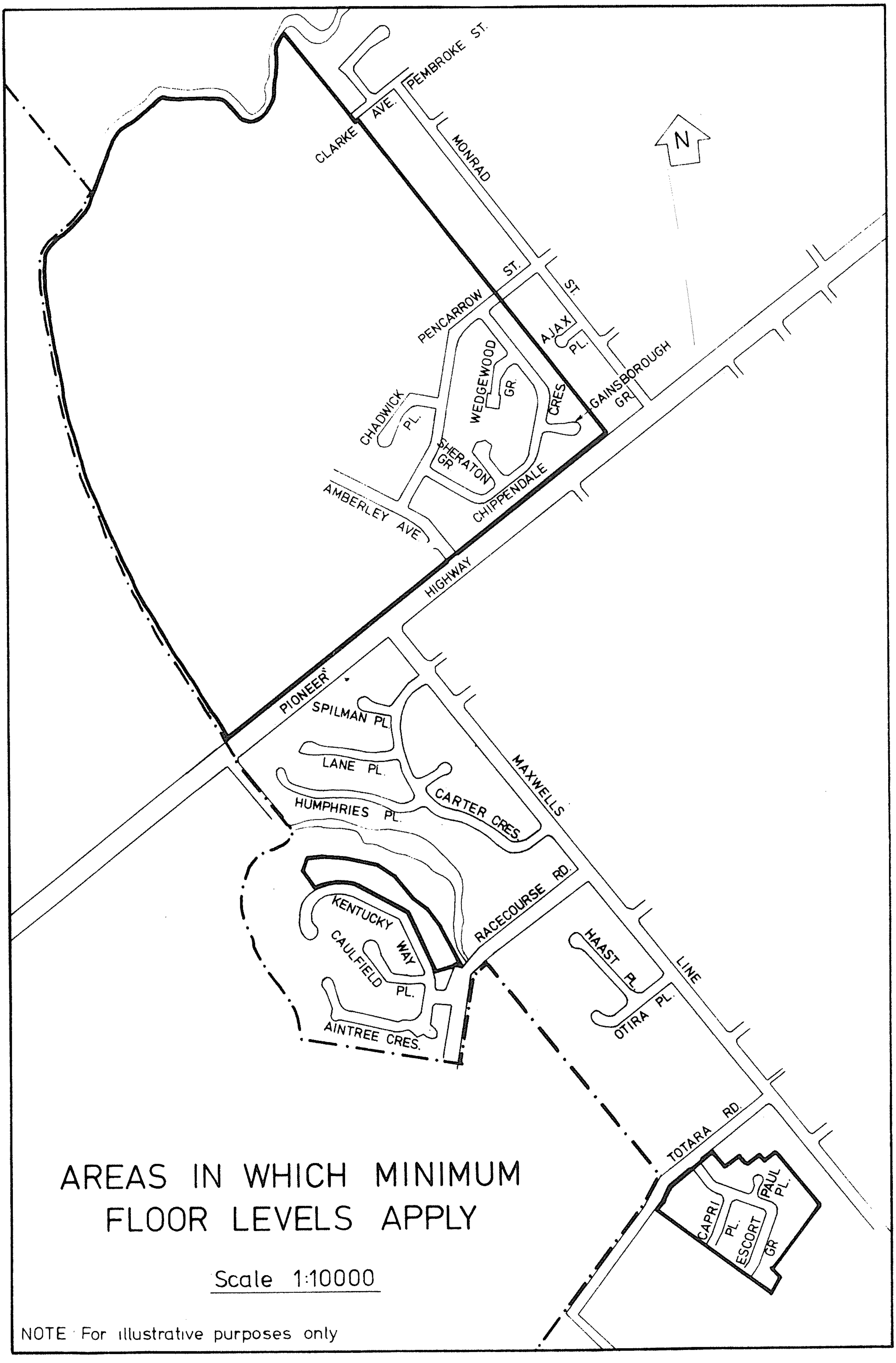
Boundary of land "vulnerable to long term landslip risk". See clause 21.1.9 of Scheme Statement.



This is to certify that this is a true and correct copy of Proposed Variation No. 1 to the County of Tauranga District Planning Scheme - Second Review which was recommended by Council pursuant to Section 47 of the Town and Country Planning Act 1977 on 2 FEBRUARY 1981.

COUNTY MANAGER

APPENDIX III



APPENDIX IV

COUNTY OF RODNEY DISTRICT SCHEME.

"PROPOSED CHANGE NO. 46 - TO PROVIDE ADVICE OF THE AVAILABILITY OF INFORMTION ABOUT THE KNOWN INCIDENCE OF LAND INSTABILITY, AND DANGERS OF FLOODING, EROSION, OR INUNDATION:

SCHEME STATEMENT AMENDMENTS:

(a) Add a new final paragraph to Chapter 5A on page 14 to read :

"LAND STABILITY, EROSION, AND FLOODING:

Ground movements in some localities in the County have led to engineering investigations which show there to be actual or potential problems of land stability. These problems most commonly (but not exclusively), relate to the incidence of an underlying geological formation, known as the Onerahi Chaos Breccia, and are of sufficient severity - in some instances - to endanger property, and to affect its suitability for building or development.

Many other factors can also affect the suitability of land for development. These can include susceptibility of dunes or cliffs to coastal erosion, steepness, the incidence of peaty subsoils, swampy conditions, and liability to flooding.

In a district with very complex geology and diverse topography, knowledge about such matters as land stability, erosion, and the risk of inundation, will always be incomplete. To carry out a sufficient study to identify all such problems in the district would be prohibitively costly, take a very long time, and would not be justified because of the localised nature of the risk in most cases.

In considering proposals to subdivide or develop land or to erect buildings, Council is required to have regard to problems of land stability, inundation, and the like. Where specific proposals come forward for consideration, Council records will be searched, and field inspections will normally be made to ascertain (so far as can reasonably be achieved), the factors which could adversely affect suitability of the land for the intended development. Where such factors are found, or suspected, Council may refuse its consent, or may withhold its consent and require specialist investigations to be carried out to establish the nature of the problem and to propose any necessary measures to ensure the safety and stability of what is proposed.

The Council has established an information system to enable it to better fulfil these responsibilities, and to make available to the public information about the incidence of such factors as instability, inundation, and the like.

APPENDIX IV (Continued):

The information in this system is available to the public. Enquiries should be made to the Head Office of the County Council at Centreway Road, Orewa. The system contains all information about problems of land stability, inundation, erosion and the like, which is known to the Council at any particular time. It is maintained up-to-date, and as information is added or amended, such changes are reported to the Council as a matter of record."

(b) Delete the second paragraph of Chapter 8, Clause (c), and substitute the following :

"As part of the work necessary to halt erosion of the Omaha Sandspit, and in order to protect the Whangateau Harbour from wave action during easterly storms, a groyne has been constructed at the northern extremity of the Sandspit.

The groyne appears to be achieving the objectives for which it was constructed, but Council will continue to exercise caution with regard to stability of land and susceptibility to erosion, or inundation, in controlling the use and development of land around the Harbour."

"EXPLANATION:

The Town and Country Planning Act requires that district schemes provide a means of avoiding or reducing danger, damage or nuisance caused by earthquake, flooding, erosion, landslip, etc. (Second Schedule : Paragraph 8).

Sections 274 and 641 of the Local Government Act, 1974, place a responsibility on the Council to take account of these factors, in dealing with proposals to subdivide land or to erect buildings.

In order to accommodate the continuing growth of information about risks of land instability, erosion, etc., an information system has been established, in which will be recorded all known information at any particular time. The information in the system is available to the public.

This Scheme Change records in the District Scheme the existence of the information system, and its availability to the public.

The Change also updates the reference in the Scheme Statement to the Whangateau Harbour, where protection works at the mouth of that Harbour have now been carried out.

GEOMECHANICS IN URBAN PLANNING - PALMERSTON NORTH APRIL/MAY 1981
NEW ZEALAND PLANNING INSTITUTE : NEW ZEALAND GEOMECHANICS SOCIETY

INVESTIGATIONS FOR REGIONAL AND DISTRICT SCHEME PREPARATION

J H LAWRENCE, MINISTRY OF WORKS AND DEVELOPMENT

REGIONAL PLANNING LEVEL : EXAMPLE

Hawkes Bay Area Planning Study (at 1:25,000): Hawkes Bay Catchment Board in conjunction with Water and Soil Division, M W D.

Ten 'sites' were considered, having a total area of 12,035 ha.

The study was completed in approximately 70 person-days - giving 171 ha/person-day. Of this total:

- 33 person-days were spent on field work which included mapping boundaries on aerial photographs (stereo pairs); walking all over sites; digging soil profiles; measuring depth to bedrock; observing and recording rock exposures; and making inventory and capability assessments.
- 30 person-days were spent on background research of published and unpublished reports, and in writing the final report. The background work also included discussions with DSIR Soil Bureau; MWD planning, engineering, water and soil, and testing laboratory staff; Catchment Board planning, engineering and soil conservation staff; and a consulting engineer.
- 5 person-days were spent researching geotechnical data, derived *in situ* from MWD district laboratory testing, and from general soil mechanics literature.
- 2 person-days were spent discussing implementation of the report.

No sampling, testing or analytical work was done specifically for this study.

Personnel involved - 7

engineering geologist
geologist/land resource mapper
botanist/land resource mapper
soil conservator
engineer
soil conservator/water and soil planning officer
resource manager.

DISTRICT PLANNING LEVEL : EXAMPLE 1

Eastbourne Borough (at 1:5,000) : Water and Soil Division, MWD.

Area = 1,273 ha.

This study was completed in approximately 93 person-days - giving 14 ha/person-day. Of this total:

- 50 were spent on field work, of which 35 were spent describing the nature and extent of landslip and flood damage that occurred during 1977. This included estimates of: volume and nature of slip material; slip dimensions; position of slips on slope; status of slope (cut, fill etc); morphology; aspect; and slope angle of shear plane, cut or fill. The other 15 were spent classifying suitability for urban use.
- 40 person-days were spent collating field information, researching literature, and writing the report. This included discussions with two consulting engineering firms, council staff, and DSIR.
- 3 person-days were spent discussing implementation of the report.

No specific analytical work was carried out on ground engineering properties due to variability of rock type and structure and the indicative level of the survey. Some analytical work was carried out on slip prediction.

<u>Personnel involved</u> - 5

engineering geologist
geomorphologist experienced in landslip studies
soil conservation/water and soil planning officer
engineer
climatologist.

DISTRICT PLANNING LEVEL : EXAMPLE 2

Mangawhai (at 1:4,000) : Northland Catchment Commission.

Area = 650 ha.

This study was completed in approximately 16 person-days - giving 40 ha/person-day. Of this total:

- 8 person-days were spent on field work, involving land inventory, urban capability and rural capability.
- 8 person-days were spent on collating field information, report writing, and plan preparation.

No specific analytical work was carried out. The soils were checked by a Soil Bureau soil scientist.

<u>Personnel involved</u> - 3

water and soil planning officer
soil conservator
soil scientist

COMMENT

No special analytical work on ground engineering properties was carried out for any of these surveys, and it is not considered appropriate that this be done at the scale of mapping involved and for the purposes for which the survey information is designed.

At the district and regional planning level, surveys of physical hazards are indicative only. They serve to highlight particularly hazardous areas and so direct detailed attention to situations where hazards could create the greatest damages and cost for the community.

Great variability in rock type, structure and ground conditions generally, would make ground engineering testing at a regional or district scale misleading and of little value, as a degree of precision could be implied that does not exist.

GEOMECHANICS IN URBAN PLANNING - PALMERSTON NORTH APRIL/MAY 1981
NEW ZEALAND PLANNING INSTITUTE : NEW ZEALAND GEOMECHANICS SOCIETY

INVESTIGATIONS FOR SCHEME AND CONCEPT PLAN PREPARATION

J P BLAKELEY, UNIVERSITY OF AUCKLAND

1. INTRODUCTION

This paper assumes that a block of land regarded as being suitable for subdivision has already been zoned Urban and a developer now wishes to proceed with the planning of a subdivision.

