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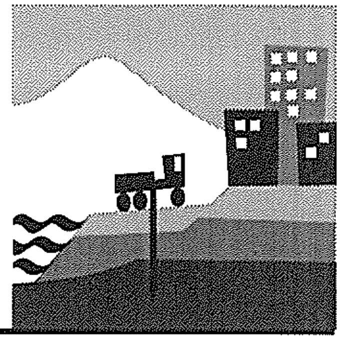

Proceedings of Technical Groups

VOLUME 22, ISSUE 1(G)

The New Zealand Geomechanics Society

Proceedings of the Symposium on

GEOTECHNICAL ISSUES IN LAND DEVELOPMENT

HAMILTON

FEBRUARY 1996

GEOTECHNICAL ISSUES IN LAND DEVELOPMENT

UNIVERSITY OF WAIKATO 16 - 18 FEBRUARY 1996

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IPENZ PROCEEDINGS OF TECHNICAL GROUPS

The IPENZ Proceedings of Technical Groups covers technical material presented to the various technical groups of the Institution and published by them.

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NZ Society of Coastal Sciences and Engineering

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PROCEEDINGS OF THE SYMPOSIUM ON:

GEOTECHNICAL ISSUES IN LAND DEVELOPMENT

ABSTRACT

This publication presents the proceedings of a symposium on "Geotechnical Issues in Land Development" held in Hamilton in February 1996. Authors presented papers on selected topics under the general headings of: Legal and Planning Framework, Planning and Development Guidelines, Regional Hazard Identification and Assessment, Development on Marginal Land, and Accreditation of Geotechnical Engineers and Engineering Geologists.

KEY WORDS

Geotechnical, slope stability, hazards

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FOREWORD

This was the eleventh symposium held by the New Zealand Geomechanics Society. The theme of the symposium was Geotechnical Issues in Land Development. It was held at The University of Waikato, 16 - 18 February 1996. The symposium followed a series of Symposia held on an approximately three year cycle.

1994	Geotechnical Aspects of Waste Management	Wellington
1990	Groundwater and Seepage	Auckland
1986	Pile Foundations for Engineering Structures	Hamilton
1983	Engineering for Dams and Canals	Alexandra
1981	Geomechanics in Urban Planning	Palmerston North
1977	Tunnelling in New Zealand	Hamilton
1974	Stability of Slopes in Natural Ground	Nelson
1974	Lateral Earth Pressures and Retaining Wall Design (Workshop)	Wellington
1972	Using Geomechanics in Foundation Engineering	Wanganui
1969	N Z Practices in Site Investigation for Building Foundations	Christchurch

The subject of this Symposium was selected by the Management Committee as an area of current interest, and has special relevance following the introduction of the Resource Management Act and the Building Act. A particular focus of the symposium was the presentation of draft Planning and Development Guidelines. Subsequently authors were invited to prepare papers in various topic areas.

ORGANISING COMMITTEE

February 1996

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☒ Papers and Discussion Sessions not available at time of printing.
These will be published in "Geomechanics News".

Geotechnical Issues in Land Development Key Note Address

D K Taylor
Consulting Engineer, Auckland, New Zealand

SYNOPSIS: All land development raises some geotechnical issues. Responsibility for seeing that these issues are addressed rests with Local and Territorial Authorities in terms of the Resource Management Act and the Building Act.

The N.Z. Geomechanics Society has, over many years taken, and continues to take, a leading role in establishing the standards by which geotechnical issues are addressed. However, available knowledge and technology have been applied erratically for reasons which are political, legal, and commercial in origin. Recent developments in administration of the Resource Management and Building Acts have increased awareness of Geotechnologists to their responsibility and vulnerability.

This address reviews the range of geotechnical services and existing standards and the extent to which they are applied, and suggests how important it is that Geotechnologists, collectively, establish and adhere to more coherent and definitive standards of professional care.

1. INTRODUCTION

The fact that the N.Z. Geomechanics Society is convening this symposium and working to produce guidelines for geotechnical practice in land development must mean that the Society is concerned about present practice and is prepared to go to some trouble to improve it.

That could be a tall order for land development is a wide topic, even from a geotechnician's point of view.

What is involved?

We could include the processes of:

- Assessment of existing land use capability
- Land reshaping
- Reclamation from swamps or waterways
- Strength improvement
- Slope stabilisation.

and consider factors of:

- bearing capacity
- settlement
- slope instability
- internal pressures
- swelling and shrinkage
- erosion (surface and internal)
- Liquefaction
- earthworks control

in the converting to a new purpose, improvement or modification of land for:

- building sites and their local infrastructure
- public infrastructure (transport, water supply, waste disposal, power generation)
- recreational use

- conservation (erosion control, flood protection)

involving:

- geology
- geomorphology
- soil mechanics
- civil engineering

and for the purposes of pastoral, agricultural and horticultural production and soil science.

Pre-occupation of existing codes of practice and of the Society is with Urban Development - that is building sites and their associated infrastructure, but all of the other kinds of development may require geotechnical input to various extents.

2. AVAILABLE TECHNOLOGY

The basic tools for investigation and testing to produce data for analysis have been around for a long time but there is a continual development and refinement, notably with in situ testing and logging of physical properties.

Examination of the reaction of the ground to body stresses and external forces has been enormously facilitated by the development of computers, which has allowed analysis of more intricate theoretical mechanisms in more complex ground conditions.

The danger is that computational sophistication has outstripped the provision of valid physical data, leading to an illusion of mathematical precision in a field more heavily dependant upon judgement than any other branch of engineering.

3. THE INFLUENCE OF SCALE & PURPOSE OF DEVELOPMENT UPON GEOTECHNICAL PRACTICE

All of the available technology can be applied - at a cost.

The ability of the geotechnologist's client to pay and that client's perception of the return for the expenditure will, in the end, determine what techniques the Geotechnologist is able to apply to a specific development.

It is the technologists function to understand and to convey to the client, the advantages, limitations and cost of the techniques available for the client to decide if they are affordable.

Major developments for buildings, infrastructure, or primary production generally employ skilled professional advice, of all sorts, including the application of sophisticated geotechnology and construction supervision, especially where the developer is the end user.

However the situation is not always so simple, and where the development is for immediate "on-sale" the professional adviser may have to fight harder to be accepted upon viable terms. It is the territorial authorities who are responsible for the enforcement, through the Resource Management Act and the Buildings Act, of standards of development, and hence for judging the quality of the professional advice depended upon by the developer - and the Local Authorities themselves.

In urban housing development the case is rather special.

The end users are people of modest financial means, who may have committed all their capital and much of their future earnings without any direct say in the way in which the land is developed, no direct contact with the professional advisers and with very limited capacity, or physical space, to deal with geotechnical failures. These people, and owners of smaller commercial developments depend heavily upon enforcement of standards by Territorial Authorities..

It is those standards, and their enforcement which continue to be a major concern of the N.Z. Geomechanics Society.

4. THE COSTS - AND WHO PAYS

B.G.C. Elwood at the 1981 Symposium on Geomechanics in Urban Planning (Ref. 1), pre-occupied with the special issue of slope failure said:

"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 costs of section development are likely to soar".

"The conflict between planning objectives and engineering consideration will place increased 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".

He hoped that we would produce a further publication to guide urban development.
His remarks can apply to geotechnology in all aspects of land development.

The geotechnologist ventures on dangerous ground in being the arbiter of what level of cost is affordable; but he/she needs to consider where the costs may fall, and needs to be objective about the degree of certainty of the results of geotechnical effort. (See Figure 1).

4.1 Costs

From the broadest community point of view the cost/benefit decisions of using, or not using, land involve complicated considerations of national and local economics, existing land ownership and use, precedents set, and political pressure, as well as the technical questions of feasibility.

From the geotechnical viewpoint costs are involved in:

- Investigation and planning of development
- Construction and precautions
- Remedying failures
- Defending legal attack
- Blame for negligence

Clearly the better the investigation and planning, the better the evaluation of construction and precautionary costs and the less the likelihood of over expenditure or failure and blame.

The first assessment of feasibility is required of Regional Councils and then district and City Councils, in producing regional and district schemes. General information upon land resources and methods of assessment are available from the N.Z. Land Resource Inventory maps (Ref.10) and the NWASCA report of 1987 (Ref. 9).

The NZLRI maps are small scale so some examination of specific areas is necessary. For this purpose geotechnical input comprises mainly geological and geomorphological assessments which might cost in the order of $10,000 per sq km and which are capable of producing a risk-based zoning which could be the basis of "use - don't use" decisions. In practice such decisions are not made by Councils, to my knowledge. Another use of the zoning is an indication of the varying intensities of more detailed investigations required and this is what has happened in practice. Rarely is the content of these investigations specified and this is where geotechnologists have to make a judgement.

Costs of more detailed investigations will depend upon the complexity of the sub-strata and the cost per unit area depends upon the amount of land examined in one commission. If that land is one domestic building site then it could be bearing a cost between $2,000 and $6,000 for an assessment.

If a calculation of slope stability is required the cost will be in the order of $20,000. Even then the geotechnologist needs to be objective about the precision of the result and very careful about the wording of the report.

Those orders of cost, even much more, may be quite acceptable for major industrial, commercial or infrastructural developments, but generally are beyond the means of individual householders.

4.2 WHO PAYS

If the Geotechnologist does not live up to the "accepted standards of the profession" (in the opinion of the Courts advised by "experts") and a landowner suffers a loss as a result, he or she could be judged negligent and will pay - perhaps sharing some of the cost amongst colleagues in an insurance scheme after paying a significant premium.

The spread of monetary costs of damage to private property by land instability is illustrated in Figure 1. In addition there are social costs, including the mental strain which is especially significant to people of modest means, aged or otherwise physically handicapped.

Logically the cost of investigations, engineering and supervision ought to be paid by party expecting to benefit, which is the developer of the land who may be a private individual, a private or public company, or a public body. Some of the cost may be carried indirectly by the community via the Territorial Authority on the basis that there is some community benefit from the development. Current practice is to pass on to the developer the directly identifiable costs of the Authorities surveillance and approval.

5. WHAT ARE THE PRESENT TECHNICAL AND PROFESSIONAL STANDARDS

5.1 Resource Management Act 1991

The Act requires Regional Territorial Councils to consider natural hazards including:

- erosion
- sedimentation
- landslip
- subsidence

where uses such as:

- erection and modification of buildings
- excavation or other disturbance of the land
- deposition of any substance on the land
- primary production

will or may affect adversely human life, property or other aspects of the environment.

All of this applies whether the land is subdivided or not, but it is only when it is subdivided that technical standards are provided.

In Part X Clause 220, conditions of subdivision may include:

- provision be made to *the satisfaction* of the territorial authority for.... protection against erosion, subsidence, slippage, inundation... arising or <u>likely</u> to arise;
- filling and compaction of the land and earthworks be carried out to the *satisfaction of the Territorial Authority.*

5.2 New Zealand Standard: Code of Practice for Urban Land Subdivision: NZS 4404 - 1981

This defines a Soils Engineer as:

"a person who is currently entitled to practice as a registered engineer and has experience in soils engineering *acceptable to the Council*, or such other person as the Council may specifically approve as being competent"

and in Section 203 defines the function for which a *Soils Engineer shall* be appointed
Section 204 sets out the general extent of preliminary site evaluation required.

Sections 205, 206 address planning and design and construction including soil investigation, stability criteria, quality of filling material, compaction standards for fill material. (The only section which provides quantitative standards, drawn from NZS 4431, Ref 4) erosion control, provision for services, temporary drainage, inspection and quality control.

Sections 207 provides for a final report as to the suitability of the *filled ground* and the *original ground.*

NOTE: This document pays considerable attention so *filled ground* and says very little about investigating and testing natural (original) ground, notably less about evaluating the stability of *existing slopes*.

5.3 Slope Stability in Urban Development (DSIR Information Series No. 122 Jan 1977 (Ref. 5)

Provided a general view of slope stability evaluation.

5.4 BRANZ Study Report SR4 1987, Assessment of Slope Stability at Building Sites (Ref. 6)

Sought to establish a uniform approach to the assessment of slope stability.

The respective functions of engineering geologists and geotechnical engineers are discussed without specifying their training and experience in a definitive way.

The report then goes on to describe appropriate means of investigation, testing and analysis, in both soils and rock and concludes with a damning discussion of Factor of Safety:

> "Factors of safety of less then unity are frequently derived from the analysis of stable slopes, despite the rigorous investigation and testing procedures used to define the input data. Conversely, failures have occurred on slopes which, according to the analysis, using input data based on equally rigorous investigation and testing procedures, have yielded factors of safety substantially greater than unity".

So much for mathematical precision!

The report makes repeated reference to the cost of investigations, observing that: "the scope of work may vary according to the ability or willingness of the client to pay for the level of assessment *actually required*: (sic). And "all parties should recognise that any attempt to minimise costs by reducing the scope of investigation may significantly impair the validity of the assessment".

Well, who else but the Geotechnologist can decide "the level of assessment actually required" - and who else should stand up and refuse to compromise by doing less then is "actually required" because the client can't, or won't pay?

5.5 The Building Act 1991 and The Building Regulations (Ref. 7)

The act provides for the vetting and licensing of certifiers *by the Building Authority* (Section 51 and 52) establishment of the independence of their action (Section 56 (6) and (7)) and forbids limitation of their liability. Geotechnologists may well be in the position of Certifiers.

Be warned that "buildings" under the act include:

- dams retaining more than 3m depth and more than 20,000 cubic metres volume of water
- retaining walls retaining more than 1.5 metres depth of ground (lower if there is a surcharge).

Section 36 (1) of the Act states that the Territorial Authority *shall* refuse to grant a building consent where the land on which the building is to take place is subject or likely to be subject to various defined forms of instability *unless the Territorial Authority is satisfied* that - adequate provision has been or will be made to protect the land or building or to restore damage.

Section 36 (2) provides a "let out" for the Territorial Authority in certain circumstances where the owner, in effect, accepts the risk.