Consideration is given to the problem of determining what geotechnical assessment and investigation it is reasonable to expect the developer to carry out up until the time that subdivision construction is complete and sections are ready for sale in order to confirm the stability of the land (or to define certain areas which because of questionable stability either should not be built on and left as a reserve or else be subject to further investigation prior to building permit issue).

The subject is considered under three headings as follows

(a) The scheme plan preparation stage.
(b) The subdivision design stage.
(c) The subdivision construction stage.

Obviously the more geotechnical assessment and investigation work that can be carried out, the smaller the risk should be of land instability subsequently becoming evident within the subdivision. However detailed geotechnical investigation involving good quality drilling, laboratory testing and slope stability analysis is costly and the budget available must be in proportion to the overall subdivision development costs. Hence considerable engineering judgement is often required to supplement the results of the investigations.

2. THE SCHEME PLAN PREPARATION STAGE

It is only comparatively recently that Terrirorial Local Authorities have considered carrying out "broad brush" geotechnical assessments of areas of land prior to the zoning of land for urban use. Also, some local authorities are now working on producing land stability maps recording all areas of known land instability within the boundaries of their area. Where such information has been obtained, it should be made available to a land developer at the time when he is giving consideration to the preparation of his scheme plan for a proposed subdivision. However it may be reasonable to assume that the onus should be on the developer or his engineering consultants to make enquiries of the local authority regarding the extent of any such information which is available.

Also, until very recently it has been unusual for a land developer to give any detailed consideration to geotechnical problems during development of the scheme plan. This may have been in part due to a lack of awareness of potential land stability problems and in part to a reluctance to commit money for a programme of geotechnical investigations until the scheme plan has been approved.

The author considers it essential that land stability be carefully considered in developing a section layout within the subdivision and suggests that as a minimum the following be done.

(a) A geological appraisal should be carried out by an experienced engineering geologist with attention being given to any existing geological reports, exposures in cliffs of the soil/rock profile and any existing investigation borehole information.

(b) A careful study should be made of all available aerial photographs. It is of great assistance if stereo pairs are available for three dimensional viewing as this will highlight any areas of past slipping or land subsidence. Also, if photos taken at different times over a period of 20 years or more are available, this can be most useful in detecting any changes in the landform that have recently occurred.

In the event that insufficient information is available from existing aerial photographs, consideration should be given to either ordering aerial photographs to be taken, or if this is considered to be too expensive, to hiring a helicopter or light plane for an hour or more to fly over the area and carefully examine the surface topography. This is seldom done but if there are any existing land stability problems they are likely to be much more apparent from the air than they are on the ground.

(c) An experienced geotechnical engineer should make a very critical examination of the initial subdivision layout proposed and also the following questions

i) *Are the proposed gradients of the cut slopes appropriate to what engineering judgement and observation of the surrounding area would suggest is reasonable?*

This is particularly important if the earthworks will cut through strong surface soil layers and into weaker soil layers beneath where, if exposed part-way down a slope seepage pressures could build up and instability could develop if appropriate drainage measures are not included in the sub-division design to counteract the problem. Any other sub-divisions in the area (or earthworks for roading or other purposes) should be examined to confirm the likely stable slope angles of cut slopes and natural slopes.

It is possible (by judicious cutting of the top of the slope and the filling in the gullies at the bottom of the slope) to considerably reduce overall ground slopes by the carrying out of appropriate earthworks, and hence to increase stability especially if good drainage measures which will lower the overall ground water-table level can be included in the subdivision design.

ii) *Are the proposed heights and weights of filling appropriate to the known overall stability of the ground in the area?*

A large sideling filling on a slope can generate high shear stresses in the underlying natural soils. Fills can also raise the overall ground water-table levels if suitable subsoil drainage measures are not installed and also settlements at the ground surface can result from the placing of fill, due to consolidation of underlying compressible soils, or due to consolidation within the fill itself (although this is unlikely to be significant in well controlled compacted filling).

For the above reasons it is desirable from a geotechnical point of view to limit fill heights as much as possible during the drawing up of the scheme plan. However it should also be borne in mind that filling well benched into existing slopes and confined as much as possible within gullies can be a considerable aid to stability (e.g. in the December 1976 Wellington storm nearly all of the reported slips were in natural ground and none in well compacted filled ground).

The "maximum earthworks approach" by removing steep slopes and valleys can produce a very stable landform provided the fills are well designed and compacted but can give a rather bleak appearance to the landscape, at least until vegetation becomes established. On the other hand, the "minimum earthworks approach" often leaving steep natural slopes and using narrow one way streets can be much more attractive environmentally but may have potential stability problems.

(d) Sufficient geotechnical investigations (drilling, laboratory testing, analysis and reporting) should be carried out to enable the scheme plan to be submitted to the local authority with reasonable confidence that nothing will be discovered during the subsequent more detailed investigations at the design stage of the subdivision which will require the subdivision layout to be substantially altered or that parts of the subdivision are determined to be unsuitable for residential development.

Up until recently it has been most unusual for a local authority to require a developer to present a geotechnical report at the time a scheme plan is submitted to Council for approval. However some local authorities are now requiring that this is to be done (e.g. Manukau City Council) and it is expected that as a result of the Abbotsford landslide this will become a much more common requirement in the near future.

3. THE SUBDIVISION DESIGN STAGE

Once the scheme plan has been approved and detailed subdivision commences it is reasonable to expect that a much more comprehensive geotechnical investigation will be carried out, especially for a subdivision on sloping ground and/or involving substantial earthworks.

Space does not permit a detailed description in this paper of the type of investigations which should be carried out and this must be governed by the advice given by an experienced geotechnical engineer. However investigations should include

(a) Drill holes to investigate the underlying soil layers beneath all important cut slopes or areas proposed to be filled. Some of these drill holes should be taken to a sufficient depth to identify the underlying bedrock (or a hard layer beneath which it is unlikely that there would be any soft ground).

(b) An appropriate laboratory testing programme to determine the relevant soil parameters required for subdivision design including slope stability analysis and settlement analysis where appropriate.

(c) Suitable methods of analysis of all slope stability and consolidation problems judged to be significant within the proposed subdivision layout.

In addition, during subdivision design careful consideration must be given to

(d) The adequacy of subsoil drainage measures considered necessary to tap all seepage and springs within gullies or to maintain the overall ground water-table at a sufficiently low level to ensure stability. This should include a careful evaluation of the quality of water likely to be involved and to ensure that all subsoil drains are designed for permanence. They should be sufficiently deep so as not to be affected by any foundation excavation work or trenching work during building construction, should not cross any unstable ground which could move and damage the drain and should be surrounded by a filter layer sufficient to ensure that they do not become blocked by clay or silt.

(e) The adequacy of the surface stormwater drainage system to prevent erosion or other problems from developing during heavy rainstorms.

Some specific comments regarding geotechnical investigations for subdivisions are:

i) The quality of the data produced from the investigation bore-holes and laboratory testing programme is very important. Bad information can be misleading and worse than no information at all. Hence it is better to have a limited amount of quality information than to spend the same amount of money obtaining much more information of doubtful reliability. However, the quantity of information obtained must be sufficient to define the variability of the soil layers within the subdivision and the likely scatter of test results within the range of normal experimental error for good quality work.

ii) Slope stability analyses should be carried out using effective stress analysis for long term stability. This requires expensive triaxial testing to determine effective stress parameters. Where possible, observation of existing slope failures (or maximum stable slope angles) may enable shear strength parameters to be obtained from back analysis but these results should normally supplement results of triaxial testing and not be used instead of triaxial testing.

iii) Slope stability analyses should not just give a single figure for factor of safety but rather a range of values of factor of safety depending upon the assumptions made. Statistical methods to assess the probability of failure are now being used in some circumstances as an alternative to the factor of safety approach.

iv) When considering settlement beneath a large fill, the likely angular distortion beneath a structure (i.e. differential settlement) is a much more important consideration than overall settlement. Hence if the fill is of a similar height over a large area with uniform subsoil layers beneath, considerable settlement could occur beneath a house founded on the fill without any observable damage occurring. More information is required in New Zealand from the monitoring of settlement beneath larger fills used in residential subdivisions.

4. THE SUBDIVISION CONSTRUCTION STAGE

As construction proceeds, it is essential that the subdivision designer should remain involved to ensure that the design assumptions are being achieved in practice in the field. He should inspect the subsoil conditions exposed by excavations. In the event that these are not as expected, the designer must be informed so that any design alterations considered to be necessary as a result of unforeseen ground conditions can be made. In practice these requirements can only be fulfilled by either the designer or his representative making regular visits (at least weekly and daily when necessary) to the site during the construction work.

If the designer has employed a specialist consultant to carry out the geotechnical investigations then the specialist consultant should also visit the site at critical times during the construction period.

The designer should also provide the specification for construction control of compacted earthworks to cover the degree of supervision and frequency of testing required and be given the opportunity to review the results of all control testing.

5. SUGGESTED COSTS OF GEOTECHNICAL INVESTIGATIONS

It is not possible to give definite guidelines on the extent of geotechnical investigations which are considered to be reasonable or adequate for residential subdivision works. However as a very broad indication, a budget of between 2% and 10% of the total subdivision costs to be spent on geotechnical investigations may be considered reasonable depending on the scope of the likely geotechnical problems to be considered in that particular subdivision and the topography of the land.

However the ultimate criterion must always be that sufficient investigation has been done to give a satisfactory assurance that each section within the subdivision after completion will be suitable for residential construction. If this assurance cannot be given on any particular section then further investigations will be required at the building permit stage.

6. ENGINEERS STATEMENTS ON LAND STABILITY

In 1977 the Earthquake and War Damage Commission after consultation with the Territorial Local Government Council produced the format for statements to be signed by registered engineers concerning land stability.

The first statement is to be provided either at the time of submitting the scheme plan for approval, or alternatively approval of the scheme plan can be granted on the condition that such a statement is subsequently provided to Council. In the preamble to this statement the following comment is given. "Because of the cost of obtaining such an opinion it should normally only be required in an area previously defined as having problems of known, potential or suspected land slope or foundation instability". It is to be given by a registered engineer experienced in the field of soils engineering and more particularly land slope and foundation stability.

The second statement is to be provided following subdivision construction to the effect that the completed works give due regard to land slope stability considerations and that there is on each section a site suitable for a residential building not requiring specific design in terms of NZS 1900 and related documents with any provisions that the engineer wishes to make. This statement must be signed by a registered engineer but with no specific requirement regarding experience in soils engineering and land slope and foundation stability.

The third statement must be signed by a registered engineer experienced in the field of soils engineering and more particularly land slope and foundation stability and relates to soils investigations carried out at specific house sites in support of a building permit application. It would normally only be required for a site which is in an area previously defined as having problems of known potential or suspected land slope or foundation instability,or for a section in a subdivision where final plans were approved subject to specific investigation and/or engineering design for that section.

7. CONCLUSION

Suggested procedures for the geotechnical evaluation of subdivisions from the scheme plan stage through to construction have been described in this paper. These procedures have evolved gradually over many years but it is considered likely that over the next few years much more rigorous standards will be enforced by local authorities.

GEOMECHANICS IN URBAN PLANNING - PALMERSTON NORTH APRIL/MAY 1981
NEW ZEALAND PLANNING INSTITUTE : NEW ZEALAND GEOMECHANICS SOCIETY

INVESTIGATIONS AT BUILDING PERMIT STAGE

T N COSTELLO
COOK MULDOWNEY COSTELLO, WHANGAREI

INTRODUCTION

In respect of residential building permit applications responsibility for determining whether or not site investigation will be required rests initially with the local body engineer and the building inspectorate.

Areas of possible hazard may be defined on the district scheme or be a matter of local knowledge and in these situations it is likely that building permits will be refused unless accompanied by a consulting engineers report giving a detailed consideration of the problems in relation to the particular building site.

The attitude of the local body may well be determined by the extent to which they have been involved in litigation.

In general, local body officers today are properly informed and are well aware of their responsibilities. They take a cautious and responsible approach.

THE CONSULTANTS ROLE

Generally, the developer responsible for a commercial or industrial building will instruct a qualified engineer (or his architect will) and be aware of or readily accept the need for a site investigation which might cost between 1 and 5% of his total building costs. In this case the local authority may be little involved except for cursory or detailed perusal depending on the local authority and final design.