Note that the Building Authority judges the capability of Certifiers. The Territorial Authority has to be satisfied with the outcome - either by reliance upon its own staff or upon the opinion of external experts, which implies a value judgement by the Territorial Authority of the qualifications of the experts, and of the extent of their investigations.

Where then are the definitions of the appropriate qualifications and the investigations?

One Territorial Authority has embarked upon an expensive process of formal, transparent examination of the credentials of experts who put themselves forward as being competent. This is an exception for most, if not all, other territorial authorities appear to make informal judgements in private.

As to the appropriate investigations we have to look to the definitions and verification methods of Regulation B1/VM4, (subject of criticism by the NZ Geomechanic Society) which is confined to the foundations of buildings, and provides *performance* requirements and quantitative guidelines for the restricted circumstances of health and safety.

Clause 2.2.1. states that "The ground conditions at the building site shall be investigated to the *extent necessary*:

This does not take us far towards a definition of investigation standards.

By whatever means the acceptability of experts is judged by territorial authorities there needs to be a better set of standards to judge the appropriateness of the investigations when "the scope of the work may vary according to the ability or willingness of the client to pay".

5.6 Are The Standards Being Used?

From the foregoing discussions it is apparent that there are standards, codes, or advisory documents in existence dealing with:

Land Resource Inventory (Ref.10)
Urban Land Subdivision (Ref. 3)

Earthfill for Residential Development (Ref.4)

(also adequate for most earthfills except high quality earth dams for example)

Slope stability at building sites (Ref.6)

(much of it basic to any sloping site)

Those documents may need some elaboration and "tweeking up" to latest developments but they are useful.

But are they being used?

There is a wide spread practice of territorial authorities to write their own standards or to edit the existing ones to an extent that does not seem to be justified on grounds of local geological peculiarities. There is widespread (but not exclusive) reluctance on the part of territorial authorities to adopt land use, or hazard zoning such as would result from the NAWASCA guidelines (Ref. 9).

The Building Act which sought to avoid just that proliferation is under attack with a Planning Tribunal declaration which implies that a Territorial Authority may require performance criteria additional to or more restrictive than those specified in the Building Act. The declaration is being appealed to the High Court.

In the Auckland Region at least there is a wide variation in use of codes of geotechnical practice. One local body (Ref. 8) has produced from a consultation process, a very good code. Others judge reports made to them by in-house processes not necessarily "transparent" or by calling for peer reviews from external sources.

6. WHAT HAS HAPPENED SINCE 1981?

The proceedings of the 1981 Conference (Ref. 1) collect seven final papers under the heading of "What should happen". In that context what *has* happened? I would suggest that results have been erratic and less than one would have hoped.

It would require some effort to survey results nationwide but this Conference may like to consider the following questions, in relation to 1981:

1. Is there an improved coverage of medium and large scale basic geological maps? Are geological appraisals commonly made as part of regional or local land use planning?
2. How widespread are Urban Land Use Capability Surveys?
3. Were coherent guidelines for minimum impact development of the Upper Waitemata Harbour Catchment produced and used?
4. Were the general principles useful in other areas?
5. Have the Territorial authorities developed satisfactory systems for recognizing and recording geotechnical hazards and zoning around them?
6. Have Territorial Authorities enforced much more rigorous standards for the geotechnical evaluation of subdivisions?
7. How often are (geotechnical) problem areas identified only after they are covered with houses? Is the problem of soil shrinkage by desiccation recognised by territorial authorities.

7. WHAT WE NEED

Mr Elwood's hope that we would produce a further publication to guide development has not yet been realised, in the geotechnical sense anyway.

With one or two exceptions neither have the territorial authorities done much in that direction. Even in those exceptional cases more elaboration of the extent and content of geotechnical investigation reports is necessary, as would be apparent to anyone confronted by quite elementary deficiencies in some reports being present by professionally qualified people - and often accepted by Territorial Authorities.

If the clients "ability or willingness to pay" has ruled the day then it shouldn't. Some of those reports would never pass the standard of care of the profession beyond a charge of negligence in the most liberal shade of informed opinion within the NZ Geomechanics Society.

The Society must formulate a view of what constitutes a reasonable standard of performance in geotechnical matters to protect its members from the pressures of the "unwilling client', their more commercial aggressive colleagues, and ultimate very expensive legal attack.

Only the territorial authorities can enforce those standards (as they are obliged by law to do) but the profession needs to formulate them.

Probably it is too much to hope for a completely standardised approach by all territorial authorities for that involves legal and political factors which the Society can affect only indirectly. But the profession would be well served by an agreement within the NZ Geomechanics Society as to the standards of care expressed as:

- The extent of investigation appropriate at various stages of land-use planning and development
- The required content of geotechnical reports
- The limitations of reliability of quantitative calculations of soil mass behaviour
- Appropriate standards of inspection during construction
- Appropriate qualifications of geotechnical experts

8. CONCLUSION

Members of this Society offer specialist services in a field which is least amenable to precise calculations, and which is recognised by the Insurance Industry as presenting the highest risk of claims of professional negligence.

Our standard of care is ill defined.

We are vulnerable to disparate opinion amongst our colleagues and to a range of different criteria applied by Local and Territorial Authorities.

A feeling of discomfort has lead to this

Symposium 15 years after we last addressed the problem.

A more unified standard within the Society is necessary.

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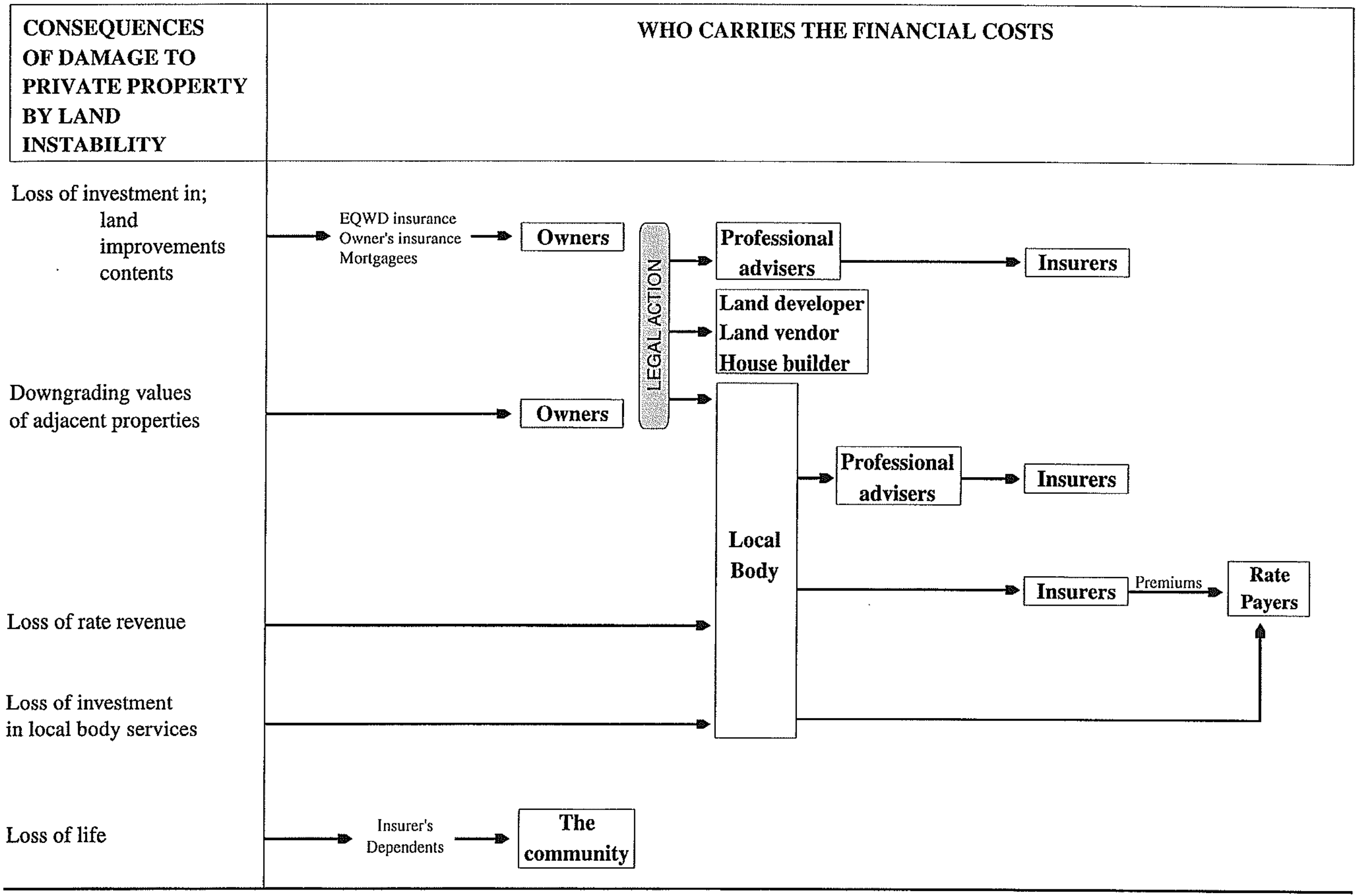

Monetary costs of landslip damage Figure 1

Geotechnical Issues in Land Development : A Resource Management Perspective.

Vernon Pickett
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SYNOPSIS: This paper looks at the contribution that geotechnical knowledge can make in the area of resource management and planning. The paper introduces a conceptual model of resource planning that the author considers has application for resource management practice, and in this context discusses the role that geotechnics can play in providing information to resolve land use issues and reduce uncertainty in both policy and project areas

1. INTRODUCTION

In 1981 the New Zealand Geomechanics Society and the NZ Planning Institute held a Symposium titled "Geomechanics in Urban Planning". It is understood that the symposium was held partly in response to concerns arising in urban development (especially subdivision) involving issues of land and slope stability. The regulatory regime then controlling land development has now gone to be replaced by the Resource Management Act 1991.

This paper will therefore look at this new regime from a resource planners perspective. It will also consider the use of a conceptual model developed by Friend et al (1969, 1974, 1987) as a tool to guide resource management practice, and discusses the role that disciplines, such as those involved in geotechnics can play in the area of land development and resource management.

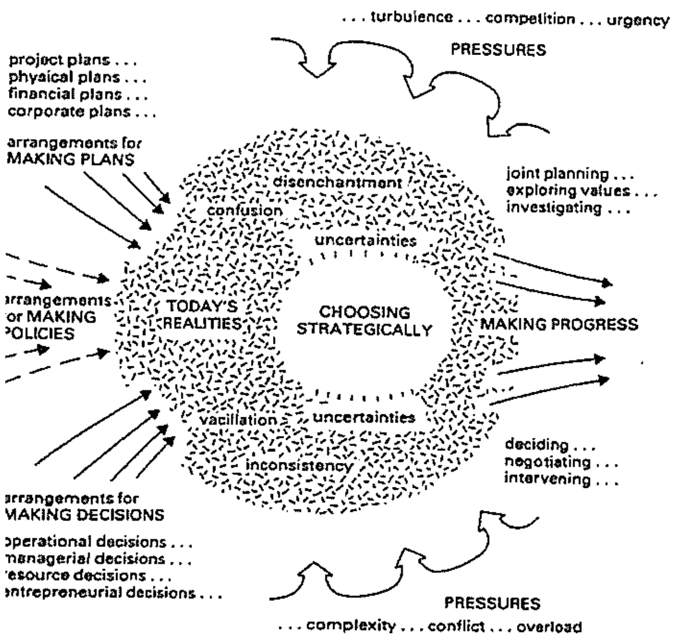
2. A PHILOSOPHY OF RESOURCE MANAGEMENT AND PLANNING

Starting with a generic definition, management can be defined as *the process of planning, organising, leading and controlling the efforts of individuals and the use of resources in order to achieve stated goals (from Stoner, 1978).* Resource management can therefore be seen as the application of these management principles to the use of natural and physical resources. Intuitively planning under this management definition involves processes of future directed choice and action directed at achieving certain defined goals.

This is essentially a decision centred view of resource management and planning. Developing this theme further, Friend and Hickling (1987) view planning as a continuous mechanism consisting of a process of choosing strategically through time (Friend J. & Hickling A., 1987). In using the word strategic, the authors do not refer to a hierarchy of decision making where strategy takes on the meaning of high level, long term and comprehensive. Rather it is about the concept of strategic choice as being concerned with the connectedness of one decision with another, not with the level of importance to be attached to one decision relative to another.

So this view of planning as a process of decision making and strategic choice implies that planning, and in particular resource planning, can be seen as a much more universal activity than is sometimes ascribed to it as a specialist function associated with the preparation of plans. Figure 1 illustrates the realities that effect decision making and planning under this view.

Figure 1, Planning Under Pressure: A view of the Realities *(from Friend &Hickling,1987)*



Before leaving this area of discussion the term *policy* and *policy system* also needs to be defined as concepts of planning because they are terms that will be referred to throughout this paper. To be consistent with this decision making approach *policy* can be defined as "a set of future intentions in relation to certain classes of situation" (Friend & Jessop, 1974). Therefore within an organisational context policies can been seen as providing a mechanism whereby certain classes of *decision problems* can be resolved by set approaches or rules of procedure (Friend & Jessop, 1969).

As a consequence *Policy systems* can therefore be seen as referring to any set of organisational and inter personal arrangements which have evolved to deal with identifiable classes of *decision problems*, however simple or complex this may be (Friend et al, 1974). This has importance when we consider the way that resource management agencies respond to issues of natural and physical resource management and their use of policies, policy systems, and rules.

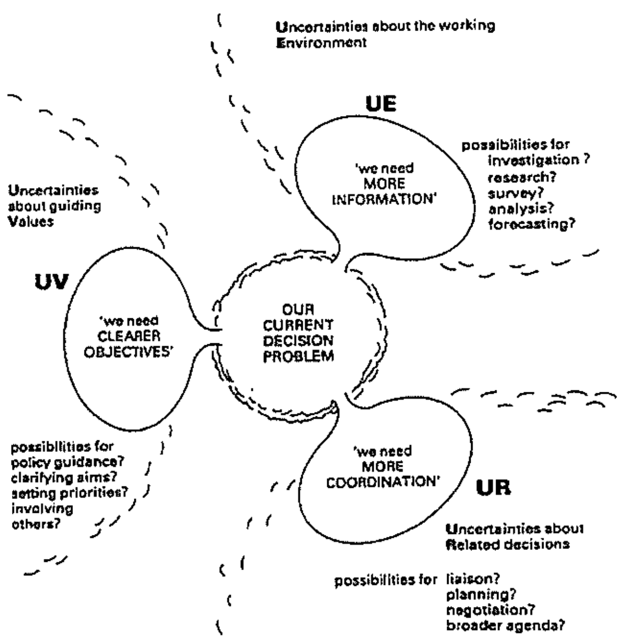
In dealing with these difficulties a snapshot view of a decision problem may help to develop a conceptual understanding of the types of responses available to resolve uncertainties and assist in decision making. It has been found from practice that *three* differing responses are often encountered in the way that people may respond to problems in order to reduce uncertainty and therefore risk (Friend & Hickling, 1987). These responses are largely dependent on the perceptions, understandings and backgrounds that individuals bring to the problem at hand.

The *first type* of response can involve a search for more information about the decision environment. This is largely a technical response in which research, surveys, technical analysis and mathematical modelling can be carried out. Whatever the form of the investigation the objective is to reduce the difficulties and the uncertainties by investing in exploration into the environment about which too little is known. This is often the type of investigation that scientists and engineering specialists can be involved in.

The *second type* of response is to take a less technical approach to the decision problem. In this approach exploration is carried out to establish more clearly what policy values should guide the choice of action. In some situations this may involve activities designed to clarify goals, objectives or policy guidelines or it may involve consultation with affected parties or individuals as to the values to be applied to resource use and allocation issues and the resolution of risk. In essence this exploration involves activities designed to reduce uncertainties by clarifying guiding values concerning the decision problem.

The *third* response may be to extend the decision agenda. People advocating this response will often argue that the decision problem cannot be taken in isolation to other decision problems that either already exist or that may exist in the future. So the demand here is likely to be for some form of co-ordination, negotiation, or planning exercise that will allow the current decision problem to be considered alongside others within a broader, more comprehensive problem focus (Friend & Hickling, 1987).

Figure 2, Three Types of Uncertainty in Decision Making, *(from Friend & Hickling, 1987)*



In summary under this model of resource management and planning the three kinds of demand are for :

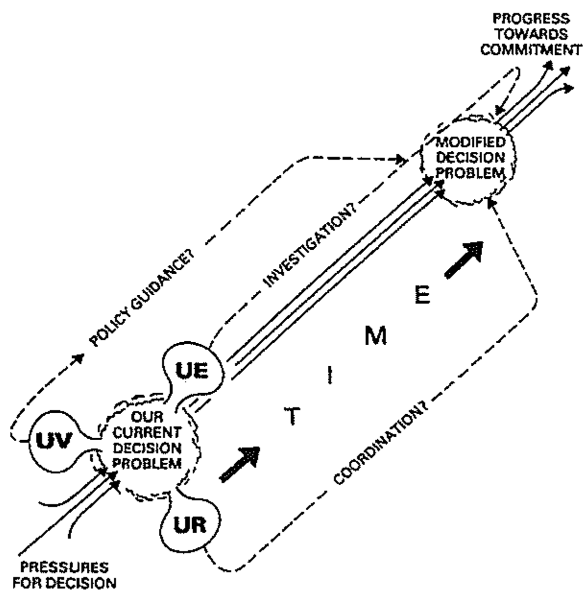
- more information
- clearer objectives
- more coordination

which are all designed to overcome uncertainty. It is therefore possible to define three kinds of uncertainty in terms of these three information demands such that they form an integral part of a strategic choice approach to decision making. These can be described as follows:

- Uncertainties about the working Environment: **UE** for short
- Uncertainties about guiding Values: **UV** for short
- Uncertainty about Related decisions: **UR** for short.

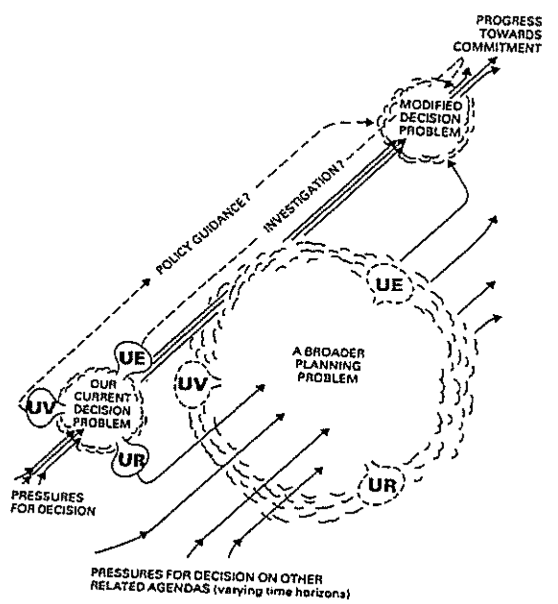
In figure 2 the three types of responses are indicated as bubbles shown emerging from the central cloud representing the decision problem. In practice however it may be far from easy to judge how uncertainty is to be managed at any moment, even in situations where the sources of that uncertainty have been clearly identified. That is the responses required are not necessarily mutually exclusive. To consider further possible ways of managing uncertainty through time, it becomes necessary to move to a more dynamic view. Such a view is presented in figure 3 by introducing the reality that any form of investigative, policy clarifying or co ordinating initiative must take time.

Figure 3, Opportunities for Managing Uncertainty through Time, *(from Friend & Hickling, 1987)*



The intended consequence of pursuing any chosen exploratory path is to make the decision problem less difficult to deal with once the outcomes of the explorations are known - in other words, to lessen the feeling of uncertainty being experienced by the decision makers, and to increase the level of confidence with which they can act.

Figure 4, Extending the Problem Focus, *(from Friend & Hickling (1987)*



Of the three exploratory routes indicated in figure three it is the coordinative **(UR)** route which often has the most far reaching significance in developing the idea of planning as strategic choice. The demand to move in this direction arises when there is a sense that the present agenda of decision making is too restricted - that the decision currently in view is significantly influenced by the uncertainties to do with intended fields of choice. Such a concern for a wider view will often lead to an extension in the time frame as well, because the pressures for a decision may be less immediate in some of those related areas. The concern for coordination may also shift the process in the direction of some form of liaison or joint working with those representing other fields of interest or other decision makers involved in related decision areas (see figure 4).

For example at a project level a resource planner involved in preparing an environmental impact assessment for a highway construction project and a Conservation Authority, may need project specific engineering-geological information to determine whether a slope stability hazard is likely to be created in terms of the projects impact on an adjoining area of national wildlife significance. In such circumstances coordination of decision making is required to ensure that relevant resource issues are addressed, and that appropriate values are brought to bear on the decision problem. This will often affect the way that information is gathered and how it is used within the project design.

3. RESOURCE MANAGEMENT - A STATUTORY VIEW

So what does the above model tell us about planning, resource management, and substantive matters such as resource use including engineering activities and the application of geotechnics.

In broad terms the above concept defines a perspective of planning that is considered to have considerable utility in guiding practice. This is because it focuses both on decision making in the resource management area, as well as the information requirements relevant to projects requiring statutory approval. However it is recognised that while this definition of resource management and planning provides the skeleton for resource planning practice, the definition also requires the context of practice to provide the substance. This is provided in New Zealand in the area of natural and physical resource management by the Resource Management Act 1991.

In this Act the purpose of resource management is defined as being:

"...to promote the sustainable management of natural and physical resources"

The Act also discusses what is meant by sustainable management. It means:

"...managing the use, development, and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, and cultural wellbeing and for their safety while:

(a) Sustaining the potential of natural and physical resources(excluding minerals) to meet the reasonably foreseeable needs of future generations; and

(b) Safeguarding the life supporting capacity of air, water, soil, and ecosystems; and

(c) Avoiding, remedying or mitigating any adverse effects of activities on the environment.

Natural and physical resources are also defined as including:

"...land, water, air, soil, minerals, and energy, all forms of plants and (whether native to New Zealand or introduced) and all structures."

4. GEOTECHNICS AND RESOURCE MANAGEMENT

Geomechanics has been defined by Taylor, *et al* (1981) as including the sciences of Geology, Soil Mechanics, Rock Mechanics, and Soil Science but can also involve seismology, meteorology, oceanography, botany and hydrology. In addition to quote Selby (1985), "... geomechanics is fundamentally based in sound and thorough field observation and measurement followed where necessary, by careful sampling and laboratory examination and analysis".

Intuitively like all scientific and engineering investigations the gathering of such information can increase our understanding of decision problems and so eliminate uncertainty, not only within the project, but in areas of resource management concerned with anticipated effects on the environment.

Very often this knowledge is used to identify and resolve issues concerning both existing and potential environmental problems such as natural hazards and their associated risk, for example: earthquake fault lines and seismicity, slope instabilities caused by geological and man made features, settlement and subsidence of natural and man made features, river and coastal erosion, and ground water loss and depletion (Taylor et al (1981), and can also contribute from an engineering and resource management perspective to their avoidance and remediation.

If we accept the use of the model of resource management and planning considered here as applied from Friend et al (1969, 1974, 1987), then there are two areas in resource planning where geotechnical information and knowledge can be of use. These are:

Policy areas of resource management such as the development of plans and policy statements that contain decision making criteria and values to be applied to resource management.

Activity areas such as resource use which may include development projects such as urban subdivisions and developments, road and highway construction and landfills, and water related activities such as hydro electric dams, river diversions, and flood protection schemes etc.

In the **policy** area Local Authorities are charged with safeguarding amongst other things, the welfare of communities and individuals, protection of the coastal environment, and the avoidance of natural hazards. Indeed the Resource Management Act requires local authorities to establish policies for the integrated management of land and other natural and physical resources. In addition Territorial Authorities as a distinct group have a further responsibility to identify and assess land at risk of erosion, flooding, subsidence, and landslips (Forsyth et al, 1995).

All these things require information to determine appropriate resource management agencies response in terms of their control mandate.

Therefore in developing policy these organisations are faced not only with determining the nature of the resource, the dynamics of it, and if necessary the mechanism to control its use but also the values to be applied in any response.

Examples to illustrate where policy has been developed in the past include slope and coastal stability and hazard modelling in relation to residential development. The details of this response include resource analysis and evaluation in terms of predetermined criteria, if necessary modelling of some form to determine the extent of hazard and risk, and the presentation of some form of policy response, typically in the form of rules and mapping to delineate the risk.

Now all these matters require decisions to made and values to be applied and implemented to minimise risk and uncertainty, not only within an organisational setting but also within a societal/community context. First there is risk recognition by individuals within the community and the resource management agency, secondly there is the resource investigation and evaluation to determine the level of risk, corresponding to resolving uncertainties concerning inadequate resource information (**UE**). Thirdly comes the decision making over an appropriate way to deal with the problem. This corresponds to resolving uncertainties in the decision environment and can be correlated to either forming the *decision problem* in figures 2 and 3 or may be constituted as part of the *"Broader Planning Problem"* in figure 4. Whatever the decision context, responses also considered by the resource management agency will inevitably include mechanisms to resolve uncertainty through other means such as:

- clarification of policy response and uncertainties due to values (**UV**), ie the form and nature of control options and the values that are brought to bear in relation to the resource decision problem and the resource itself ie its value to a community. For example existing property rights and investments may also need to be considered and as consequence consultation will be required with the community affected as to the appropriate response to overcome uncertainty and its associated risk.

- clarification of the policy response either in relation to mechanisms available through other agencies or statutes, or are required for example in other areas of the District or Region in order to provide consistent responses in decision making. These investigations are focused at resolving uncertainties in related areas of choice or **UR**.

In the **activity** area of resource management, decision making on resource utilisation is an inherent part of the design process. It is the scope of the decision making that is controlled by the policy framework that is relevant to resource management and this is regulated at the national level by policy instruments such as the Resource Management Act and related national policy statements, the Building Act , Historic Places Act, Reserves Act and the Conservation and Environment Acts. At the Regional and District level resource use is regulated under statutory mandate from Government through mechanisms such as regional policy statements, regional resource plans and district plans.

For project proponents then, there is not only the national requirements of policy and policy systems to be taken into account, but also the regional and district environmental and resource policy requirements to comply with. Now a key requirement of this process is not only to comply with the "local" resource management policy systems comprising objectives, policies, and methods (including rules), but also to meet the national goal of sustainable resource management. A critical component of this policy system is the requirement for significant activities to undergo a process of environmental scrutiny, which includes those subject to resource consents to be assessed as to their *Environmental Effects* .

Assessment of Environmental Effects (AEE) or Environmental Impact Assessment under the Resource Management Act, is a policy process or requirement designed to ensure that project decision making incorporates environmental issues. It is therefore an attempt to expand project design perspectives to make them more comprehensive in order to improve resource decision making by both project proponents and resource management agencies such as local authorities. It acts in two ways:

- firstly the schedule four requirements for AEE acts directly on project proponents as "a code" to ensure that appropriate information is gathered, used and presented to the resource management agency; and

- secondly it ensures that resource management agencies take into account and require certain standards of information in their decision making on projects requiring resource consent.

The process set out in the Act for AEE is based on normative (ideal) concepts concerning resource management practice. Like all ideals implementation can be subject to differences of individual perceptions, values and understanding of uncertainties in the decision environment affecting a project (Morgan, 1994). The AEE process is however an attempt to provide some uniformity to decision making by resolving uncertainties in the environmental area or **UE** but also inevitably requires contributions from other decision areas to resolve **UR** and **UV**.

Therefore in all three areas of uncertainty technical and scientific information can often be of critical importance. The Resource Management Act requires that appropriate information be applied to all resource use policy and decision making in order to achieve its key principles. In many situations this may require decisions on resource use and policy to be made in quite complex environments in which knowledge about consequences is limited, and in which values concerning risk minimisation need to be determined and applied.