In the case of a dwelling, the owner or builder may come to the consulting engineer only because it is a local authority requirement.

The extent of the investigation and testing carried out by the Consultant will depend on

1) The known or suspected hazards to building development on the site.
2) The magnitude of building loads in relation to strength of supporting soils and the sensitivity of the building to movement.
3) The capital investment in the building or development and the importance of maintaining its function.

For residential buildings the extent of practical investigation will be dictated by finance. For obviously hazardous sites the Consultant may face the difficult task of telling the client that the cost of investigation to determine the stability, or of works to safeguard the stability, will be excessive and the clients investment in the section is virtually made worthless.

The paper by Taylor, Gulliver and Rogers delivered earlier to this symposium covers the major hazards likely and examines their significance.

In the text that follows the particular hazards requiring evaluation in site investigation at building permit issue are considered.

AIMS OF SITE INVESTIGATION

The investigation will be directed to identify, quantify and recommend methods to safeguard against hazards such as flooding, erosion and ground movement.

1) Flooding may be best identified from local knowledge and experience or from research at the local level. Some local

bodies have fully researched information available - for example catchment plans which determine safe building levels in relation to flooding.

Alternatively ground surveys or surveys plus research on existing contour plans, stereoscopic photogrammetry etc can establish catchment areas and methods of calculation are available to establish flood levels from assumed rainfall figures - often set by the local authority.

2) Large scale slipping may be identified by geological studies as have been carried out for Nelson and Whangarei City Councils and cautionary information incorporated in the District Scheme.

An Engineer may be skilled (or lucky) enough to identify large scale failures by reconnaissance on the ground and topographical studies and from aerial photographs but generally a geologist or engineering geologist would be required and these studies are most appropriately undertaken by the local authority at the time of establishing zoning.

Frequently such problem areas are only identified after they are covered in houses.

Hopefully local authorities are now aware of this type of problem and are obtaining early information to avoid such difficulties.

3) Faults and fault movement are comprehensively treated and are covered elsewhere in this conference in the paper delivered earlier by Lensen.

4) Surface slips and slumps and gulley erosion are the types of problems likely to be encountered particularly in residential development.

If these are occurring on a time scale likely to cause problems then local knowledge may indicate problem areas or alternatively ground reconnaissance and study of aerial photographs may be used.

The obvious physical record of such failures must be taken seriously and play a most important part in arriving at judgements based on the most careful site investigation that can be carried out within a reasonable budget.

5) Settlement is treated in the paper by Kayes and Orbell above. Well accepted and widely used methods are available for predicting settlement although there is always a good deal of uncertainty about time/settlement predictions. Once the probability of significant settlement is identified then methods can be used to prevent its occurrence or minimise its significance, for example by preloading and/or accelerating drainage or piling to underlying firm layers.

6) Bearing capacity is rarely a problem in residential construction. Once the shear strengths of the subsoil layers are established it is generally a simple design exercise. Often knowledge of the soil type will be sufficient to establish a design bearing capacity.

7) Foundation movement caused by expansive clays on slopes, that is soil creep, is the most commonly encountered problem in residential buildings. (See paper by Weseldine preceeding).

In the main, timber houses are able to accommodate such movements but in masonry and brick veneer dwellings severe and unsightly cracking can occur which can become structurally significant.

If the significance of these problems is properly assessed they can be provided for in the house design.

Indeed, in the new code NZS 3604 footings not specifically designed are required to be taken 450mm below ground level which goes a long way towards overcoming these difficulties.

8) Coastal Erosion

The significance of this particularly in relation to dune movement is not given sufficient regard and investments in beach residences as well as industrial installations totalling many billions of dollars in this country are likely to be put at risk with the passage of time.

Site investigations necessary in these instances are essentially careful long term (10-20 year) measurements of the patterns of waves, currents, winds and sand and coastal material movement and are matters for specialist study and interpretation.

A consulting engineer or engineer's geologist may be able to make an assessment of the likely risk of building on a site but it is unlikely that proper study is a practical possibility. (See Dr Gibbs paper preceeding).

SITE INVESTIGATION

The site investigation necessary or more importantly practical for a building proposal will vary.

No hard and fast rules can be laid down. The investigation at building permit issue stage will be specific to the building proposed and its immediate environs.

The first steps will always be to accumulate all the available information about a site including the history of flooding erosion or slip failures, engineering information about excavation and filling or reclamation and local knowledge about subsoil strata from adjoining drilling etc.

Study of geological information may enable the identification of problem areas - for example in Northland Ruatangata sandstone and Onerahi chaos breccia give rise to difficulties.

Evaluation of this and consideration of the building proposal will determine the extent of site investigation and testing desirable and acceptable to the client.

It will include the following:

1) Determination of materials underlying the site and recording of consistency, classification, soil type etc and ground water level. This may be done by drilling or by test pit excavation. Soil sampline may be by 38mm or 100mm undisturbed sampling tubes or disturbed sampling.

2) Testing may commonly include
   a) Atterburg limit tests.
   b) Moisture content/density/linear shrinkage.
   c) In situ shear vane, pocket penetrometer.
   d) Raymond penetrometer (S P T).
   e) Scala penetrometer.
   f) Unconfined compression testing.
   g) Triaxial shear testing may be carried out in more comprehensive site investigations.

3) Analysis of test results - stability checking, settlement prediction.

4) The preparation of a report on the investigation and testing, with recommendations on the foundation design and safeguards necessary.

RESIDENTIAL BUILDINGS

Extensive investigations by means of machine drilling equipment, undisturbed sampling, laboratory testing etc will generally be impractically expensive and often the investigation will be by site assessment, limited hand augering and sampling, and in-situ shear vane testing or scala penetrometer testing. The value of laboratory Atterburg limit testing, moisture contents and linear shrinkage should not be underestimated particularly when considering moisture and instability problems.

Carrying out of detailed investigation into possible slip areas is difficult, uncertain and expensive and the exercise of careful observation and judgement most important. Consideration of clay type classifications may be of value in view of the association of montmorillonites in many failures.

SUMMARY

The site investigation required at Building Permit issue may vary enormously and is a matter mainly for the judgement of the person responsible. It should be as detailed and thorough as is practical in light of a careful assessment of the risks the building may be subject to. Good design can overcome many likely ground movement difficulties.

FIFTH DISCUSSION

of "What should happen"

- papers by Hancox; Lawrence; Williams; Tremaine; Blakeley; and Costello.

I G Speden (NZ Geological Survey, DSIR, Lower Hutt)

Geological Survey has, at its District Offices and Head Office, a large amount of unpublished information. This is why we encourage those seeking geological information and advice to consult with us. This information is a valuable asset, which has greatly facilitated work by many other government departments and non-government agencies, as well as that of Geological Survey. Regrettably, with the emphasis on energy programmes, we do not have the person-power to compile and synthesize the information at the rate we would like to.

Basic geological information is most readily used or interpreted by geologists. Other users, such as planners, generally prefer information on specific topics or presented in a simplified manner; for example, special purpose maps, such as those showing depth of weathering or hardness of rocks, and interpretative maps such as those indicating potential slope instability or mineral resources. A publication by the US Geological Survey, "Nature to be Commanded .... must be obeyed" (USGS Professional Paper 950, 1978), vividly illustrates the importance of basic data and what can be done with it to provide information of use to land managers, administrators and planners.

A questionnaire of "Uses of Geological Maps" (Speden and Riddolls, 1980), circulated in late 1978 and possibly kindly filled in by some of you here, indicated three major requirements,

1) for coverage by 1:50 000 scale geological maps,
2) for large scale maps to facilitate large scale investigations, and
3) for reliable information.

Although there may be some doubt as to the meaning of reliability - whether this is scientific reliability; or reliability at a standard determined by a user - there is little doubt that respondents stressed the importance of reliability, perhaps in part to cover the possibility of litigation.

Geological Survey would be pleased to have comments on the relative merits of basic geological and derivative maps.

D K Taylor (Tonkin and Taylor)

I would like to comment on the geological maps produced by DSIR. They are of very high quality and will no doubt stand up to criticism in geological circles. But we have so few of them. What I would like to see is simpler, less reliable perhaps, geological maps which are simply indicative of what kinds of geological conditions are present in the area. This would make it so much easier for us (the geotechnical consultants) to focus our investigations - drilling programmes or whatever - right from the start. The Industrial Series in Auckland was excellent, - we had that 20 years or more ago, long before we had the geological map of Auckland. Although it was criticised adversely, and probably still is by the purists, it was just what was needed. Perhaps the approach taken by Mrs Lawrence will fill this gap.

M J Crozier (Victoria University of Wellington)

My questions or comments relate to Table 3 in Mr Hancox's paper. Firstly, I notice that angles are given but not maximum heights. Secondly I think that you could go 6-7^0 higher in the Wellington greywackes. Are you not being very conservative? Conservative values can lead to very great increases in costs of excavation and/ or cost of lost land.

Reply (Hancox)

Yes, I realised that I was taking a risk by including numbers. So much depends on the nature of the rock at the site in question. The values are for natural slopes and the question of height doesn't arise then.

M T Mitchell (Soil mechanics consultant, Hamilton)

You mention a 1:25,000 map scale. My experience is that one begins with a 1:5,000 aerial mosaic and that to get from this to the 1:25,000 scale one needs the kind of engineering geological investigation which you describe.

I attach importance to soil survey information also. Hillslope instability is often related to the different permeabilities of the various soils (horizons).

G J Lensen (NZ Geological Survey, DSIR, Lower Hutt)

Mrs Lawrence, did you in your urban capability study of the Eastbourne area (Wellington) include earthquake shaking effects on the very steep old seacliffs that are now used for building sites?

Reply (Lawrence)

Not directly. However the most hazardous situations from a landslip viewpoint in Eastbourne, would also be vulnerable during earthquake shake; so the ranking of areas would probably not change?

G J Lensen

By excluding that you mislead the user of your survey into a false sense of security.

Reply (Lawrence)

Perhaps so. But the fact that both you and I live there means that we do not regard the risk as unacceptable.

G J Lensen

I live on the flat well away from the steep cliffs.

B J Forde (DSIR and Palmerston North City Council)

Does Mrs Lawrence feel that the three studies she described (the regional study and the two district studies) provide sufficient information for those local bodies to discharge their responsibilities under the first and second schedules of the Act? We have heard her reply to Mr Lensen on the question of including earthquake shaking in the Eastbourne study. The local body does need to know whether it has done all it can be expected to do, or not. If the latter then it could possibly be found negligent.

Reply (Lawrence)

In the case of the regional study in Hawkes Bay I would say "yes, sufficient information was presented for them to be able to make a responsible judgement". But I am not a lawyer or a planner.

At the district scheme level also I think "yes, the council did have sufficient information on which to base zoning decisions." At Eastbourne the council modified their zone boundaries in the light of comments we made.

In fact they included a proviso in their district scheme to the effect that all areas within urban zones may not be free from land-slip hazard. I would ask Judge Sheppard whether they can do this. Is it satisfactory from a legal point of view?

Chairman

Do you feel obliged to respond Judge Sheppard?

J F G Sheppard

I feel obliged not to respond to that.

I M Parton (Worley Consultants Ltd, Auckland)

I would like to reinforce the comments made by Mr Blakeley regarding the involvement of geotechnical engineers in the initial stages of subdivision planning. Subsoils investigation work combined with laboratory testing and slope stability analysis is required at the scheme plan stage as steeper and more difficult terrain is subdivided for residential development. This work need not be prohibitively expensive providing the work is undertaken in a logical manner.

Dr Riddolls earlier commented on the need to employ properly qualified people to interpret geological maps and extract the information contained on the maps for planning purposes. The same argument may be applied to subdivision planning and the need to employ geotechnical engineers to advise on the location of roading, reserves, etc. Money can be wasted when the subdivision is planned without specialist advice and the role of the geotechnical engineer reverts to that of attempting to preserve stability in the later stages of development. The same applies to the level of investigations required to give reasonable assurance of stability.

Costs of investigations vary widely depending on the nature of the terrain and the number of sections in the development. I believe Mr Blakeley is correct with his 'ball park' figures of 2%-10% of total costs. My firm has undertaken investigations, stability analysis and reporting on single lots which are geologically simple for less than $1,000. Where geological conditions are more complex or several lots are involved costs may range up to $3,000. Certainly for subdivisions involving 20 or more lots the cost would approach or exceed the $20,000 referred to by Mr Taylor.

Some Local Authorities appear to be a little over-zealous in their interpretation of Section 274 of the Local Government Act by failing to recognise that the level of intensity of investigations depends on the complexity of local ground conditions.

Mrs Judy Lawrence touched on the subject of 'format statements', detail of reporting at subdivision stage, and the responsibilities of Local Authorities. Cost is an important factor in the subdivision of 1 or 2 lots of urbanised land. Many of these investigations are done on the basis of walk-over survey, hand auger holes of limited depth and observation of groundwater levels.

Under these circumstances the engineer who signs the "format statement" is using his judgement and experience to assess the factors likely to affect the stability of land. Where there is any doubt as to the stability of the land, further investigation and laboratory testing should be undertaken to determine whether or not the land is suitable for subdivision.

Reply (Blakeley)

The real cost in carrying out slope stability analyses lies in getting the right data to put into the analyses : that is where the money goes. The computations can be done very cheaply now on quite small computers - desktop calculators even.

I agree with Dr Parton that these investigations need not be expensive - particularly for those conducted at the scheme plan stage where, as I outlined, most of the decisions are based on judgements of experienced people. However, at the design stage I do believe you have to get into the physical reality of the situation and get some good data.

J G Hawley (Aokautere Water and Soil Science Centre, MWD)

I don't see the need to define formally the amount of investigation necessary at any of these stages (Regional, District, Scheme, Concept or Building Permit) because so much will depend on the particular situation - the geological setting and the history of the piece of land in question. Just how much needs to be done at each stage is a matter for an experienced geotechnical engineer to make a judgement on. The three 'format statements' which have been mentioned are relevant here. They presuppose reliance on professional judgement rather than on regulations.

A N Bickers (Palmerston North City Engineer)

I feel that I have heard some conflicting points of view. The extent of work outlined by Mr Blakeley prior to scheme plan preparation and subdivision design is far more extensive than I have experienced. Do the costs involved really fall within the 2%-10% range we have been hearing about?

Reply (Blakeley)

The work which I outlined, particularly that relevant to scheme plan preparation, is actually very inexpensive. It varies of course from area to area, - some places are much more tricky than others, for geological reasons. The real problem is getting everyone to agree that the simple inexpensive things - examination of aerial photographs (old and new) and holding discussions with geologists and pedologists who have insight into how the piece of landscape was formed - must be done. I am backing up the point brought out in Gulliver's paper, and by Don Taylor. Don't rush into the expensive sampling and testing until you have looked very hard at the geomorphological setting. I will stick with the 2%-10% guideline, and add that I believe that recent events - certainly in the Auckland area - have been such as to make the public more aware of the need for this kind of work to be done.

J G Gibb (MWD Water and Soil Division)

With regard to concept plan preparation you appeared to favour the cut and fill approach over leaving the natural contour. I see one danger in this in the case of sand dunes. Disturbance of the dunes can lead to very serious wind erosion and deposition - as has happened at Himatangi.

Recontouring dunes usually means lowering them somewhat. This can have the effect of increasing the distance which a given storm will cut back into the dune. At Raumati we observed losses of dune volume of the order of 100 m^3 per metre length of shoreline in a single storm event. There is some evidence to suggest that a given storm will take a certain volume. At Omaha after the spit was "improved" by lowering it, the amount of erosion on the lowered part was much larger than that on the nearby natural dunes.

Arguments in favour of leaving dunes intact are not therefore only aesthetic ones: there are practical arguments also.

Reply (Blakeley)

I am sorry if I gave the impression that I was strongly in favour of maximum earthworks. All I meant to convey was that earthworks do tend to improve things from a slope stability (landslip i.e. mass movement) viewpoint. Slopes are invariably much flatter after earthworks than before, and properly engineered fills are very stable indeed. I accept the point you make, that in the particular case of sand dunes any disturbance may lead to serious surface erosion, - wind erosion. Earthworks do of course lead to a temporary increase in susceptibility to another form of surface erosion, namely rill erosion - until the area is revegetated and stormwater drainage systems are installed. My point about reducing the risk of mass movement does not conflict with these observations regarding increasing risks of surface erosion: the earthworks reduce the risk of mass movement but increase the risk of surface erosion (by wind and water).

Reply (Costello)

I'm sure that for the last 15 years anyway local bodies have been very aware of the need (and their responsibility) to impose conditions on subdividers carrying out mass earthworks so that these do not create nuisance beyond the confines of their land. While the execution of this responsibility may in many instances have been open to adverse criticism they have nevertheless been aware of it.

The current decline in the pace of development and the swing away from major earthworks in some instances have made it easier for local bodies to get on top of this one. They are better able to police things - require silt traps to be built and/or require earthworks to be carried out on small areas at a time so that large areas are not exposed to erosion at any one time.

As a result of this symposium many local bodies will be more aware of the problems associated with dispersive soils.

Reply (Lawrence)

The guidelines drawn up by the Auckland Regional Authority for the control of erosion during earthworks is very relevant to the rill erosion - but not to the wind erosion.

J N Chapperton (Frazer Thomas Gunman Shaw & Partners, Papatoetoe)

I believe that more detailed investigations should be made before the scheme plan is prepared. Only by doing so can you avoid aggravating many of these geotechnical problems. Once you get to the building permit stage you are talking of a one section at a time approach and this could be uneconomic - for each owner individually.

L W Martin (Cuttris McKenzie Martin & Co, Lower Hutt)

I think that a lot of the investigations Mr Blakeley has described should be made before the land is zoned "urban". Furthermore I see no objection to the local authority, i.e. the ratepayers, paying for such investigations. In the long run the subdivision will benefit the ratepayers even more than the subdivider.

Reply (Blakeley)

I would add to that the comment that the investigations at the subdivision design stage must be related to the cuts and fills that are being proposed. You could do some of that investigating at the zoning stage but there would usually have to be further work done (compaction tests for example) for the particular subdivision design that the developer had in mind.

D R Anderson (Johnston, Hatfield, Anderson & Partners, Dunedin)

Landowners within a borough or a city tend to have expectations of development, and of the capital gains associated with it. To rule out, on geotechnical grounds, land which has been incorporated from a county into a borough or a city could be a difficult and an unsatisfactory business - for all concerned.

Would it not be wise to test the suitability of land for urban development carefully before it is transferred from a county to a borough or city? Land is being transfered in this way all the time. Are the geomechanics people being consulted?

Chairman

Would councils be prepared to arrange for and fund such preliminary geotechnical investigations?

Reply (Forde, Palmerston North City Council)

Who benefits and who pays? A council (i.e. its ratepayers) could not be expected to fund geotechnical investigations for every landowner who thought they just might want to subdivide sometime. The costs would have to be met - in part if not totally - by the subdivider in each case.

Reply (Blakeley)

In section 2 of my paper I noted that some local authorities are now producing land stability maps recording all areas of known land instability within their area. But you are asking for the full range of geotechnical considerations not just land instability - and you are asking for these to be examined before incorporation into the city or borough. I do not know of this being done.

Reply (Lawrence)

The type of study we did in Hawkes Bay is very much the sort of thing Mr Anderson is advocating. Rather than carry out, at the pre-zoning stage or before county boundary changes are made, the kinds of investigations which John Blakeley was talking about - for scheme plan and concept plan preparation, I believe that it is sensible to have a broader look at things : knock out areas that would be prohibitively expensive to service, areas with obviously difficult foundation problems, slope instability or flooding problems and so on. This should go a long way towards avoiding the difficulty Mr Anderson sees. The areas chosen, after this kind of broad brush (1:25,000) study for incorporation into a borough should not then be found to be unsuitable for urban development - or even particularly expensive to develop.

P W Williams (University of Auckland, Geography Dept.)

I would like to emphasise two points:

1. A lot of the discussion, particularly on John Blakeley's paper, has tended to sound as though land instability was the only thing that needed to be investigated. All of the hazards discussed in this symposium should be kept in mind.
2. Preliminary studies must be carried out on whole catchments. Whether scheme plans or concept plans are satisfactory or not can only be judged properly by a council if they can refer to some sort of "whole catchment development plan".

In the case of runoff for example one cannot judge the likely effectiveness of proposed control measures if one doesn't know what other people in the catchment are likely to do. If you just pick off each development one at a time as it comes along you will probably run into trouble - and, at the very least, into unnecessary expense.

Reply (Costello)

I agree, and at the risk of sounding parochial I may say that Whangarei City is well on the way to preparing "whole catchment management plans".

J Griggs (Northland Catchment Commission)

I have been thinking about how I might report back to my catchment board on what has been said at this symposium. Would it be possible for each paper to be summarised in a few sentences and for the whole thing to be summarised in a couple of pages of language which can be understood by elected board members drawn from a variety of backgrounds.

This relates to the point made earlier - the importance of getting messages across to the decision makers, - the council officers and the council members.

I G Speden (NZ Geological Survey)

Communication between interested parties is extremely important, including in educative roles. Nevertheless, it may be necessary to establish priorities on whom it is most important to address. In the United States for example, experience has demonstrated that the most effective means of ensuring that scientific and technical information is understood and used, is for the specialist to explain the methods of preparation, intent, and uses of a document or map directly to legislators, planners, local authority council members and the judiciary. This seems best done through joint workshops and field demonstrations. Specialist meetings or workshops seem to be relatively ineffective, except for enabling specialists to talk to each other.

I M Grierson (Harrison & Grierson & Partners, Auckland)

I hope that it will become mandatory for a bibliography to be appended to all district and regional schemes showing what data sources were used. Only if this is done can the schemes be challenged sensibly (in specific departure applications) or revised economically.

K J Tremaine (Palmerston North City Planner)

I agree. I can recall an instance in the Tauranga County scheme where readers are referred to a particular "land stability investigation by Tonkin and Taylor, consulting engineers, Auckland". It is available at the County office.

<u>M T Mitchell</u> (Soil mechanics consultant, Hamilton)

Who should carry out this hazard rating work? So far we have heard mainly from people in government organisations. Should not the private consultants be doing more? We now have many private partnerships offering multidisciplinary expertise.

(Editor: No reply was given to this question. The paper by Taylor Gulliver and Rogers, that by Kayes, and that by Gulliver, all came from the private consultants Tonkin and Taylor. Mr Blakeley's paper was founded I would think on his work as a private consultant and Mr Costello is in private practice now. Of the remaining speakers four are employed by universities and eleven by other publicly funded bodies - DSIR, MWD, local bodies and the Justice Department.

Most would agree that it would be a good thing if all of this work could be done on a "user pays" basis. However there is a real problem in identifying all of the users of geological surveys, soil surveys and so on. If the costs had to be met by just the few identifiable users the work would simply not be done.)

STRUCTURED DISCUSSION

Chairman The first question we have been asked to discuss is

"What must local authorities (and other parties) do in order not to be liable when the failures occur?"

Panel Response (M Jones, planner, Whangarei)

They must exercise their duty of care. They must identify the risks and the areas in which the various risks are significant. In order to exercise their duty of care in this they must take professional advice. They are then obliged to produce a town plan or a district scheme which avoids so far as is possible (or reasonable) the dangers arising from those risks.

A professional advisor to a council must not only give them advice when they call for it but also as and when he considers it appropriate so to do. He should have a well-developed sense of what the responsibilities of the council are and bring the appropriate facts and professional opinions before them at the right time.

Panel Response (Horsley, lawyer - Massey University)

That is a very fair assessment.

Councils have had very positive legal obligations placed on them. They will naturally wish to err on the side of caution.

Where the risks are clearly very real councils will have no difficulty in saying 'no'. The most common situation however is that where a moderate to low level of risk can be identified. What should they do then? Should they (or could they) issue a warning of some kind and in so doing attempt to transfer onto the homeowners the responsibility for keeping the hazard under control?