The conceptual model discussed in this paper characterises three general areas of uncertainty in decision making. It is suggested that technical and scientific experts often need to be involved in inputting their knowledge in all three areas in order to provide appropriate policy implementation and to ensure good environmental decision making.

5. CONCLUSION

In conclusion this paper has looked at definitions of Resource Management and Resource Planning as mechanisms governing decision making concerning the sustainable use of natural and physical resources. It also considers the application of a planning model developed from operations research theory (Friend et al) and in relation to the utility of the model, looks specifically at the way that geotechnical information can be used to resolve uncertainties in relation to both resource policy making and project decision making in terms of the concepts introduced in the Resource Management Act 1991.

Because of the breadth of scope often required to achieve comprehensiveness in this area, work should ideally be carried out as a multi disciplined task. Practitioners in the discipline of Engineering Geology and Geotechnics will therefore be required to provide information input into the resource management process. Inevitably this will involve them in dealing with matters that are non technical and will involve debates over issues that often bring differing values into play regarding natural resources.

It is hoped that by describing the use of the model of resource decision making and the role that information can play in that process, that a greater understanding can be gained concerning the application of the Act and the role that your discipline can play in the use and management of our natural and physical resources.

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The Legal and Planning Framework - the RMA and the Building Act 1991

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SYNOPSIS: The RMA and the Building Act consolidated and reformed the law relating to resource management and building respectively. The RMA determines whether a particular building may lawfully be erected upon a particular site. This will depend upon compliance with the bulk and location controls in the district plan which commonly specify matters such as the maximum height and the minimum yard requirements, and may also depend the activity for which the building is to be used. The Building Act is concerned with the structural integrity of the building. Natural hazards are an important consideration under the RMA, especially in determining under section 106 whether a subdivision consent is to be granted. They are also relevant under section 36 of the Building Act in determining whether a building consent is to be issued in respect of land subject to natural hazards. Competent geotechnical advice is of crucial importance.

1. THE RESOURCE MANAGEMENT ACT

1.1 The long title of the Act is "An Act to restate and reform the law relating to the use of land, air, and water". The RMA came into force on 1/10/91 and repealed or amended over 50 statutes including the Town and Country Planning Act 1977 (land use planning), Part XX of the Local Government Act 1974 (subdivisions) and the Water and Soil Conservation Act 1967 (discharges to, damming or diversion of water).

1.2 The purpose of the RMA is set out in section 5(1) as being "to promote the sustainable management of natural and physical resources" which are defined in section 2(1) as including land, water, air, soil, minerals, and energy, and all forms of plants and animals, and all structures (further defined as meaning any building, equipment, device, or other facility made by people and which is fixed to land; and includes any raft).

1.3 "Sustainable management" is defined in section 5(2) as meaning managing the use, development, and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural well being and for their health and safety while -

(a) Sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations; and

(b) Safeguarding the life-supporting capacity of air, water, soil and ecosystems; and

(c) Avoiding, remedying, or mitigating any adverse effects of activities on the environment.

1.4 The purpose is central to the RMA, and several sections use the expression "in achieving the purpose of this Act".

1.5 Section 9 prohibits the use of land contrary to a rule in a district or regional plan unless allowed by a resource consent or protected by existing use rights. Note that any land use is permitted which does not contravene a rule in a plan. Subsection (4) defines "use" as including the erection or demolition of any structure and any excavation, drilling, tunneling, or other disturbance of the land.

1.6 Unless expressly permitted by a rule in a district or regional plan or by a resource consent, the RMA prohibits:

(a)The subdivision of land (section 11);

(b)In the coastal marine area, reclamations, constructions, or the removal of sand, shingle, shell or other natural material;

(c)Using, disturbing, reclaiming or draining the bed of any lake or river (section 13);

(d)Taking, using, damming, diverting water, heat or energy from water, or heat or energy from the material surrounding any geothermal water (section 14);

(e)Discharging contaminant or water into water or contaminant onto or into land in circumstances that may result in that contaminant or any resulting contaminant entering water, or discharging contaminant from any industrial or trade premises into air or onto or into land (section 15).

1.7. Section 88 requires an application to include an assessment of effects on the environment in accordance with the Fourth Schedule. Geotechnical input is often required as part of that assessment and geotechnical evidence can form an important part of a case as the first matter to which a consent authority is directed to have regard under section 104(1)(a) is any actual and potential effects on the environment of allowing the activity.

1.8 Section 106(1) states that a consent authority shall not grant a subdivision if it considers that either-

(a)Any land in respect of which a consent is sought, or any structure on that land, is or is likely to be subject to material damage by erosion, falling debris, subsidence, slippage, or inundation from any source; or

(b)Any subsequent use that is likely to be made of the land is likely to accelerate, worsen, or result in material damage to that land, other land, or structure, by erosion, falling debris, subsidence, slipping, or inundation from any source

unless satisfied that sufficient provision has been made or will be made to avoid, remedy, or mitigate the effects by rules in the district plan, conditions of a resource consent, or other matters including works.

1.9 The natural hazards referred to in section 106(1) are not defined in the RMA.

"Falling debris" was inserted by the 1993 Amendment Act. The other hazards previously appeared in section 641 of the Local Government Act as amended in 1981.

In *Alpe and Semini v. Rodney County* (1981) 8 NZTPA 257, 262 the Tribunal rejected the interpretation that "subject to erosion" meant actually subject to erosion and adopted the shorter Oxford English Dictionary definition of "subject to" as:

> "Exposed or open to; prone to or liable to suffer from something damaging, deleterious or disadvantageous. Liable to the incidence or recurrence of an action, process or state."

However, the High Court in *Bosworth v. Planning Tribunal* (1983) 9 NZTPA 32 held that it was not open to the Tribunal to hold that land which had not as yet suffered any erosion was "subject to erosion" for the purposes of section 641(2)(b) of the Local Government Act 1974 (in its pre 1981 amendment form). Section 106(1) uses the same words "is likely to" and by virtue of Chilwell J's reasoning must therefore apply to the present likelihood of future erosion, etc.

1.10 The functions of regional councils as set out in section 30(1) include: the control of the use of land for the purpose of soil conservation and the avoidance or mitigation of natural hazards; in respect of any coastal marine area, the control (in conjunction with the Minister of Conservation) of land and associated natural and physical resources and any actual or potential effects of the use, development, or protection of land, including the avoidance or mitigation of natural hazards; the control of the taking, use, damming, and diversion of water; the control of discharges of contaminants into or onto land, air, or water and of water into water; and in relation to the bed of a water body, the control of the introduction or planting of any plant for the purpose of soil conservation or the avoidance or mitigation of natural hazards.

1.11 The functions of territorial authorities under section 31 include the control of any actual or potential effects of the use, development, or protection of land, including for the purpose of the avoidance or mitigation of natural hazards; and the control of subdivision of land.

1.12 "Natural hazard" is widely defined in section 2(1) as meaning any atmospheric or earth or water related occurrence (including earthquake, tsunami, erosion, volcanic and geothermal activity, landslip, subsidence, sedimentation, wind, drought, fire, or flooding) the action of which adversely affects or may adversely affect human life, property, or other aspects of the environment.

1.13 The Planning Tribunal in *an application by Canterbury Regional Council* [1995] NZRMA 110, 124-125 held that it was unlikely that Parliament would have intended that both classes of local authority would have identical functions in respect of the avoidance or mitigation of natural hazards. The difference in the language used in describing the respective functions should be taken to have been deliberate and to indicate differences in those functions. The Tribunal accepted the submission that the subject of the Regional Council control function of avoidance or mitigation of natural hazards is the hazards themselves and not the effects of the use, development or protection of land for those purposes, which is a territorial authority function. The Tribunal thereby attached importance to the different wording in the two sections and drew a distinction between controlling the use of land for a particular purpose and controlling any actual or potential effects of the use of land for that purpose. The Tribunal rejected as inapplicable the argument that these specific regional council powers should override the general territorial authority power, holding that the functions of those classes of local authorities were different. The Tribunal held (at page 121) that the regional council function in section 30(1)(b) does not exclude territorial authorities from performing their functions described in section 31(b) of controlling within their districts any actual or potential effects of the use, development of protection of land for the purposes of soil conservation, the maintenance and enhancement of the quality of water in water bodies, and the maintenance of the quantity of water in water bodies.

1.14 The matter then made its way to the Court of Appeal [1995] NZRMA 452. The Court of Appeal agreed (pp457-458) that the RMA provided a hierarchy of instruments to the extent that regional policy statements must not be inconsistent with national policy statements and certain other instruments, and district plans must not be inconsistent with national policy statements and the same other instruments nor with the regional policy statement or regional plan. The Court held that it did not follow that there could be no overlap between the functions of regional councils and territorial authorities. To the extent that matters have been dealt with by an instrument of higher authority, the territorial authority's plan must not be inconsistent with the instrument. Beyond that, the territorial authority has full authority in respect of the matters set out in section 31. The distinction between use and effects of use drawn by the Tribunal was not upheld by the Court which held that it was difficult to see how a territorial authority could control the effects of use without regulating the use itself and accepted the submission that what is limited is not so much what can be controlled, but the purpose for which it can be controlled. The control of the effects of land use must involve some degree of control of the use itself. Counsel for the territorial authorities accepted that they could not control the use of land for the purpose of soil conservation but argued that they could exercise such a power for any of the purposes set out in section 31(b) even if an incidental result turned out to be the promotion of soil conservation. The Court made a declaration that:

> A regional council may, to the extent allowed under s68 of the Resource Management Act, include in a regional plan rules which prohibit, regulate or allow activities for the purpose of carrying out its functions under s30(1)(c) to (h). A territorial authority may, to the extent allowed under s76, include in a district plan rules which prohibit, regulate or allow activities for the purpose of carrying out its functions under s31. Neither a Regional Council nor a territorial authority has power to make rules for purposes falling within the functions of the other, except to the extent that they fall within its own functions and for the purpose of carrying out its own functions. To that extent only, both have overlapping rule making powers, but the powers of a territorial authority are also subject to section 75(2).

1.15 The Court accepted that the definition of "natural hazard" limited the term to occurrences which could have adverse effects. The RMA did not require regional councils to control the occurrence itself as earthquakes, tsunami and volcanic eruptions, which are the examples given in the definition, cannot be controlled. The regional council is rather given the power to control the use of land for the purpose of avoiding or mitigating the natural hazard, which means avoiding or mitigating the effects of the occurrence. One way of doing this would be by the control of the erection of buildings or structures in a flood plain. The Court then held that the control of the use of land for the avoidance or mitigation of natural hazards is within the powers of both regional councils and territorial authorities (page 460) and proceeded to make a declaration that the Canterbury Regional Council does have power to include in part of its regional Waimakariri Flood Plain Management Plan rules to control any actual or potentially effects of the use, development or protection of land for the purposes of the avoidance or mitigation of natural hazards.

1.16 Geotechnical investigations and evidence will therefore be important in ensuring that both regional councils and territorial authorities are able to include appropriate provisions in their plans to avoid, remedy, or mitigate natural hazards.

2. THE BUILDING ACT

2.1 The long title of this Act is "An Act to consolidate and reform the law relating to building and to provide for better regulation and control of building". One of the aims of the Act was to introduce one unified system of control of buildings instead of the fragmented system of controls that previously existed with different controls being exercised by various government departments and other agencies and with each local authority having its own building bylaws. Parts of the Act came into force on 15/2/92 and the balance of the Act on 1/7/92. It compressed 30 Acts into a single Act.

2.2 The purposes of the Act are stated in section 6(1) as being to provide for -

(a)Necessary controls relating to building work and the use of buildings, and for ensuring that buildings are safe and sanitary and have means of escape from fires; and

(b)The co-ordination of those controls with others controls relating to building use and the management of natural and physical resources.

Under subsection (3) in determining the extent to which the above matter shall be the subject of control, due regard shall be had to the national costs and benefits of any control, including safety, health, and environmental costs and benefits.

The Minister of Internal Affairs in moving the third reading of the Bill, stated that it had three clear objectives: first to lower the cost of bureaucracy, second to introduce a performance code, and third to introduce private sector competition for local authorities through the building approval process.

2.3 Part IV sets out the functions, powers, and duties of territorial authorities which include receiving and considering applications for building consents and approving or refusing them within the prescribed time limits, and issuing project information memoranda.

2.4 The fundamental control under the Act is imposed by section 32(1) which states that it shall not be lawful to carry out building work except in accordance with a building consent issued by a territorial authority in accordance with the Act. Under section 33(1) an owner intending to carry out any building work shall, before the commencement of the work, apply to the territorial authority for a building consent. "Building work" is defined in section 2 as meaning work for or in connection with the construction, alteration, demolition or removal of a building, and includes sitework.

2.5 "Building" is defined in section 3(1) as meaning, unless the context otherwise requires, any temporary or permanent movable or immovable structure (including any structure intended for occupation by people, animals, machinery or chattels); and includes any mechanical, electrical, or other system, and any utility systems, attached to and forming part of the structure whose proper operation is necessary for compliance with the building code; but does not include-

(a) Network utility operator systems for the reticulation of other property
(b) Cranes
(c) Cablecars, cableways, ski tows
(d) Any description of vessel used in navigation
(e) Vehicles
(ea) Aircraft
(f) Containers as defined in section 2 of the Dangerous Goods Act 1974
(g) Magazines as defined in section 2 of the Explosives Act
(h) Scaffolding used in the course of the construction process
(i) Falsework used in the course of the construction process.

2.6 Any person may apply to a territorial authority for the issue, within 10 working days, of a land information memorandum, commonly known as a LIM. Somewhat strangely, this provision is not to be found in the Building Act but is tucked away in section 44A of the Local Government Official Information and Meetings Act 1987.

The matters to be included in a LIM include information identifying each (if any) special feature or characteristic of the land concerned, including but not limited to potential erosion, avulsion, falling debris, subsidence, slippage, alluvion, or inundation, or the likely presence of hazardous contaminants, being a feature or characteristic that is known to the territorial authority but not apparent from the district plan under the RMA.

Note that an application for a LIM can be made only to a territorial authority and not to a regional council notwithstanding that one might reasonably expect a regional council to have more information about the natural hazards to which a property is subject. A request for that information could be made of a regional council under section 10 of the Local Government Official Information and Meetings Act 1987.

2.7 An owner contemplating undertaking any building work for which a building consent is required may apply to a territorial authority for a project information memorandum, commonly known as a PIM, under section 30(1) of the Building Act. Under section 31(2)(a) the PIM shall include information, likely to be relevant to the proposed building work, identifying each (if any) special feature of the land concerned, including (but not limited to) potential erosion, avulsion, falling debris, subsidence, slippage, alluvion, or inundation, or the likely presence of hazardous contaminants, being a feature or characteristic that is likely to be relevant to the design and construction or alteration of the building or proposed building, is known to the territorial authority, but is not apparent from the district plan under the RMA.

For the purposes of section 31, the land concerned is the land on which the proposed building work is to be undertaken and any land likely to affect or be affected by the building work.

2.8 A PIM is directed to natural hazards relevant to the proposed building work, and is therefore narrower in scope than is a LIM.

2.9 Section 36 states that except as provided in subsection (2), a territorial authority shall refuse to grant a building consent involving construction of a building or major alterations to a building if-

(a) The land on which the building work is to take place is subject to, or is likely to be subject to, erosion, avulsion, alluvion, falling debris, subsidence, inundation, or slippage; or

(b) The building work itself is likely to accelerate, worsen, or result in erosion, avulsion, alluvion, falling debris, subsidence, inundation, or slippage of that land or of any other property

unless the territorial authority is satisfied that adequate provision has been or will be made to-

(c) Protect the land or building work or that other property concerned from the hazard concerned; or

(d) Restore any damage to the land or that other property concerned as a result of the building work.

2.10 Where the territorial authority considers that-

(a) The building work itself will not accelerate, worsen, or result in any of the listed natural hazards on that land or any other property but

(b) The land on which the building work is to take place is subject to, or is likely to be subject to, one of the listed natural hazards; and

(c) The building work is in all other respects such that the requirements of section 34 (relating to the grant of a building consent) have been met-

the territorial authority shall, if satisfied that the applicant is the owner, grant the building consent and include as a condition that the territorial authority shall forthwith notify the District Land Registrar who shall make an entry on the certificate of title to the land that a building consent has been issued in respect of a building on land that is subject to or likely to be subject to one of the listed natural hazards.

2.11 Registration against the title provides notice to all the world, and in particular draws the matter plainly to the attention of any would be purchaser. Most importantly from the territorial authority's point of view, such a condition exempts it from any civil liability to anyone having an interest in the building on the grounds that it issued a building consent in the knowledge that the building or the land on which the building was situated was, or was likely to be, subject to damage arising directly or indirectly from any of the listed natural hazards. The risk is effectively transferred to the owner of the building who can make his or her own decision whether or not to proceed to construct the building in a position where it is subject to a natural hazard.

2.12 In addition to the hazards listed in section 106 of the RMA, section 36 lists two further hazards. *Butterworths New Zealand Law Dictionary*, 4th edition by Professor Spiller of Waikato University (1995) defines "alluvion" as "Land that is gained from the sea by the washing up of sand and earth, so as in time to make terra firma" and "avulsion" as "The sudden removal of soil from the land of one person, and its deposit upon the land of another, by the action of water."

2.13 Geotechnical Engineers will obviously have a key role to play in satisfying a territorial authority in terms of section 36(1) that adequate provision has been or will be made to protect the land or building work or other property from the natural hazard concerned or to restore any damage resulting from the building work, or alternatively that in terms of subsection (2)(a) the building work itself will not accelerate, worsen, or result in one of the listed natural hazards. An engineer supplying a report in these circumstances owes a contractual duty of care to the owner who engages him or her and a tortious duty of care to third parties such as subsequent purchasers and the territorial authority.

2.14 Section 36 has not yet been the direct subject of any case law. *Burton v. Auckland City* [1994] NZRMA 544 was an application for judicial review of a decision of the Council to grant, without public notification, resource consents to subdivide, to remove trees, and to excavate a driveway. Blanchard J held that the balance of convenience lay in maintaining an interim order preventing the removal of the 20% of the trees on the bank that had not already been removed but, because of the denuded state of part of the slope, he extended the interim order to all tree felling and bush clearance, not just the trees over 6 metres in height. His Honour then added (at 559):

> "In making a determination under s36 of the Building Act if Mr Bartlam" [the owner] "now applies for a building consent the council will necessarily have to take into account the position in relation to trees (or lack of them) and be guided in that respect by such reports as it may receive from engineers and other experts."

As yet this appears to be the only judicial reference to section 36.

2.15 Is "the land on which the building work is to take place" in section 36(1)(a) to be read as meaning only that land covered by the building?" In *Alpe and Semini v. Rodney County* (1981) 8 NZTPA 257 the Planning Tribunal had to construe section 641(2) of the Local Government Act as inserted by the 1979 Amendment Act as a response to the Abbotsford landslip. The words there used were "the land on which a building is proposed to be erected" and "the land, or any part of it". The Tribunal held that the term "the land" used in those paragraphs was not a precise term and that it is not necessarily the whole of an applicant's landholding which is referred to but that in its context it must mean more than the mere space upon which it is proposed to erect a building - more than the land enclosed by the outer walls of the building - but that it was not necessary for the Tribunal to be more specific than that and to say by how much more (page 262).

2.16 However, in *Bosworth v. Planning Tribunal* (1983) 9 NZTPA 32, Chilwell J in the High Court held that the word "land" in section 641(2)(b) means "the area of land on which it is proposed to erect or alter the building, the area enclosed by the perimeters of the proposed building work". Those same words would also apply to define "the land on which the building work is to take place" in section 36(1)(a).

Earthquake and Geological Hazard Mitigation Strategy: A Background Statement

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SYNOPSIS: The objective of the hazard strategy is the mitigation of risk to the regional community posed by earthquake and geological hazards.

The strategy contains a series of actions or initiatives to ensure that the risks associated with earthquake and geological hazards are explicitly recognised, quantified, and either accepted or mitigated. Implementing the initiatives will be the task of local authorities, including the Wellington Regional Council.

The strategy is necessary to encourage all the key stakeholders in the Wellington Region to work towards a common goal, as quickly and cost effectively as possible.

The strategy is intended to build on the work carried out by the Regional Council and other organisations over the last 5 to 6 years. As the overall approach and priorities are clarified, the Regional Council, other local authorities, and other organisations will be better able to budget and plan their hazard mitigation programmes.

1. INTRODUCTION

1.1 Why prepare a hazard mitigation strategy?

The Wellington Region is susceptible to significant adverse effects from earthquakes and other geological hazards such as landslides. Earthquake and geological hazards may affect localised areas or their effects may be widespread. The hazards have relatively low probabilities of occurrence, but high potential impacts. Loss of life, injury, damage to property and infrastructure, and social and economic disruption are some of the adverse effects that have been experienced in the past. These effects are likely to occur again in the future.

There is an obvious need to mitigate the adverse effects of earthquakes and other geological hazards in the Wellington Region. Lessening the impacts of these events will save lives, reduce damage and disruption, and enable a faster recovery. Successful and cost effective earthquake and landslide mitigation programmes have been implemented in other countries, and such a programme will assist the Wellington Region.

The development of the Earthquake and Geological Hazard Mitigation Strategy is a direct response to three key issues. These are:

(1) the regional significance of earthquake and geological hazards;
(2) the difficulties of implementing hazard mitigation techniques; and
(3) the need for co-ordination of the wide range of individuals, groups and agencies which currently play a part in meeting hazard mitigation challenges.

The strategy deals specifically (and deliberately) with only earthquake and geological hazards. In making the decision to limit the strategy to these hazards, it is recognised that they represent only part of the full range of natural and technological hazards that threaten the Wellington Region.

The knowledge and technology exists today to allow earthquake and geological hazard mitigation to occur. These resources need to be taken advantage of if we are to make a real impact on risk reduction.

1.2 The outcome

The main aim of the strategy is to implement the natural hazard policies contained in the Regional Policy Statement. This will ensure that over the long term the risks from earthquake and geological hazards in the Wellington Region are explicitly recognised, quantified, and either accepted or mitigated.

Furthermore, the aim is to encourage continuous improvement in hazard and risk mitigation, and to ensure that the key community and sector groups, local authorities, and Government agencies are aligned in working toward this goal.

1.3 A strategic approach

A strategy has been prepared to provide a planned and calculated approach to achieve the above outcome, taking into account the challenges likely to be encountered in the process.

The strategy focuses on achieving its objectives in the long term. For the strategy to achieve its long term goal there must however be short term (annual) commitment and support from all local authorities and other key stakeholders in the Region. The strategy does not require immediate investment of large amounts of capital and does not impose significant constraints on individuals or organisations. If it did do this, it would fail. The strategy will be successful if in, say 50 years time, the risks from earthquake and geological hazards are explicitly recognised, quantified, and deemed to be acceptable.

1.4 Barriers to risk mitigation

The existence of earthquake and landslide hazards in the Wellington Region has been known for a long time. However the Region is still vulnerable to a level risk that is undesirable, and probably unacceptable. Although much work has been done to reduce risk throughout the Region, barriers remain which continue to obstruct this process. In developing a strategy to mitigate risk, these barriers must be addressed.

Some of the barriers to risk mitigation are:

(1) the Wellington Region has not experienced a highly destructive earthquake in a heavily populated area in recent time;

(2) earthquake and geological hazard events occur infrequently and have a low probability of occurrence. Therefore, they are given low priority compared to the many and varied immediate needs of the community such as employment, housing and health;

(3) community and government perceptions of earthquake and geological hazards often underestimate the level of risk that such events pose;

(4) many current mitigation measures concentrate on the preservation of life (e.g., building codes) and do not address other impacts such as loss of functionality of buildings. The latter has proved to be a significant factor in recent earthquake events such as Loma Prieta (USA), Northridge (USA) and Kobe (Japan);

(5) earthquake and geological information is often in a language or format that is not understandable or directly usable by nontechnical users, and/or is not effectively transferred to them;

(6) there is a lack of detailed information on the nature and potential effects of some earthquake and geological hazards. Similarly, there is a lack of information on practical mitigation measures, including the cost of such measures;

(7) there are many organisations in the Wellington Region involved with natural hazard mitigation work, but coordination between them needs to be improved to mutual advantage;

(8) there is a shortage of people trained to analyse technical hazard information, to extrapolate the data and to translate the basic data into products that can be applied in the community;
(9) there is insufficient evidence of hazard information and other mitigation actions contributing to risk reduction. Politicians and other decision makers who control expenditure must be convinced that hazard mitigation is worth the investment. Decision makers are not always presented with all the relevant information to make informed decisions on funding priorities;

(10) there is a feeling of inevitability and lack of power or control to do anything about mitigating potential adverse effects; and
(11) the cost-benefit of mitigation measures is not easily established. This makes prioritising the implementation of mitigation measures difficult.

The barriers described above have been taken into account in developing the hazard mitigation initiatives in the strategy. However, mitigation will only be achieved if the measures are implemented.

2. CURRENT PROGRAMME

2.1 Earthquake hazards

In recognition of the earthquake threat, the Regional Council initiated a programme in 1988 to assess the risk posed by earthquakes, identify mitigation options, and implement measures to ensure that the level of risk is acceptable.

Since 1988, the Regional Council's earthquake hazard work has concentrated on:
(1) defining the nature and extent of earthquake hazards (active faulting, ground shaking, liquefaction and ground damage, slope failure and tsunami) in the Region;
(2) translating the hazard information into reports and maps;
(3) transferring the hazard information to a variety of users including emergency management organisations, territorial authorities, education institutions and businesses;
(4) identifying and quantifying the geographic variation of earthquake risk to buildings, key emergency service facilities and the population; and

(5) developing natural hazard objectives, policies and methods in the Regional Policy Statement.

Current work in the 1995/96 year includes the development of a series of comprehensive earthquake hazard maps.

2.2 Geological hazards

An assessment of landslide hazard was started in 1988 as part of a broad assessment of natural hazards in the Region. The main purpose of the assessment was to provide hazard information to assist the Regional Council and territorial authorities to carry out their statutory and planning functions.

The landslide hazard assessment provides geographical information on the relative susceptibility of the main urban areas to landslide hazard. The assessment deals only with rainstorm generated slope failures.

3. RESEARCH AND THE APPLICATION OF HAZARD INFORMATION

3.1 Information requirements

It is unfortunate that we do not always make full use of the hazard information available. This is commonly because the information is not always presented in a language or format which is understandable or usable.

Improved communication between earthquake and geological hazard experts and the community is necessary if research is to be effectively translated into actions that mitigate hazards. Hazard information prepared by scientists or engineers is often unsuitable for or unusable by nontechnical users. Most professional planners and local authority officers do not have the training or experience to apply earthquake and geological hazard information. Their experience with natural hazards is more likely to be with flooding or site specific problems.

Users who are unfamiliar with, or not proficient in using technical hazard information are likely to misuse it or not use it at all.

Planners, civil defence officers, and developers use hazard information in different ways to scientists and engineers. There is therefore considerable scope to be innovative in the area of information translation and transfer.

3.2 Application of hazard information

Hazard and geology researchers and users of hazard information in the Wellington Region have recognised the problem of applying technical hazard information to practical mitigation purposes. Progress is being made and the gap between scientists and users is closing. Scientists have improved understanding of the potentially wide application of their findings, and planners are gaining an improved understanding of technical information. This process is assisted by a contestable funding regime whereby applicants for research funds benefit from showing that their work has practical application and is supported by hazard information users.

However, even when hazard information is available, and has been translated, transferred and used for hazard reduction, it may still not be used effectively. A survey of local authorities in California in 1986 found the most common reasons for ineffective use and inaction were limited staff time and limited funds. Other reasons included:

(1) a lack of leadership, as well as a lack of attention from management and elected officials, due to competing day-to-day problems;
(2) a lack of interest or commitment;
(3) the perception of potential public opposition to politically sensitive programmes; and
(4) the perception that the hazard was so low that the existing effort was adequate.