C Collins (Water & Soil Division MWD, Head Office)

The last part of Section 641 of the Local Government Act says that a council must refuse to grant permits if it is not "satisfied" that all is well. What must a council do - how detailed a set of investigations must it carry out - in order to be able to say that it is "satisfied"? It is going to be difficult (impossible) to specify what they must do because circumstances vary so much. Furthermore some hazards appear just on one or two sites in an otherwise safe area.

Chairman

Yes. Councils may well be anxious about whether they have failed to say 'no' as often as they should, - i.e. whether they have failed to identify some hazards.

However, it is worth noting here that where a council has said 'no' and the owner disagrees with the council's assessment Parliament has provided for an appeal to be made to another body.

J H Lawrence (MWD, Water and Soil, Head Office)

Does Mr Horsley regard the level of investigation which I described in my second paper this morning as being sufficient for Regional and District scheme preparation?

Panel reply (Horsley)

We have here an unhappy marriage between lawyers and scientists: the scientists assess the hazard by interpreting the physical facts, - the lawyers can only interpret the words.

J H Lawrence

Will we have to wait for case law then to answer my question?

Panel reply (Horsley)

Yes, as the law stands at present, we will.

K J Tremaine (Palmerston North City Planner)

Case law will almost invariably be made in relation to one site, or at most a few sites, and it will be very specific to those sites and to those particular circumstances.

Each person is entitled to examine the town plan and see what restrictions there are on their particular property. For this reason investigations on which town plans are based must be sufficiently detailed to allow the hazards relating to individual sites to be identified.

I am not sure that what Judy Lawrence described for district scheme preparation was detailed enough to allow site by site requirements to be set by a council.

J G Hawley (MWD, Aokautere)

On this first question - "What must local authorities do in order not to be liable when the failures occur?" - we have been given (by

Lawrence, Blakeley and Costello) an idea of what might be appropriate at the various stages - from regional scheme preparation through to the issuing of building permits. What I want to know is whether, if they do these things to the standards described, they will still be liable when the failures occur. Is there any level of care which a local body can exercise which will make that body no longer liable when the unforeseeable happens?

Panel reply (Horsley)

I can only say that I do not think that a local body could get around this one with a disclaimer. Local bodies have these statutory obligations placed on them, and they cannot simply disclaim them.

J G Hawley

I see this leaving local bodies in an impossible position - because when one is considering natural hazards one is talking about probabilities, not about facts.

J H Lawrence

What about the professionals involved? Can they give disclaimers?

Panel reply (Horsley)

Yes, and if they did so their disclaimers might stand up in court. The responsibility would then fall back on the local body who, as I see it, cannot shelter behind any disclaimer - their own or anyone elses.

D K Taylor (Tonkin & Taylor, consultants)

If we are talking about liability, the test would be whether the local body or the professional consultants could be held to have been negligent. That would be judged on the basis of what their peers would have done in the circumstances i.e. what is normal and reasonable practice. How well can we define the levels of normal and reasonable practice?

M Wesseldine (Manukau City Council)

I recall hearing about a case - relating to the Whitby subdivision where this question came up and evidence was heard that the consulting engineer had done things in accordance with accepted practice. The judge ruled, I believe, that the consulting engineer had therefore no case to answer.

Chairman

Thank you. I read into Mr Taylor's question however a concern that the levels of "accepted practice" appropriate to each stage of urban development may not yet be as well defined as they need to be. Could it even be that in most situations a defendant may find it possible to find some fellow professional who will assert that what was done was normal and reasonable.

I M Parton (Worley Consultants Ltd, Auckland)

When one gets into a specialised field like geomechanics the standards required should be those of a "registered engineer specialising in geomechanics or in hydrology or whatever, - not just those of a "registered engineer" or even of a "registered engineer specialising in civil engineering". In the case of geologists and soil scientists the position is rather less clear because those professionals do not have registration.

The point is that if one takes on work of a particular kind - land stability, flood level prediction or whatever - one sets oneself up as an expert in that field. People called on tc assert, after the unforseeable has happened, that standards of care were above or below what was normal and reasonable are likewise setting themselves up as experts.

Some people here have been saying that we should do more here or less there - and at one stage we got confused by talk about costs. In some situations the real expert needs to do very little - take one look at the site and walk away. I am thinking particularly of the hopelessly bad sites - the obviously unstable ones, the ones which are obviously in floodways and so on. But the same can be true to a lesser extent of the really good sites - where the geology is well understood, the neighbouring ground has been developed for a long time with no problems, and so on.

I don't see much hope of Parliament or individual local bodies, or planners being able to define what is an appropriate level of investigation: only the geotechnical experts can do so and they will set very different levels of investigation in different areas.

M Wesseldine (Manukau City Council)

I have the responsibility not only of rezoning but of deciding what levels of investigation are appropriate before rezoning, - on behalf of a local authority.

If I worried about all the things that could happen I would never be able to retire with my health. I do my best and that is all anyone can do.

Chairman

We have had agreement here I think that the standard of care appropriate in each situation will depend very much on that particular situation. It has also been implied that most people of standing in the relevant disciplines will agree on what levels of investigation are appropriate in different situations - whether triaxial testing is called for or whether it is a case where one takes one look at the property and walks away - or somewhere in between the two.

I now propose the second question for discussion which is

"Is it proper for local bodies to invite and accept absolution from the responsibilities given in Section 641-2a and Section 274-1a?"

The first of these relates to the duty of councils to refuse building permits in certain circumstances: the second relates to their duty to refuse scheme plan approvals in certain circumstances.

The word absolution I take to refer to what might arise in marginal situations where a local body would like to refuse permission but is under pressure (from developers or owners or whoever), to allow things to go ahead. This pressure could take the form of an offer from the developers to furnish the local body with an exoneration. Such a document might say that in signing the plan or building permit the local body does in no way imply that the site is suitably free from hazards.

Panel Response (Horsley)

This is very much what I referred to earlier as a disclaimer. The statutory responsibilities of local authorities are so clearly placed on them in this regard that I do not believe that disclaimers would stand up in court.

B J Forde (Palmerston North City Councillor)

Yes the council has responsibility.

The extremes are of course very easy to administer - the patently unsuitable can be ruled out and the patently suitable can be accepted. In both of these cases the level of geotechnical and other investigation can be quite small as already discussed.

It is the grey area in between that is of concern. I would like to see something which is not presently available and that is a tagging of the title. This would alert prospective purchasers to the likelihood that special professional investigations and special designs based on those investigations may be required by the council.

Houses in Palmerston North change hands on average every 5 to 6 years and a house may have a life of say 100 years. So we must think not only of the first purchaser but of all his or her successors in title.

I am chairman of the subdivisional approval committee in this city and by the end of this afternoon I will have to have approved or rejected 9 subdivision approvals. This is the "nitty-gritty". I will tend to reject if in doubt - to protect the Council and the citizens - knowing that the landowner can appeal to the Planning Tribunal if he feels unfairly dealt with.

G E Orbell (Soil Scientist, Hamilton)

I agree with Mr Horsley that disclaimers by councils are improper. In addition to the statutory position (or perhaps behind it) is the fact that councils are unlikely to go bankrupt whereas developers do go bankrupt. Councils are the only parties which purchasers can rely upon for compensation.

<u>B J Forde</u> (Palmerston North City Councillor)

In cases where there was uncertainty I would invite the sub-divider, who no doubt had had discussion with the City Engineer's department and with the City Planning department, to come and put his case to the Committee. The more evidence the Committee has on which to base an informed decision the better. In some circumstances the Committee might decide that the consultant for the sub-divider was more appropriately qualified than the local body officer for the circumstances.

<u>J G Hawley</u> (MWD, Aokautere)

Does the Council require geotechnical opinion to be provided in <u>every</u> instance?

<u>B J Forde</u>

No, but the applications are screened by the City Engineer's department and by the Planning Department.

<u>J G Hawley</u>

If a council did do a deal - sign an exoneration, disclaimer, absolution or whatever - and then the place was sold, and then things went wrong and the council were taken to court, would that bit of paper have any value? Would it get the council off the hook?

<u>Panel reply</u> (Horsley)

No. The council would be responsible.

<u>J G Hawley</u>

There would be the likelihood then that when things go wrong and such a disclaimer has been signed, the developers would put the property in some other name quickly and so get themselves well clear of any litigation.

<u>Panel reply</u> (Horsley)

I believe that in all cases, whether the property has been sold or not, the local body retains responsibility regardless of disclaimers.

Chairman

There is no doubt that various forms of disclaimer of this type are currently being drawn up in New Zealand. There seems to be no-one here present who is willing to speak in favour of them - as a technique which could be used in marginal cases.

G E Orbell (Soil Scientist, Hamilton)

Where a council refuses to approve a subdivision and it goes to appeal and the judgement is that the council should not have refused approval, is the council then obliged to pay compensation if things go wrong?

Chairman

That is not quite how the Planning Tribunal's decision would be phrased. The Planning Tribunal might cancel the council's decision. There would then be a scheme plan before the council for approval. Council would be obliged to examine it afresh taking into account all matters raised in the earlier proceedings.

Incidentally the Planning Tribunal does have a means for expressing its views as to whether the council or the subdivider was being less than reasonable. I refer to its power to award costs.

Chairman

Our third question, which has been touched on already by councillor Forde, is

"What information should be registered on titles?"

We may have in mind the recommendation of the Abbotsford Commission, the remit passed by the Municipal Conference this year, and the expressions of opposition to it given by the Registrar General and by the Minister of Internal Affairs.

We must keep it in mind that at the present time there is no clear legal authority for information on stability, flooding and so on to be registered against titles. There is also one Planning Tribunal decision which suggests that (at least in the circumstances of that case) it was not permissible and not reasonable for certain notations to be registered on the title.

I M Grierson (Surveyor)

Comment has been made earlier in favour of registering such information against titles - as being of concern to prospective purchasers. I would suggest that a solicitor should do more than just search a title on behalf of the purchaser. Unpaid rates on a property are not shown on the title. A solicitor must check with the local authority regarding the rates and I would say that it would be reasonable to check with that same local authority for information in the district scheme and in any other property records held by them.

A solicitor who failed to do this sort of thing might well be held to be negligent.

I have heard of computerised systems overseas - one called "Landstand" - on which such information is recorded along with position, basic coordinates, area and so on.

J H Lawrence

Additional information comes to hand from time to time regarding individual sites, district schemes are revised, and so on. Things are changing all the time - so an updatable computerised system would help.

J G Gibb (MWD, Water and Soil Head Office)

There are places around our coast where the "land" referred to on the titles is now out in the sea. I would like to see the position of the high water mark together with the date recorded on the titles of coastal properties.

B J Forde

I still feel (in spite of what Mr Grierson has said) that geotechnical information should be included on titles. I didn't mean to imply that a solicitor should only search the title and do nothing else. I know that it is the practice of some solicitors to obtain a letter from the council planning department to say that the property that their client is proposing to purchase can be used for the purposes they have in mind. Not all legal firms do this.

One difficulty (which was raised at the Municipal Conference) is that where there are no "caveats" on the title the purchaser might assume that no hazards exist. This would be true only for pieces of land which had been subjected to geotechnical investigation.

As for including information on the district scheme I can say that we have done this here for areas where we require a minimum floor elevation - against flooding. This is for a substantial area that we could delineate clearly. Smaller areas which had in fact an instability or a flooding risk are not so easily identified on a district scheme.

Anonymous

I see a difficulty in showing on the title the whole range of information we have been considering. I suggest that when a council has turned down a site then there is a good case for registering that fact on the title. There would probably be only a dozen or so properties in a local body area.

We are speaking only of those properties in areas which would have been given a 'd' ranking in the Hawkes Bay or Upper Waitemata Urban Capability surveys.

Chairman

Question 4 is

"How should the results of geotechnical investigations be presented so that they may be used appropriately by planners and elected representatives?"

We have been asked to consider this question for each of the hazards -

volcanic
earth deformation and shaking
mining
high compressibility
landslip
high soil dispersion
high soil shrinkage
flooding, and
coastal (erosion, landslip etc)

Panel Response (Northey, DSIR, Soil scientist)

We are considering a pretty wide range of hazards which are going to vary enormously from place to place. I know that we could get detailed answers on this from the experts in each of the different fields, but what we really want to hear now is how the planners and elected representatives would like to have the information presented - so that it is convenient for them to use.

Costello

The geotechnical map of Whangarei prepared by Ian Brown of DSIR was of immense value: it showed degrees of risk. It also gave an indication of rock type. That was a commissioned work and DSIR has a basic rate that it charges for such services.

B W Riddolls (Investigation Geology Ltd, Auckland)

The Whangarei map was compiled last year from existing information and aerial photographic assessments. Very little additional field work or laboratory testing was done.

I G Speden (NZ Geological Survey, DSIR, Lower Hutt)

(See comment printed above in discussion following the paper by Hancox).

L J Brown (NZ Geological Survey DSIR , Lower Hutt)

There are something like 250 counties, boroughs and cities in New Zealand - each of which has (or should have) a "district scheme". These schemes come up for revision every five years and it is impossibl for organisations such as my own to contribute to all of them - even in the most basic terms.

What we do give is simply a geological comment on the scheme. This comprises comment on the general geological setting, comment on the economic geology, and comment on any geological hazards of which we are aware.

The list of hazards which you have given us Mr Chairman - which is the list covered yesterday by the specialist speakers - is a frighteningly long one for planners to cope with.

New Acts of Parliament take a while to 'bed down'. I feel that after fourteen years we are now starting to use the 1967 Water and Soil Act properly. The Town and Country Planning Act 1977 may take a similar time to 'bed down'.

The smaller number of united councils may help us to get on top of this situation. It will be easier for us to deal with the 27 of them than with the 250 or more counties, boroughs, and cities.

I do not see any great increase in funding for geological investigations coming: we must make the best use of the staff and of the information which we now have.

K G Lawn (Paparua County Council, Christchurch)

I agree with the last speaker that as united councils are set up it may be found that it is best for them to liaise with the government agencies. The individual counties, boroughs and cities may then be prompted by the united council to engage geological consultants to carry out investigations in particular areas.

R C M Dunn (Auckland University)

My comments to this question principally relate to the probability of a failure or risk involved versus the consequences.

The first point is that if geotechnical data is to be useful for town planning purposes, then it is vitally important it contain an evaluation of its reliability, or more preferably some probability of failure as well as an estimation of the consequences, which would result. This is because geotechnical information must be put in a some priority order with all the other factors to be taken into account by town planners and councillors.

We were reminded this morning by Dr Lensen that we can expect a magnitude 7 earthquake in New Zealand every 10 years. This type of information clearly indicates the probability involved. As a traffic engineer and part-time planner, I can compare this with the expectation that within the same period about 5000 persons will be killed on our roads, approximately half of these on urban roads. Maybe this puts a magnitude 7 earthquake in perspective?

Several speakers such as Professor Williams and Dr Gibb have discussed flooding and sea erosion. These factors are often considered under the title of water and water resources which is another important set of factors to be taken into account in town planning decision making. For instance, in the Auckland region, problems in this area often weigh more heavily than most others.

Cr Forde's question to Mrs Lawrence this morning on the adequacy of urban capability surveys strikes at the theme of my comments. Planners and councillors are required to make decisions on the use of land for given purposes. In doing so, they need to weigh up the numerous counterbalancing factors. Hence, it is vitally important that they be informed with geotechnical information which contains evaluations of its reliability or more preferably, the estimated probability of failure and resulting consequences.

Chairman

The fifth question is:

"Can a local body take action to ensure that land which is being mined, or is going to be mined, will be left in a condition fit for urban use after the mining has been completed?"

J H Lawrence (MWD, Water and Soil, Head Office)

The difficulty here is that in many situations those who conduct the mining operations are not still around when the restoration stage is reached. Major mining operations run for several decades and it is not just the individuals who disappear from the scene, companies go out of existence.

L S Hale (Hauraki Catchment Board)

In Te Aroha we have a tailings heap - about 100,000 cubic yards of materials - perched 1000 ft or so up Mt Te Aroha. The old Tui Mine from which these tailings come was reactivated in the early 1960's.

At that time the Catchment Board had difficulty in obtaining all the conditions that it considered desirable. In addition to this, the policing of those conditions that were obtained appears to have been inadequate.

The Te Aroha Borough Council didn't object to the mining because they welcomed the commercial activity which the mining brought to the Borough.

The miners placed about 100,000 cubic yards of tailings in a stream bed - which was one of the water supply streams for

Te Aroha. They built up a dam in front of it of rather more solid material.

After a time the people who controlled the mine changed and then it closed down - owing a lot of money.

The tailings were there and the Catchment Board felt it had to do something about it. So they diverted surface storm water around the heap and put a filter over the front face of the dam. They also send a man up every week (and after every storm) to check the thing.

So far the Catchment Board has spent over $30,000 on it. The Mines Dept recently offered a grant of $25,000 as a "first and final" payment. But the Catchment Board can see its costs rising to $50,000 - and the heap is still there, posing a threat to an urban community of 3,000 people.

The water which comes out of that stream is so full of heavy metals and other toxic substances that when they sprayed it on the bowling greens the greens died. Te Aroha used to get some of its drinking water from that stream : they now have to get it from other sources.

There is some talk now of the Mine being reopened.

I suggest that if the State carries on giving mining rights and financial assistance to miners it must also give a guarantee to the community that in the event of the miners failing to maintain and leave the site in a satisfactory condition the State will accept responsibility.

Panel Response (Horsley, Lawyer, Massey University)

The Mining Act is quite separate from the Town and Country Planning Act. It is not possible to use town planning controls under the Planning Act to control a mining operation which is licensed under the Mining Act.

However I believe that the Mines Dept. has given the go-ahead to some small mines "subject to town planning consent". So in those cases the two acts have been linked together, - but if this link is not made at the time of the granting of the mining licence the two acts cannot be linked.

This has been done for some very small mining operations. Big operations are a different thing altogether.

D N Jennings (MWD, Head Office)

I have been involved, together with Mines Division, in the rehabilitation of some open-cast mines. Several areas have been rehabilitated so that their agricultural productivity is at least as high as it was before the mining - in some case quite a bit higher. This is of course the rural rather than the urban scene, so is outside the scope of this symposium - but in fairness this work should be noted.

Subsidence of urban areas as a result of underground working is of course a different matter entirely.

Chairman

Our last question is

"Does (or should) any liability for compensation exist when land which was zoned for urban use is re-zoned because it is found to be exposed to an unacceptably high level of risk from a natural hazard?"

Panel Response (Horsley, Lawyer, Massey University)

Strictly speaking compensation cannot be claimed under either the Local Government Act (Section 641) or the Town and Country Planning Act (Section 126).

However, there are "existing use" rights under the Town and Country Planning Act, so that if land is re-zoned a person carrying out a certain activity has the right to carry on that activity. This does not however cover the real issue raised in this question.

A council does have the option of designating land for a specific public purpose- recreation for example. However, this means that the council must actually buy the land.

I think the answer to the question posed - where land which was zoned "urban" is rezoned "rural" - is that the owner who paid an "urban" price for it or is expecting to sell at "urban" prices, is just out of luck.

There will of course be situations where land becomes unsuitable for urban use because of actions taken by the council. I am thinking of a council which adopts a stormwater management plan, and in so doing puts an area which was zoned for urban development at risk from flooding. Compensation would usually be payable in that situation but where the rezoning comes from a better appreciation of the natural hazards compensation will not be payable.

Chairman

Thank you. I am now going to ask Mr Forde who is chairman of the Planning Committee of the Palmerston North City Council to give us a short summary of points he has noted in this Symposium.

B J Forde

I propose to speak briefly to nine points - which I am selecting from a much larger number which I could speak on.

i) The technical reviews (which we heard yesterday) of the different types of physical hazard were very valuable. If you don't understand a hazard it is very difficult to plan to avoid it. Clearly there are people who can teach us a lot about them.

ii) We have been thinking of hazards at very different scales - from the effects of the Mt St Helens eruption down to the appraisal of an individual section. This is the range which geotechnical experts and planners have to cover.

iii) Elected councillors cannot indulge in single factor planning. Some of my colleagues tell me that one should plan entirely on the basis of protecting agricultural land. But councillors must consider that as well as the nine physical hazards - and a number of other factors. The urban capability survey technique described this morning is on the right lines with its "inventory" of separate factors and its collective "interpretation" of these factors.

iv) Citizens are entitled to expect competent decision-making by its elected representatives. They are entitled to expect that local body officers are competent and that they know when to recommend engagement of specialist consultants. In other words the fundamental duty of care must be exercised by all concerned - local body officers, consultants and the elected decision-makers.

v) I see a need for the education of local body officers, planners and elected groups of people - in the basic facts and concepts behind these geotechnical hazards. The elected representatives would need to be addressed in very simple, non technical terms.

vi) I was very impressed with what Professor Williams is doing in the Upper Waitemata to get public involvement, and the involvement of interest groups, in the planning process. This is an important stage - between the scientific studies of hazards and the zoning/planning.

Dr Gibb has also succeeded in getting public involvement in his coastal hazard work.

vii) Here in Palmerston North we have made one strong move to counteract the tendency for decision makers to become isolated from the community. We have about 60 non-councillors on advisory committees. There is a district planning advisory committee (which reports to the Planning Committee which I chair). It is chaired by an architect - there is a surveyor on it, two consulting engineers and various other people from the private sector. (We have advisory committees for other things as well - such as 'economic development' and 'social planning'.)

These advisory committees increase public involvement in the decision making process.

viii) One of the realities of local body existence is that decisions have to be made. If a scheme plan has come in for approval then, within a reasonable time, approval will have to be given or it will have to be refused, or conditions will have to be laid down. The same applies to notified departures, objections to district schemes and so on.

It is all very well to set out high-sounding principles in a district scheme. The crunch comes when an applicant wants to do something else and you are faced with consultants reports, speeches from lawyers and so on. It is at this stage that councillors and local body officers need to have a real grasp of the scientific background to these different hazards - so that they can distinguish between those arguments which have the real weight of facts and probabilities behind them, and the scare stories.

ix) I hope that the information and the results of the discussions at this symposium will be conveyed to our colleagues - both professional and lay - around the land in a way that they can understand so that planning decisions may be made in ways which

- recognise the scientific background to each situation
- are fair and reasonable
- will stand the scrutiny of law.

Thank you.

Manawatu Evening Standard

Ministry of Works and Development

(Ray Pigney/NZ Newspapers)

EDITOR'S CONCLUSIONS

(J G Hawley)

Several times during discussions at this Symposium the request was made that a blunt summary for laymen - particularly for city councillors - be written. This is an attempt to answer that request : the opinions expressed are, as the title implies, those of the editor and do not necessarily reflect those of any particular contributors to the Symposium.

Legal responsibility (of local authorities consultants and other parties) was the topic which dominated the discussion at this Symposium : geotechnical issues received comparatively little attention.

It seems likely that "duty of care" is the fundamental legal principle which would be applied by the highest courts of appeal in most cases where damage had arisen from natural hazards. It seems that this principle does not come through clearly enough in the Local Government or Town and Country Planning legislation, - or in local body bylaws and approval processes.

Looked at from another angle, current laws relating to urban development do not reflect with sufficient clarity the fundamental truth that in all analyses of, or encounters with, natural phenomena, professional people can not guarantee anything - they can express professional opinions only. This is as true of earth scientists as it is of medical practitioners.*

It follows from the above that local bodies who commission, receive, and act in accordance with, professional opinion can not guarantee that any area is suitable for urban development - in the sense of being completely free from all risk of being adversely affected by natural hazards.

Against this background of probabilities rather than certainties the responsibility of a local body can not reasonably be held to extend beyond carrying out (or commissioning) investigations by appropriately qualified people and then acting in accordance with the results of those investigations.

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*The analogy with medical practitioners is a good one. A doctor who is responsible for the well being of the patients in his hospital is not necessarily liable or culpable when one of them dies.