The strategy identifies the importance of having high quality scientific information as a prerequisite to any effective hazard mitigation. However, it also recognises the importance of translating that information into a useable form and transferring it to non-technical users. It addresses those actions or initiatives likely to improve the effective use of scientific information by non-scientists.

4. DETERMINING MITIGATION PRIORITIES

4.1 Introduction

In constructing a strategy to reduce the risks of earthquake hazards, it is necessary to prioritise the possible options for achieving that reduction. This requires us to visualise the possible consequences of an earthquake event in the Region. To do this, we can refer to events from the past and to studies of possible future events.

In 1855 a magnitude 8.1 earthquake was generated on the Wairarapa Fault. Buildings throughout the Region were severely damaged but there was little loss of life. In the following 90 years there have been 13 severe earthquakes in the Region - 1868, 1890, 1897, four in 1904, 1913, 1924 and three in 1942. The June 1942 earthquake was a magnitude 7. Almost every brick and stone building in the Wairarapa either collapsed or was badly damaged. In August 1942 there were two more severe earthquakes. Losses totalled about 2 million pounds.

In terms of lives, property and damage to the Region's infrastructure, future potential loses are expected to be high enough to impact significantly on the Region's economy (and the New Zealand economy), as well as the general wellbeing of the community.

4.2 Earthquake risk assessment study

An earthquake risk assessment study for the Wellington Region was recently completed by the Regional Council. The study provides a good estimate of the likely effects of an earthquake and can be used to determine mitigation priorities.

The aim of the risk assessment was to identify and quantify the geographic variation of risk to buildings, key emergency service facilities and the population from earthquake hazards for the main urban parts of the Region. The study was based on two earthquake scenarios. Scenario 1 is a large distant shallow earthquake that would produce moderate levels of shaking in the Wellington Region. Scenario 2 is a large earthquake centred on the Wellington to Hutt Valley segment of the Wellington Fault.

Some 16,000 properties (residential, commercial and industrial) are expected to experience *extensive* or *complete* damage during a Wellington Fault event (magnitude 7.5). The cost of repair has been estimated at $3.9 billion. It is reasonable to assume that actual damage figures may be in the range of 0.5 to 2 times the calculated figure. These figures do not include damage to infrastructure and lifelines which can be expected to add significantly to the costs of a severe earthquake in the Region.

Casualties from building damage, for a daytime Wellington Fault event, have been calculated at 3905 injured and 530 dead. The actual casualty rate could be in the range of 0.5 to 3 times these values. Casualty rates are calculated on the basis of building damage and do not include casualties from the failure of other structures or freak events.

4.3 Implications of risk assessment study

The risk assessment results provide information that can be used to determine mitigation priorities. The more obvious implications and areas of concern highlighted by the study are that:

(1) significant damage is expected to commercial and industrial buildings constructed in the 1930's to 1970's period. The emphasis (in terms of life safety) in the past has been on pre-1930 unreinforced masonry and brick buildings;
(2) the community's ability to provide temporary residential and commercial accommodation and to deal with health problems arising from damaged buildings is limited;
(3) the fire service's ability to cope with ignitions and the spread of fires, in addition to immediate rescue work, is likely to be limited. This is an important issue given the vulnerability of many of the fire stations in the Region;
(4) the Region's hospitals and other medical centres' ability to cope with injuries will be limited. Again, this is an important issue given the vulnerability of some of the major hospitals in the Region;
(5) the resources available for the reconstruction of buildings are limited. These resources are required in addition to those necessary to repair and reconstruct lifelines, other critical facilities and other structures; and
(6) there may not be enough engineers and building inspectors to cope with the large number of post-earthquake building inspections that will be required.

Most properties with *extensive* or *complete* damage are likely to be vacated for a significant period following an earthquake. Buildings with *slight* or *moderate* damage should be habitable immediately or shortly after the earthquake in cases where only minor repair or securing work is required.

5. HAZARD AND RISK MITIGATION INITIATIVES

Hazard mitigation needs to be approached on as many fronts as possible. Forty one mitigation initiatives are presented in the strategy. These initiatives have as their objective the *awareness of, avoidance of, accommodation of,* or *response to*, the effect of earthquakes and landslides on people and their land uses, structures and socioeconomic activities. Their general aim is to reduce human casualties, property damage and socioeconomic interruptions.

The initiatives are grouped into six main mitigation areas. These are:

(1) hazard and risk research;
(2) education, public awareness and advisory;
(3) statutory planning;
(4) external programmes and organisations;
(5) engineering and infrastructure; and
(6) emergency management.

Each section is subdivided further into more specific application areas. In each subsection the Regional Policy Statement methods are listed first with a short explanation/discussion following each mitigation initiative. There is a significant degree of overlap between the six main hazard mitigation areas identified. Furthermore, the success of many of the initiatives given in the strategy is dependent on the implementation of others.

Many of the initiatives given in the strategy are general in nature and will require further scoping and refinement. The more specific initiatives are generally well defined individual projects or statutory work, such as submissions on district plans and resource consent applications. Fourteen of the 41 initiatives are *methods* taken directly from the Regional Policy Statement and therefore have a statutory basis. The inclusion of the Policy Statement methods in the strategy will mean that the policies and methods are more visible to non-statutory organisations with natural hazard responsibilities. All the initiatives are consistent with the overall objective and policies given in the Natural Hazards chapter of the Regional Policy Statement.

Some of the initiatives are currently being carried out by the Regional Council but have never been defined or recognised in a formal policy document.

To be effective, most initiatives in the strategy depend on sound scientific information. Application focused research in the areas of geology, engineering geology, seismology and engineering is an important part of the strategy.

The implementation of any of the initiatives given in the strategy is dependent on the allocation of resources through the Council's annual plan process. To proceed further with these initiatives, it will be necessary to determine a cost for each of the non-statutory initiatives to prioritise them and develop an implementation programme on this basis.

6. IMPLEMENTATION OF STRATEGY

The hazard strategy will be implemented through the Council's Annual Plan process.

The Annual Plan details the functions and activities the Council will carry out each year. Decisions on expenditure are made by Councillors following consultation with the community.

In implementing the strategy, the emphasis will be on implementing those initiatives which are also Regional Policy Statement *methods*. Regional Policy Statement *methods* should be implemented within the next ten years. However, this does not preclude the implementation of the other initiatives during this period.

7. REVIEW OF STRATEGY

The general success and acceptance of the strategy depends on regular review and reassessment of the risk reduction initiatives. An assessment should consider the level of known risk, effectiveness in avoiding damage and loss, implementation feasibility, potential acceptability and cost. The effectiveness of avoiding or minimising damage and loss must be the most important consideration for the Regional Council.

It is envisaged that the strategy will be reviewed every 3 years. Key stakeholders will be advised of any significant changes to the strategy.

Seismic Hazard Identification, Vulnerability Assessment and Mitigation

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SYNOPSIS : Seismic ground damage hazards are among the primary engineering considerations for land development initiatives in New Zealand. Identification and mitigation of these hazards at development stage is crucial to reducing the vulnerability of the community. The Wellington Region has been in the forefront in seismic hazard studies and mitigation.

The Wellington Regional Council has pro-actively lead a hazard strategy, with studies to assess and map active faults, the surface geology, ground shaking, liquefaction and slope failure, followed by a risk assessment to assess the vulnerability of the built environment and population to these hazards.

Porirua City Council has included seismic hazard zones and criteria for control of new development into their draft district plan, whilst lifeline studies have considered the vulnerability to seismic hazards, and helped initiate mitigation measures.

Hazard maps have enabled the risk to new development to be identified at an early stage, when there is more flexibility in terms of siting of structures, ground improvement and appropriate design measures.

1. INTRODUCTION

New Zealand is among the most seismically active regions in the world. Past earthquakes and studies have shown that there is a high risk of damage from earthquakes. Large earthquakes affecting urban areas have been absent during the last 50 years when significant urban development took place in New Zealand. However, the level of damage caused by recent large earthquakes overseas and increased media coverage brought about by communications technology is raising the awareness of earthquake hazards among the community. The Resource Management Act 1991 has placed increased responsibility on the local authorities for the identification of hazards.

The risk posed by seismic ground damage hazards (fault rupture, liquefaction and slope failure) is an important geotechnical engineering consideration in land development initiatives in New Zealand. Identification of such hazards, assessment of the impact on the proposed development, and the implementation of mitigation or specific design measures, as appropriate, are vital to reducing the vulnerability of the community to seismic hazards.

The most comprehensive earthquake hazard studies to date within New Zealand have been carried out for the Wellington Region. This reflects the high seismic hazards in the Region, the awareness of the community and the pro-active role taken by the Wellington Regional Council. The Council's strategy is outlined in an accompanying paper by Kingsbury (1996). The Wellington Regional Council has led studies through consultants, to identify and map the seismic hazards in the Region, and assess the risk to the built environment and the people.

At territorial authority level, the Porirua City Council have considered the effect of the hazards on the district's infrastructure and put in place measures to ensure that new development in the district takes into consideration the seismic hazards, with a view to reduce the vulnerability of the city and its people.

The Wellington Earthquake Lifelines Group have also considered the vulnerability of lifelines in the Region to earthquake damage, with the active support of lifeline authorities and companies. Some lifeline and other organisations have commissioned follow-on studies to assess the risk to their assets and initiate mitigation measures.

The identification, investigation, assessment and mitigation of seismic hazards is an important issue in land development. The identification of hazards at development stage would enable mitigation measures to be put in place, and hence avoid costly earthquake damage and disruption, and the significantly higher cost of mitigation if carried out after development.

This paper presents experience in the Wellington Region on seismic hazard zonation, risk studies and the application of this information to initiate measures to reduce the long term vulnerability of the community to seismic hazards. In particular, it highlights the importance of recognition of hazards and consideration of mitigation measures in land development.

2. HAZARD IDENTIFICATION

Studies to identify seismic hazards were commissioned by the Wellington Regional Council between 1988 and 1994. The studies comprised mapping :

- ❑ Active Faults
- ❑ Ground Shaking Zones
- ❑ Tsunami Hazards
- ❑ Liquefaction Zones
- ❑ Slope Failure Hazards

The initial scientific studies of the active faults, ground shaking and tsunami were undertaken by the Department of Scientific and Industrial Research (DSIR, presently the Institute of Geological and Nuclear Sciences) and the Oceanographic Institute, followed by geotechnical engineering studies to assess liquefaction and slope failure hazards led by Works Consultancy Services.

The developed areas of the Wellington Region were divided into the following five study areas :

- ❑ Wellington City
- ❑ Hutt Valley
- ❑ Porirua Basin
- ❑ Kapiti Coast
- ❑ Wairarapa

This study area approach allowed the seismic hazard assessment to concentrate on the urban and suburban areas where the consequences of the hazards are high. Slope failure hazards were also mapped along some important state highway corridors falling outside the urban study areas.

2.1 Scenario Approach

Early in the hazard identification programme, the Wellington Regional Council adopted a scenario approach to consider the seismic hazards. The hazards were primarily assessed for the following two possible earthquake scenarios, likely to give different levels of earthquake damage :

- ❑ Scenario 1 is a large, distant, shallow (<60 km) earthquake that produces Modified Mercalli (MM) intensity shaking of V-VI in bedrock over the Wellington Region, with a return period of about 20 to 80 years. Such an event could be a magnitude 7 earthquake centred 100 km from the study area, at a depth of 15 km to 60 km.
- ❑ A Scenario 2 event is a large earthquake centred on the Wellington -Hutt Valley segment of the Wellington Fault. Rupture of this fault segment is expected to be associated with a magnitude 7.5 earthquake at a depth less than 30 km, giving MM IX-X shaking on bedrock in Wellington, Hutt Valley and Porirua.

The scenario approach was chosen by the Wellington Regional Council, given :

- ❑ the relatively high probability of occurrence of the large Wellington Fault (Scenario 2) event in close proximity to the urban areas, with a potentially major impact on the Region, and ;
- ❑ the potential for frequent large distant earthquakes (Scenario 1), with amplified ground shaking and liquefaction, and consequently significant damage in the most susceptible areas underlain by of soft cohesive or large thicknesses of cohesionless deposits.

A third intermediate scenario was chosen for the slope failure hazard study as discussed in Section 2.6 below.

2.2 Active Faults

The initial study comprised investigation and mapping of active faults in the Wellington Region (Department of Scientific and Industrial Research, 1989-1990). The active faults in the western part of the Wellington Region were investigated and mapped, using available information supplemented by field studies. The magnitudes and return periods of earthquakes likely due to rupture of these faults were also assessed. The active faults mapped in the western part of the Wellington Region are shown on Figure 1.

The active fault locations were published by the Wellington Regional Council (1991) as strip maps at a scale of 1 : 25,000. The maps show the level of accuracy with which the fault positions are known.

2.3 Tsunami

A study of the potential for tsunamis to affect the Wellington Harbour was carried out by the Oceanographic Institute for the Wellington Regional Council. The areas around the Wellington Harbour which are likely to be affected (due to inundation) by tsunamis have been mapped.

2.4 Ground Shaking

Ground shaking hazard studies were carried out for the five study areas (Department of Scientific and Industrial Research, 1990-1991). The studies included :

- ❑ Assessment of the potential level of ground shaking on bedrock based on the known active faults and the return periods for shaking ;
- ❑ Mapping of the surface geology of the study areas based on available information and some limited field work, including the thickness, age and characteristics of the sediments ;
- ❑ Installation of instruments in areas of different sediments to monitor microzone effects and the likely modification of ground shaking by the presence of soils overlying bedrock ;
- ❑ Based on the above, assessment of the level of ground shaking across the study areas, reflecting the variation of ground conditions ;
- ❑ Preparation of ground shaking hazard maps for the five study areas, under the two earthquake scenarios.

Five ground shaking zones were mapped, with Zone 1 representing the lowest level of shaking on bedrock, and Zone 5 representing the highest level of shaking due to amplification, in areas underlain by soft soil deposits. Ground shaking hazard maps were published by the Wellington Regional Council (1993) at scales of 1 : 20,000 to 1 : 50,000. A section of a typical ground shaking hazard map is shown on Figure 2.