It follows that neither a local body nor its professional advisers are <u>necessarily</u> culpable when events prove that an area or site which was held to be "suitable" for urban development is in fact "unsuitable". In such situations the question which should be asked is whether any party is guilty of <u>negligence</u> i.e. failed to exercise their "duty of care". For example:

(a) did the local body fail to commission appropriate professional geotechnical investigations?

and/or

(b) did the geotechnical investigators fail to carry out such investigations as would be regarded by their peers as normal in such circumstances?

and/or

(c) did the local body and/or the planners fail to act in accordance with the results of the geotechnical investigations?

The law should be amended so that the responsibilities of local bodies and of their professional advisers are more clearly defined to be "duties of care".

Because in the natural environment one can speak only of probabilities rather than certainties, failures will occur from time to time in spite of a reasonable level of care having been exercised by all concerned. It is proper and reasonable that such unforseeable situations should be covered by insurance. Conversely, insurance should not be called upon to cover damage resulting from the failure of local bodies and/or their advisers to exercise their reasonable "duties of care".

At least nine physical hazards must be considered at five distinct stages of urban development. However the implied matrix of forty-five investigations reduces in any particular situation to a very few key ones.

It would be helpful if guidelines were available indicating what are reasonable levels of "care" - as regards both the local body and its advisers. Such guidelines would be helpful not only for the commissioning of surveys but also as references when failures had occurred.

It has been shown in this Symposium that it is now possible for guidelines to be established as to what level of "care" it is reasonable to expect of the different parties involved at each stage of urban development. "Urban capability surveys" have been shown to be practical, useful, and of low cost in several different geological settings throughout the country. They comprise an inventory of physical hazards (and a derived urban capability class, subclass and unit) displayed on a map (at say 1:10,000 to 1:25,000 scale) together with explanatory notes.

Such urban capability surveys when well executed provide sufficiently detailed geotechnical information for preparation of regional and district schemes. For particular areas they may however indicate that some special professional investigations should be done for some particular hazards, - such as flood water management or landslip.

Procedures for conducting such surveys may be learnt from studies of what has been done in areas surveyed to date. Guidelines for conducting such surveys are currently being prepared by the Ministry of Works and Development for the National Water and Soil Conservation Organisation.

The balance of professional expertise required for conducting urban capability surveys lies with earth scientists (principally with engineering geologists and soil scientists) rather than with civil engineers or surveyors.

The information shown on urban capability surveys should enable those areas to be identified which require soil sampling and testing to be carried out (by civil engineers) at the subsequent Concept Plan and Scheme Plan stages of development.

Completion of one or more of the three statement "formats" drafted by the Territorial Local Bodies' Association (for any one of three stages) may be called for by the local body for areas over which they have reason to be concerned. These statements include the phrase "in my professional opinion, not to be construed as a guarantee". These words reflect the true situation faced by those giving such advice - the nature of the ground and its response to being developed can be described only in terms of probabilities not in terms of certainty or guarantee.

Considering in summary fashion each of the natural hazards in turn.

a) The Volcanic hazard

The risks of death or injury being suffered by citizens as a result of volcanic activity (even in places such as Rotorua, Taupo, Stratford and Auckland), is one or more orders of magnitude lower than that to which they are exposed as a result of motoring hazards when they travel in cars. Volcanic hazard must therefore be deleted from the list of hazards to be considered, in all areas except those (such as Whakarewarewa and White Island) which are currently more or less continuously active.

b) Earth shaking and deformation

Even areas straddling the Wellington fault (both in Wellington City and in the Hutt Valley) have been urbanised, and the risks associated with living near this fault-line are accepted by many geologists and other professional earth scientists. Such areas can not therefore be excluded at the regional or district scheme stages.

However it has been shown (Mr Lensen's paper) that at the scheme plan and building permit stages special design requirements may be established and that these requirements are not such as are likely to make the development of such areas uneconomic. Adherence to such requirements is likely to reduce very substantially distress experienced when movement occurs on a fault.

c) Mining

Obstructing access to mineral resources (particularly gravels) has been a major source of conflict between mining and urban development overseas. In some parts of New Zealand urban development would obstruct future open cast coal mining.

The effects of extraction of water from below urban areas - a major concern to Venetian authorities - do not look likely to be significant in New Zealand: the discovery of a major oil or natural gas field below an urban area seems unlikely in this country.

The effects of extracting minerals (such as coal or gold) from below urban areas by tunnelling are sufficiently well understood for conflict to be avoided by careful planning and control.

d) Settlement

(1) of natural ground. Large areas of compressible soils (e.g. peats, soft alluvial muds) are easily recognisable at the regional scheme planning stage. Some such areas may be developed in spite of the difficulty. Different treatments are appropriate to different soils/ situations, but could include draining of the ground (preferably well in advance of construction) piling through the soft materials, and placing a surcharge (weight of fill) over the area to promote consolidation. Even when one or more of these is done there would still be much wisdom in choosing flexible construction materials - e.g. weatherboards rather than brick veneer. i.e. exercising some control at the "building permit" stage.

Soils with a significant volcanic content may be found over much of the North Island. Many of these exhibit "sensitivity", i.e. they lose strength very markedly if distorted, and then (commonly) lose volume by expelling water.

In all of these "settlement of natural ground" situations soil scientists have the key role to play in identifying the problem while civil engineers have the key role to play in finding ways to overcome it.

(2) of man-made ground. Properly engineered earth fills do not present problems (of either settlement or landslip). Rubbish tips do however present problems because it is often not possible (economic) to achieve high densities and the material dumped almost invariably includes large volumes of organic material which is both weak and compressible. Unless a civil engineering solution can be found old rubbish dumps are better redeveloped as parks or playing fields than as housing sites.

The most difficult areas of compressible man-made ground to identify are the old "handyman's tips". They are generally small and being unrelated to the geological setting are often not susceptible to being located by earth scientists. Civil engineers may be engaged to devise methods for overcoming such problems as they are encountered.

e) Landslides

Landslides have occurred only very rarely in properly engineered earth fills: handyman's fills are notoriously unstable. The remainder of this section is about the stability of slopes in natural ground.

There is a growing awareness that the civil engineering procedures (developed for recompacted earth structures such as dams, roads, airfields, embankments etc.) have little relevance to the prediction of the stability of slopes in natural ground. Weak layers within the soil are commonly too thin to be sampled using conventional borehole techniques and the scatter of values obtained from laboratory tests is commonly more than wide enough to cover the range from "should have failed" to "OK".

Stability assessments are therefore better made by earth scientists (particularly engineering geologists) than by engineers. The engineer has the key role to play in devising ways to overcome the problems detected by the earth scientists.

It is usually possible to make an area of sloping ground less susceptible to landslip after it is urbanised than it was before. This is because the "umbrella effect" of the houses themselves should cause less water to reach the soil during storms. However if stormwater is not collected successfully from all impermeable surfaces (roofs, driveways etc.) and lead to safe drainage systems, the effect of the "umbrellas" is to concentrate the stormwater: slopes in even the strongest soils can be placed at risk where this occurs.

f) Soil dispersion

It has been known for many years that soil dispersion is one of the fundamental processes responsible for tunnel gully formation. (The tunnels-tomos-which form in some volcanic soils are not however the result of dispersion.)

Tunnel gully erosion occurs over large areas of New Zealand's pastoral hill country (see Figs. on pages 294 and 295). Only on the Port Hills near Christchurch however has a significant amount of urban development occurred on such areas.

It is now known that where soil is to be reworked - such as in the backfilling of trenches, road construction etc. - dispersion may be inhibited, by mixing in small quantities of lime or phosphoric acid.

For the remainder of the land (the unreworked land) any steps which can be taken to prevent the soil from drying out to the point of cracking will help to control this serious form of slope instability.

g) Shrinkage and swelling

In a few areas in NZ (notably Manukau City) urban development has taken place on soils (clays) with high shrink/swell characteristics. In such areas trees should not be planted near houses or other structures (driveways etc.) which are susceptible to ground movement. Trees with high growth rates are generally those which pump water out of the ground fastest and they are therefore the ones most to be avoided. Some trees from arid areas (e.g. eucalypts) continue to pump water at appreciable rates after the soil has dried to the point where other trees have virtually stopped: silver dollar gums are a common example.

h) Flooding

Areas of flat land are to be found adjacent to the lower reaches of most rivers. These are the "geomorphic flood plains". The soils on them (alluvium) have accumulated over thousands of years as each flood has receded.

It must be assumed that such plains will be flooded again, unless ample stopbanks have been built, - or the plains have been substantially uplifted tectonically, i.e. many ancient alluvial plains are now well above flood levels.

Urban development always tends to make stream and river flows more 'peaky' because water runs off roofs and sealed driveways etc more rapidly than it does off pasture, scrub or forest. (Fortunately this effect becomes less marked the more extremely intense the rainstorms are: even forests, once saturated pass very intense rainfall to the streams and rivers without delay.)

Many urban areas in NZ have been developed without proper "duty of care" being exercised by local authorities with regard to the safe handling of the increased stream flows.

It has been shown that with careful planning, streams and their precincts can usually be maintained as pleasant reserve/ recreational spaces in urban areas rather than being allowed to become unsightly, dangerous, drains.

It is usually possible to design developments so that in the more extreme events it is the roadways rather than the houses themselves which become the floodways. The flooding of houses during the most extreme events may however be unavoidable, and this is a very proper time for insurance schemes to be called upon.

i) Coastal hazards

The concept of a coastal hazard zone put forward by Mr Gibb is sound, simple and practical - both technically and legally. The validity of the positioning of the inland boundary of the zone will depend in each and every situation on the quality of the investigations undertaken.

Opposition to the concept will (has) come from owners of land within coastal hazard zones who see their property values reduced. However, as Mr Horsley has emphasised, it is the hazard itself rather than the zoning which has really reduced the value of the property - or rather, the property never did really have the value the owners thought it had.

There would seem to be no reason why the delineation of coastal hazard zones could not be commissioned by all counties with coastal areas. (However there may be a scarcity of people able to do the job well.) Such hazard zones would be incorporated in any urban capability surveys done of adjacent areas.

APPENDIX 1

A LEGISLATIVE AND CASE LAW UPDATE

P HORSLEY
(Massey University)

The 1979 Local Government Amendment Act that gave rise to S.641 was subject to intense criticism from local authorities who were responsible for such areas as Orewa, Wainui Beach, and the flood plains in Taieri, Rangitaiki and Hauraki Plains.

The 1979 Act was repeated and replaced, by the 1981 L G Amdt Act, and the emphasis was altered from the protection of land to the protection of the buildings on the land.

Section 641 thus became much more flexible. Councils are now obliged to refuse building permits where:

1) the land is not suitable for the building (S.641(2)(a);
2) the land is subject to slipping or consequential flooding (S.641(2)(b));
3) residential buildings are likely to be subject to damage from flooding (S.641 (2)(c)); and
4) the erection of the building is likely to exacerbate any existing problem (S.641(2)(d)).

Provision is made for the issue of a permit for a building on unstable land if the building is relocatable, in which event the council and its employees shall not be under any civil liability on the grounds that they knew there was a possibility of damage arising from erosion, subsidence or slippage. There must, however, be a note on the Certificate of Title if protection from civil liability is to apply (S.641A).

Useful comments on the 1979 and 1981 Amendments can be found in the 1981 New Zealand Law Journal at p395, and the 1983 NZLJ at p73.

The Planning Tribunal has been very active in examining the law and assessing some of the current techniques for hazard control.

The passage of the L G Amdt Act (No. 2) 1981 (which came into force on 23 October 1981) had an immediate impact on Judge Skelton when his Planning Tribunal looked at the designation of flood prone land for a new automatic telephone exchange in Karetai v MWD 8 NZTPA* 328 (Nov 1981). The construction of the proposed building would be such that it would be immune from any foreseeable flooding.

The Tribunal noted that the new S.641(2)(b) made the safety of buildings the main concern rather than the protection of the land. Because the building would be immune from flooding, the land was held to be suitable for the proposed use.

It was also stated that under the new provision, the only inundation to be considered was that which might arise from erosion subsidence or slippage. The Judge noted that his earlier decision in Southland County v Southland County 8 NZTPA 61 (Feb 1981) was based on the old S.641 and had to be read and construed accordingly.