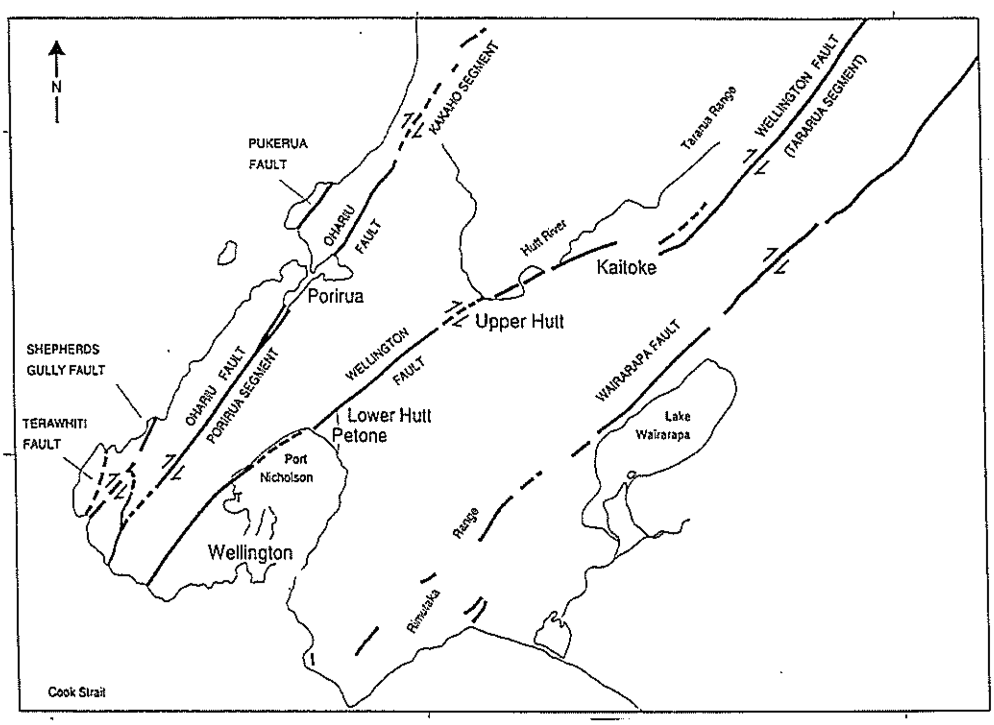

Figure 1 Active Faults in The Wellington Region

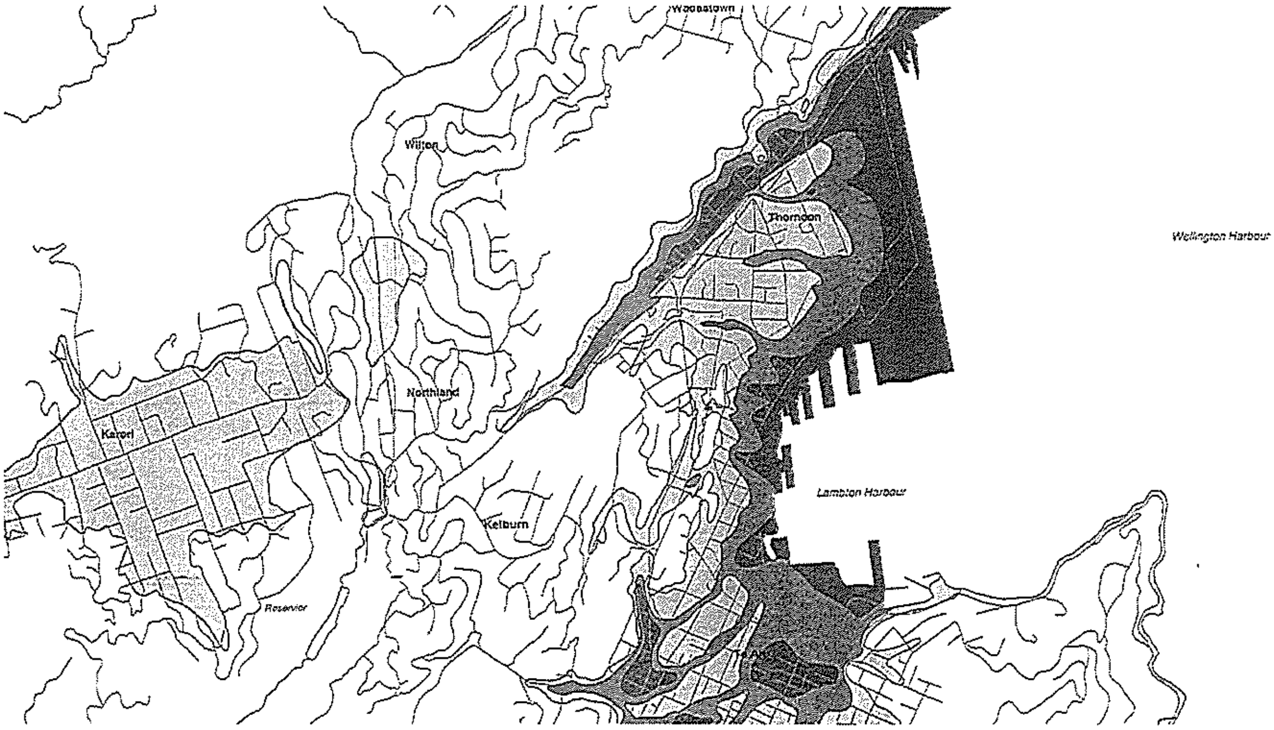

Figure 2 Typical Ground Shaking Hazard Map

2.5 Liquefaction

A liquefaction hazard study covering the five urban areas of the Wellington Region was carried out for the Wellington Regional Council (Works Consultancy Services, 1993a).

Liquefaction is the loss of shear strength of saturated sands and low plasticity silts due to the increase in porewater pressure and reduction in effective stress during earthquake shaking. Liquefaction is manifested by sand boils, ground subsidence, floatation of buried tanks, failures of slopes and lateral spreading of banks and embankments on liquefiable ground.

A specific methodology was developed for the liquefaction hazard study of the Wellington Region (Brabhaharan et al, 1994), and comprised :

- ❑ compilation and review of historical records of liquefaction in the Wellington Region ;
- ❑ compilation of accessible information from past site investigations in the region, and carrying out some additional investigations to fill gaps in the data ;
- ❑ use of ground shaking hazard maps with associated peak ground acceleration estimates which take account of attenuation with distance, and amplification by soft/deep soils ;
- ❑ evaluation of the liquefaction hazard using the site investigation information, surface geology maps and geotechnical methods ;
- ❑ verification of the liquefaction assessment using the available historical records of liquefaction ;
- ❑ assessment of the likely ground damage due to liquefaction (subsidence and lateral spreading), using geotechnical engineering methods and simple rules ;
- ❑ mapping to derive liquefaction hazard and ground damage zones ;

The potential for earthquake induced liquefaction is classified as :

- ❑ High
- ❑ Moderate
- ❑ Variable
- ❑ Low
- ❑ No Liquefaction

Liquefaction potential and ground damage (showing areas vulnerable to subsidence and lateral spreading) maps were produced to scales of 1 : 10,000 to 1 : 25,000, and were published by the Wellington Regional Council (1994) at scales of 1 : 50,000 to 1 : 100,000. A section of a typical liquefaction hazard map is shown in Figure 3.

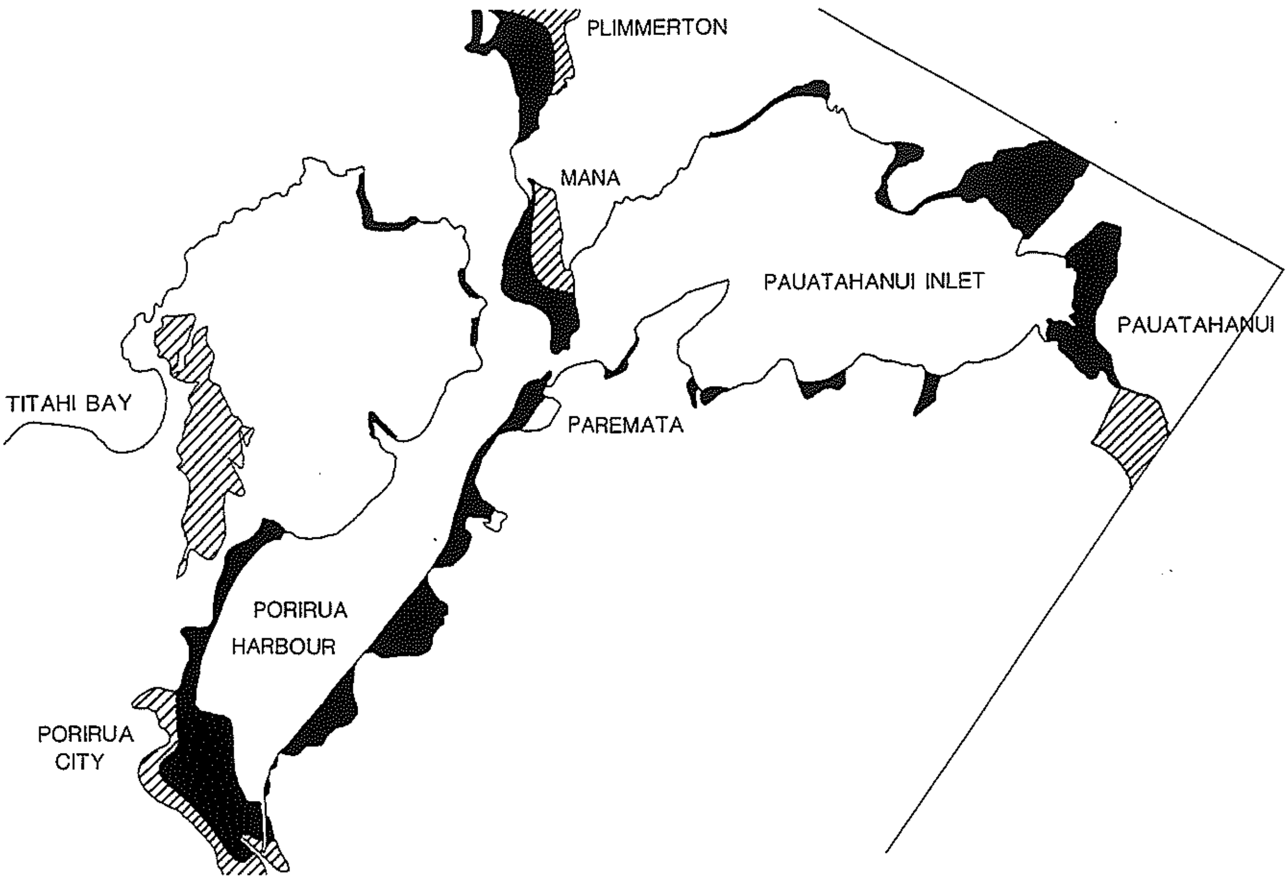

Figure 3 Typical Liquefaction Hazard Map

2.6 Slope Failure

An earthquake induced slope failure hazard study was carried out for the Wellington Regional Council, by Works Consultancy Services (1994) in conjunction with the Institute of Geological and Nuclear Sciences. The study covered the four urban areas of Wellington City, Hutt Valley, Porirua and Kapiti Coast, and in addition included the important state highway corridors of SH 58 between Hutt Valley and Paremata, and SH 2 between Upper Hutt and Featherston (Rimutaka Hill Road). Given the flat topography of the main urban areas of the Wairarapa, and the consequential low susceptibility to slope failures, this study area was excluded from the study.

The largest and most widespread failures during the recorded history of the Wellington Region occurred during the 1855 Wairarapa Earthquake in January 1855, which caused MM X shaking in Wellington. These failures included the large landslide along the harbour front between Ngauranga and Petone, which can still be seen today. This failure has been documented as a painting by Colonel C E Gold.

A methodology was developed for mapping the earthquake induced slope failure hazards in the Wellington Region, following a review of worldwide literature on similar mapping (Brabhaharan et al, 1996). The methodology was tailored to suit the geology, topography and seismicity of the Wellington Region. The methodology comprised :

- Compilation of factor maps (eg slope angle, slope modification, geology, landslides) from available information and site reconnaissance ;
- Integration of factors based on local engineering geological knowledge, and slope failures caused by past earthquakes in the Wellington Region ;
- Use of a third intermediate scenario in addition to Scenarios 1 and 2 discussed in Section 2.1 above. The Intermediate Scenario, giving MM VII-VIII ground shaking on bedrock enables an assessment of the potential for slope failures during a moderate and more frequent earthquake than Scenario 2 ;

- ❑ Appraisal of slope failure hazards using the factor maps, the earthquake scenarios and data from historical earthquakes in the region ;
- ❑ Review of slope failure mechanisms ;
- ❑ Assessment of likely ground damage from slope instability.

The earthquake induced slope failure potential has been classified as very minor, minor, significant, severe and very severe. The likely form and extent of slope failures have also been suggested for the various levels of hazard.

Earthquake induced slope failure hazard maps were produced to a scale of 1 : 25,000, and were published by the Wellington Regional Council (1995) at scales of 1 : 40,000 to 1 : 45,000. A typical slope failure hazard map for a section of the Wellington Region is shown in Figure 4.

2.7 Mapping Techniques

The hazard maps were prepared in ArcINFO geographical information system (GIS) format, and provided as digital data. They are held in the Wellington Regional Council's GIS computer database, and the information can be used easily.

3. VULNERABILITY TO HAZARDS

3.1 Regional Risk Assessment

An earthquake risk assessment study to assess the vulnerability of the community to seismic hazards on a regional level was carried out for the Wellington Regional Council (Works Consultancy Services, 1995a). The study identified and quantified the geographic variation of risk from earthquake hazards, to buildings, key emergency facilities and the population in the main urban areas of the Wellington Region.

The risk assessment study was carried out for the two earthquake scenarios discussed in Section 2.1 above. The risk to buildings was assessed as the probability of the buildings being in one of five damage states :

- ❑ none
- ❑ slight
- ❑ moderate
- ❑ extensive
- ❑ complete.