Two other decisions of the Planning Tribunal were based on the repealed S.641 and have to be regarded with caution particularly in light of the High Court decision of Bosworth v Planning Tribunal, Bosworth v Rodney County.

In the first Alpe and Semini v Rodney County 8NZTPA 257 (July 1981), Judge Turner's Tribunal considered the County's action in refusing building permits for dwelling houses fronting Orewa Beach, because the land was subject to erosion, subsidence, slippage and inundation by the sea.

The Tribunal looked at the expression "subject to erosion" in S.641 and held that it meant "exposed or open to erosion". Because no provision had been made - or could be made for the protection of the land from erosion, the Tribunal held that the Council was bound to refuse the building permits under S.641(2)(c).

* NZ Town Planning Appeals (Butterworths)

This decision has effectively been reversed by the High Court decision of Chilwell J in the Bosworth cases (delivered Feb. 1983 and noted at a NZTPA 32). The Judge held that it was not open for the Tribunal to find that the appellants land which had not as yet suffered any erosion was 'subject to erosion' for the purposes of S.641(2)(b). He also noted that the 1981 Amdt specifically requires regard to be had to the likelihood of future erosion and that the original form as enacted in 1979 should be construed as confined to the past or present incidence of erosion. He also defined the meaning of the word "land" in S.641(2)(b).

In Mathew v Auckland City 8 NZTPA 264 (Aug 1981), Judge Skelton's Tribunal looked at land that was liable to slippage. After obtaining an Engineer's Certificate on the stability of the site, the appellants purchased a cliff top section and applied for a building permit. The Council refused it under S.641(2) on the grounds that the site was inherently unstable and that the rest of the land could not be adequately protected against slippage.

Numerous expert witnesses were called and on the basis of their evidence the Tribunal found that the upper layers of the site were subject to a degree of slippage, but this could be acceptably controlled by certain physical measures, particularly by a specific storm water drainage system.

The Tribunal looked at the meaning of the word "land" and held that it included not only the land on which the proposed building will be placed but also the land which will be used for purposes directly associated with the servicing and the use and enjoyment of that building. Accordingly the word "land" meant the whole of the particular site.

The decision of Chilwell J in Bosworth's case restricts this wide definition. He has stated that it means "the area of land on which it is proposed to alter or erect the building, the area enclosed by the perimeters of the proposed building work".

This more restrictive definition is in line with the intent of the 1981 Amdt, to ensure more flexibility and less onerous requirements in the field of hazard control.

Another decision of Judge Skelton's Tribunal that predated the 1981 Amdt is still good law. In Trustees Executor and Agency Co Ltd v Timaru City 8 NZTPA 257 (Aug 1981) the Tribunal looked at the legality and appropriateness of an erosion zone adjacent to the Washdyke lagoon that would protect land against marine erosion and prevent residential or industrial development. The affected landowners claimed that the zone in effect created a reserve and that the Council's objective could be achieved by way of designation. The Tribunal had no difficulty in finding that the land was seriously at risk from marine erosion and flooding and that the zone was both appropriate and legal given the powers of Clause 8 and S.4(3) of the TCP Act 1977. It also said that the decision of Judge Treadwell's Tribunal in MWD v Taranaki County was no longer applicable given that it was decided on the basis of the more restrictive powers of the 1953 TCP Act.

In Troughton v Mt Maunganui Borough 8 NZTPA 388 (April 1982) Judge Sheppard's Tribunal considered the hazard line technique when it looked at a coastal foredune area that was vulnerable to erosion from both wind and water. The Council proposed to protect the ecologically sensitive features by designating the area "proposed foreshore reserve" with an underlying zoning of Recreation that would enable the land to be used for passive recreation. The landowners objected to the measures.

The Tribunal found that it was appropriate to apply a zoning that would preclude building on the area both for ecological reasons and because of the risk of damage to buildings from flood or erosion. It also considered that the effect of the zoning on possible compensation, should the Council acquire the land, should not be taken into account.

The Tribunal also supported the Council's action in using the Public Works Act 1981 to designate the area as an essential public work required for soil conservation purposes, and said that it was inappropriate for the Council to refuse building permits under S.641 because it would be too restrictive.

Judge Sheppard's Tribunal again looked at appropriate controls for highly sensitive, vulnerable coastal dunes in Clifford v Christchurch City 9 NZTPA 40 (Oct 1982). Residential development had taken place on half the sections of a coastal subdivision. The Council's proposed zone permitted residential development as of right, rather than as a conditional use, in reliance on the building controls available under S.641. Landowners appealed against the controls while the North Canterbury Catchment Board proposed that parts of the area should be designated for coastal protection works and/or recreation purposes.

The Tribunal held that a designation is inappropriate where no public authority will accept financial responsibility for the works. It also rejected the recreation zone suggested by the Catchment Board because it was unduly restrictive and onerous on existing owners, especially as there were parts of the area on which building would be permitted subject to strict controls.

The Tribunal felt that conditional use controls for building were suitable for such areas. While predominant use status for dwellings would create the illusory impression that such uses were appropriate throughout the area, the procedural burden of a conditional use application would highlight the hazard and enable neighbours and the Catchment Board to participate in the planning process. If controls were exercised solely through S.641 and its following sections, such an opportunity would not necessarily be available, the Tribunal concluded.

Some local authorities have expressed concern about their responsibility for district scheme hazard controls causing a devaluation of property values for the affected properties, or a difficulty of resale. It should be stressed that the controls, such as a hazard line, do not cause the devaluation or the difficulty, but rather the physical hazard itself.

Compensation can only be awarded in terms of the TCP Act (there is no similar provision under the Local Government Act so no liability arises in respect of S.641). Section 126(5) and (6) set out the compensation provisions. Generally speaking compensation does not arise from the provisions of a district scheme (S126(5)) unless the requirements of S.126(6) can be met.

Under this section the owner or occupier must show either

(a) that the zoning or designation deprives him or her of the right to continue to use land for existing purposes (this subsection has to be read in conjunction with the existing use provisions under Ss 90 and 91 of the Act), or

(b) that the scheme deprives the person of the right to change to another use (e.g. residential to industrial, rural to residential, low to high density of the site) and the owner can prove:

- the proposed use would not detract from the amenities
- nor cause an extension of services which would not be economic
- nor involve uneconomic subdivision of lots of 4 ha
- nor involve uneconomic ribbon development along a highway
- and that the site is physically suitable for the proposed use.

A hazard line, for example, will impose obvious limitations on property owners but existing use rights can remain (cancelling out the first area of claim under S.126(6)) while any change of use would be inappropriate because of the physical unsuitability of the area (cancelling out the second area as well).

In assessing the likelihood of possible compensation claims, great care will obviously have to be taken especially in respect of the nature of the control and the physical problems a local authority has to contend with.

However, the existing use provisions of the TCP Act hold the key to effective control of uses and buildings that do not conform with district scheme controls. The hazard line technique, for example, would usually have the effect of restricting development or redevelopment. By being included in a district scheme, such a hazard line automatically gives existing land-owners minimum statutory rights for the reconstruction of buildings to a limited extent (S.91) and a continuation of existing uses (S.90).

The rationale for the existing use provisions is the control of uses and buildings that do not conform with new district scheme provisions. The two sections (Ss 90, 91) are inserted principally for the benefit of the owners of such land and buildings, and given the limitations set out in the sections, they can continue indefinitely. The Council can, if it wishes, set out more liberal provisions in its district scheme that go beyond the minimum statutory requirements.

An excellent discussion of existing use provisions is set out in an article by Keith Berman in the Legal Research Foundation Booklet entitled 'The Town Planning Act Seminar' May 1978.

Part of his discussion has to be read subject to the 1980 Amendment to the TCP Act that changed S.90(1)(a).

The booklet is available from the Foundation C/- Auckland University Law Faculty.

APPENDIX 2

LIST OF REGISTRANTS

ADE, Mr R G	Tauranga County Council
ANDERSON, Mr D R	Johnston, Hatfield, Anderson & Partners, Dunedin
BARKER, Mr P R	Soil Bureau, Lower Hutt
BARNES, Mr P M	Wanganui City Council
BELL, Mr D H	Geology Dept, Univ of Canterbury
BERRYMAN, Mr K R	NZ Geological Survey, Lower Hutt
BHULA, Mr G	Wellington City Corporation
BICKERS, Mr A N	Palmerston North City Corporation
BIRD, Mr G	Earth Science Dept, Univ of Waikato
BLAKELEY, Mr J P	Applied Research Office, Univ of Auckland
BORLASE, Mr O M	Otago Catchment Board, Dunedin
BREEN, Mr A R	Housing Corporation, Christchurch
BROWN, Mr A S	Wellington
BROWN, Mr L J	NZ Geological Survey, Lower Hutt
BROWN, Mr R J	Rangitikei-Wanganui Catchment Board
CHAMBERS, Ms J	Brickell, Moss Rankine & Hill, Lower Hutt
CLAPPERTON, Mr J N	Frazer, Thomas Gunman Shaw & Partners, Papatoetoe
COLLINS, Mr C	NWASCO, Wellington
COSTELLO, Mr T N	Cook, Muldowney Costello, Whangarei
CROZIER, Dr M J	Dept of Geography, Victoria University
DAVIDSON, Mr C C	Davidson, Ayson & Associates, Blenheim
DAVIS, Mr C M	Palmerston North City Corporation
DEPLEDGE, Mr D	State Coal Mines, Huntly
DUCK, Mr C W	Nelson Catchment Board
DUNN, Mr M J	MWD, Hamilton
DUNN, Mr R C M	University of Auckland, School of Engineering
EDGAR, Mr B D	Waiapu County Council, Te Puia Springs
ELLIOTT, Mr R D R	Cook County Council, Gisborne
ELLIS, Mr P W	Murray North Partners, Auckland
FORDE, Dr B	Palmerston North City Corporation
FOWKE, Mr N	NZ Geological Survey, Huntly
FRENCH, Mr T	Palmerston North City Corporation
GANDAR, Mr J S	MWD, Wellington
GIBB, Dr J G	NWASCO, Wellington
GRIERSON, Mr I M	Harrison & Grierson & Partners, Auckland
GRIGGS, Mr J	Northland Catchment Commission, Whangarei
GULLIVER, Mr C P	Tonkin & Taylor, Auckland
HALE, Mr L S	Hauraki Catchment Board, Te Aroha

HANCOCK, Mr G	P M Hancock & Associates, Hamilton
HANCOCK, Mr P M	P M Hancock & Associates, Hamilton
HANCOX, Mr G T	NZ Geological Survey, Lower Hutt
HARLAND, Mr J	MWD, Wellington
HAVILL, Mr S F	Auckland Harbour Board
HAWLEY, Dr J G	Aokautere Science Centre
HAYMAN, Mr M J	Manukau City Council
HELLBERG, Mr M	Earthquake & War Damage Commission
HIGH, Mr R	MWD, Auckland
HODGSON, Mr R A	E R Garden & Partners
HOLMES, Mr R G	North Canterbury Catchment Board
HORSLEY, Mr P	Lawyer, Massey University
HUTCHINSON, Mr G K	Westland Catchment Board
JACK, Mr N	Palmerston North City Corporation
JACKSON, Mr D A	Spencer Holmes Miller & Jackson, Wellington
JEFFERY, Mr A C	Thames-Coromandel District Council, Thames
JENNINGS, Mr D N	MWD, Wellington
JESSEN, Mr M R	Aokautere Science Centre
JONES, Mr J A	Wellington Regional Council
JONES, Mr M E	Murray North Partners, Whangarei
KANANGHINIS, Mr N	Upper Hutt City Council
KAYES, Mr T J	Tonkin & Taylor, Wellington
KINNEAR, Mr S R	Hutt County Council
KOORNEEF, Mr J	TSE Group Consultants, Wellington
KULARATNE, Mr PWD	Hutt County Council
LAWN, Mr K G	Paparua County Council, Christchurch
LAWRENCE, Mrs J H	NWASCO, Wellington
LENSEN, Mr G J	NZ Geological Survey, Lower Hutt
LUXFORD, Mr N S	Babbage Partners Ltd, Auckland
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PERSON, Mr E V	Napier City Council
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