The risk to key emergency facilities in the Region was also assessed in a similar manner.

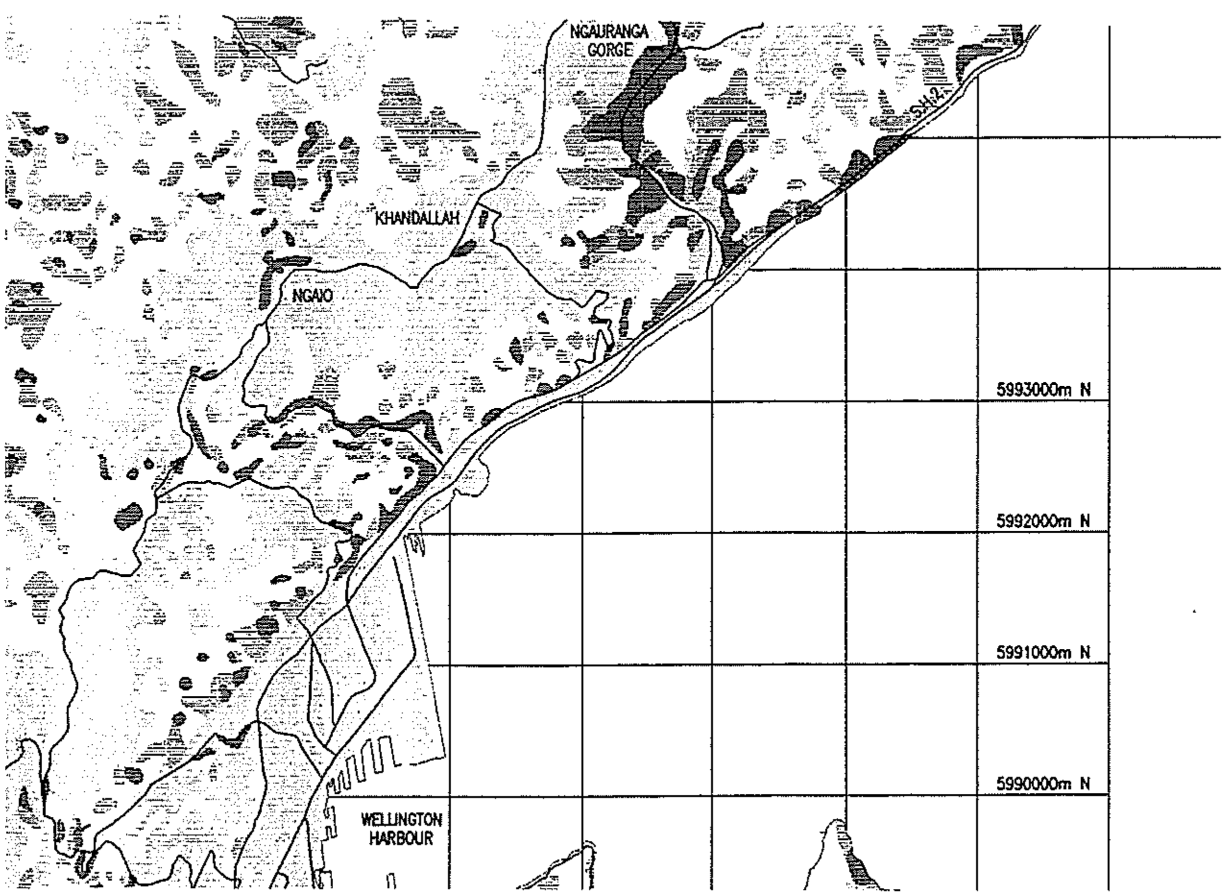

Figure 4 Typical Slope Failure Hazard Map

The cost of repair of the earthquake damage was also estimated. The damage is based on the estimated damage ratios and Valuation New Zealand rolls and values. The study deliberately excluded lifelines and other associated infrastructure as these were considered in the lifelines studies discussed below.

The study also made an estimate of the numbers of deaths and injuries likely due to earthquake damage to buildings, for the two earthquake scenarios. These estimates excluded possible deaths from freak events such as failure of a dam or collapse of a bridge carrying a train.

The results of the study are summarised in Table 1, and show the high vulnerability of the community to earthquake hazards in the Wellington Region.

3.2 Territorial Authority Study

A comprehensive seismic hazard study at a territorial authority level was completed for the Porirua City Council (Works Consultancy Services, 1993b). This study assessed the risk to the infrastructure of the Porirua District from four different earthquake scenarios. In addition to the two scenarios discussed above, the risk was assessed for a large regional earthquake and a M 7.5 earthquake event due to rupture of the Ohariu Fault which has a smaller probability of occurrence, but crosses the Porirua City Centre.

The infrastructural damage considered included :

- Water supply, including pipelines, pump stations and reservoirs ;
- Sanitary Drainage System ;
- Roads, Retaining Walls and Bridges ;
- Buildings, including major city centre buildings, commercial and industrial buildings, residential buildings and premises with dangerous goods.

3.3 Lifeline Studies

Studies on the impact of earthquake hazards on lifelines in the Wellington Region were carried out by the Centre for Advanced Engineering (1992) and the Wellington Earthquake Lifelines Group (1993, 1994 and 1995). These studies assessed the risk to lifelines such as telecommunications, water supply and drainage, electricity, gas, railways and roads. Critical areas were identified for further study.

A similar lifelines study has recently been completed for Christchurch (Centre for Advanced Engineering, 1994).

3.4 Vulnerability of Organisational Assets

A number of organisations have commissioned separate studies to assess the vulnerability of their assets to seismic hazards in the Wellington Region. For example, the Wellington Regional Council commissioned a study to assess the risk to their bulk water supply system from seismic hazards (Works Consultancy Services, 1995b). Similar studies have also been completed for Telecom New Zealand by Works Consultancy Services. Such specific studies have enabled organisations to prioritise mitigation measures.

Table 1 Wellington Region Risk Study Summary

EARTHQUAKE SCENARIO	DAMAGE REPAIR COST ($ MILLION)		NUMBER OF			
	Residential Buildings	Commercial & Industrial Buildings	Injuries		Deaths	
			Day	Night	Day	Night
Scenario 1	123	234	245	13	19	2
Scenario 2	1,956	2041	3,906	360	530	43

4. HAZARD MITIGATION

4.1 Hazard Reduction Methodology

The mitigation of seismic hazards require a structured approach, which may comprise :

a) *Identification of the presence of possible hazards.* This step will be facilitated if there are seismic hazard maps available for the area.

b) *Consideration of the impact of the hazard on the facility (existing or proposed) and the risk.* If the hazard has insignificant risk, then it may be concluded that no mitigation is warranted.

c) *Carrying out site specific investigations.* Such investigations may be required to confirm the hazard, and assess the extent of the hazard and its impact on the facility.

d) *Performance assessment of the existing or proposed facility.* Using the results of the site specific investigations, the risk can be quantified.

e) *Assessment of mitigation options.* Options available for mitigation of the hazards may include :
   - ❑ acceptance of hazard
   - ❑ relocation of facility to less hazardous area
   - ❑ ground improvement to minimise seismic ground damage hazards
   - ❑ specific design measures to reduce vulnerability

   A combination of these measures may be appropriate in some instances.

f) *Consideration of whether mitigation is justifiable.* It is important to consider the appropriateness of mitigation options, as a zero risk mitigation option is rarely justifiable. Considerations may include :
   - ❑ Potential for loss of life
   - ❑ Strategic importance of facility, during and in the aftermath of earthquakes
   - ❑ Importance for business continuance
   - ❑ Cost of mitigation measures
   - ❑ Economics of mitigation measures, assessed using a method such as that presented by Brabhaharan and Vessey (1992).

g) *Prioritise and implement mitigation measures.*

Hazard reduction or mitigation measures can be classified into those for :

❑ Existing facilities, buildings or structures
❑ New development.

These categories differ in the range of options and measures available for reducing the hazard to the facility, and the cost of such mitigation measures. For example relocation and ground improvement may be more viable for new development while prioritising mitigation measures may be applicable to existing facilities.

4.2 Territorial Authority Role

The Resource Management Act 1991 specifies one of the functions of territorial authorities to be *"The control of any actual or potential effects of the use, development, or protection of land, including for the purpose of the avoidance or mitigation of natural hazards .."*(Section 31(b)). In addition, territorial authorities have a function under the Building Act 1991 to ensure that buildings and other structures are designed to an adequate standard, including performance under earthquake conditions.

While the NZ Loadings Standard NZS 4203:1992 specifies load conditions and forces to be considered for earthquake design, it does not adequately specify requirements with respect to earthquake ground damage hazards such as fault rupture, liquefaction or slope failure. Design to NZS 4203 : 1992 on its own will not provide a satisfactory level of protection against such hazards. In addition, it does not cater for the enhanced near-fault ground shaking levels. There is an additional requirement to ensure that these hazards are appropriately taken into account in the design of facilities in areas subject to such seismic hazards.

This places an additional responsibility on the local authority to ensure that such hazards have been adequately taken into consideration, and mitigation measures incorporated as appropriate, prior to the issue of resource or building consents. It is also important that the local authority itself is aware of such seismic hazards. These requirements reinforce the importance of seismic hazard studies. Knowledge of the hazards will enable a territorial authority to provide developers with hazard information through land information memoranda (LIM).

To reduce the vulnerability of the community to seismic hazards, territorial authorities may also specify criteria for new development. Such criteria would be useful to ensure that development adequately takes into consideration the seismic hazards, for example by avoiding high hazard areas for critical facilities (eg hospital not built on an active fault with a significant probability of rupture), and ensuring that public facilities or facilities containing hazardous substances avoid hazard areas or incorporate appropriate mitigation or design measures.

Porirua City Council has taken some pro-active measures in its draft district plan, including :

- inclusion of a seismic hazard map, delineating areas in the district where seismic hazards should be considered in any new development
- incorporation of criteria for control of development in the seismic hazard areas. These measures are designed to ensure that the seismic hazards are taken into consideration, rather than be overly restrictive. Some restrictions are nevertheless proposed, particularly with regard to critical facilities. The Porirua City Council's perspective is discussed further in an accompanying paper by Robertson (1996).

5. EMERGENCY RESPONSE PLANNING

In addition to the engineering initiatives to mitigate hazard, other measures such as emergency management, response and recovery planning can help reduce the impact of major earthquakes on the community. At an organisational level, they could carry out business continuance planning to ensure that their organisation can survive and function, and perhaps exploit the opportunities created, in the aftermath of a large earthquake.

Once again such planning requires a knowledge of the hazards and the consequent risks to the built and natural environment as well as the population.

6. CONCLUSIONS

Wellington Region has been in the forefront in seismic hazard strategies and mitigation initiatives in New Zealand, with the Wellington Regional Council taking a pro-active role. The Wellington experience provides a framework for dealing with seismic hazard issues.

Wellington Regional Council has had studies carried out to assess active faults, tsunami, ground shaking, liquefaction and slope failure hazards, and published maps presenting the information. It has also had the risk to buildings, key emergency facilities and the population assessed. Studies by the Wellington Earthquake Lifelines Group has identified the risk to the lifelines in the Region, such as electricity, gas, roads, telephone etc. The Porirua City Council has had similar studies carried out to assess the potential risk to the infrastructure of the district. Some large organisations also have commissioned studies to assess the seismic hazard to their infrastructure. These studies all show that the built environment and the community are highly vulnerable to the seismic hazards in the region.

The assessment of the hazards and the vulnerability studies are important to reduce or mitigate the long term vulnerability of the community to seismic hazards. Based on the identified hazard information, a structured approach to seismic hazard mitigation is outlined. Hazard mitigation measures can be considered for existing facilities or new development. More options are available at lower cost to mitigate seismic hazards if considered at the time of initiating new development. Remedial measures for existing structures are more costly and options are limited.

The territorial authorities can take a leading role in ensuring that seismic hazards are given adequate consideration in new development. This can be achieved through the powers vested in them through the Resource Management Act 1991 and the Building Act 1991, and using instruments such as the district plans and land information memoranda (LIM). The existing standards do not adequately cover the seismic ground damage hazards to structures. Porirua City Council has adopted the approach of including seismic hazard zones in their new draft district plan, and have incorporated criteria for the control of development in the seismic hazard zones. Other territorial authorities in the Wellington Region have also taken initiatives to include seismic hazards in their district plans.

Seismic ground damage hazards are among the primary geotechnical engineering considerations for land development initiatives in New Zealand. Local authorities, developers as well as consultants and designers should consider the risks to the proposed development posed by seismic hazards, with a view to mitigate the hazards where appropriate. This approach is crucial to reduce the long term vulnerability of the community to seismic hazards.

7. ACKNOWLEDGEMENTS

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TERRITORIAL AUTHORITY PERSPECTIVE/CONTROL OF DEVELOPMENT

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SYNOPSIS: Many buildings and activities require the consent of Territorial local authorities before they can proceed. In a limited number of situations, the presence, or likely presence of a seismic hazard may influence either the design, or the location of a facility or activity. Local authorities are faced with the challenge of assessing whether seismic hazard is an issue with any particular proposal while minimising the cost, and time, entailed in such a check. This paper sets out one approach being taken to these responsibilities.

1. INTRODUCTION

Territorial Local Authorities have a number of responsibilities in relation to seismic, and other hazards. These include civil defence, management of infrastructure, management of corporate assets etc. This statement deals only with responsibilities under the Resource Management Act 1991 as dealt with through the district plan, and, in less detail, to a lesser extent with the requirements for Project Information Memorandums (PIM's) and Land Information Memorandums (LIM's).

2. INTRODUCING THE DISTRICT PLAN

The District Plan, or District Scheme as it was under the previous legislation, has traditionally been both the single most comprehensive geographic document produced by local authorities, and a key source of public information. There are two aspects of the district plan which are vital to an appreciation of the methods by which control of the effect of hazards can be included into these documents.

The first issue is one of certainty. District plan rules must be unambiguous, both in terms of the nature of the activity which they control and the extent of the city over which they apply. District Plan maps are part of a statutory document, the means by which the rules and policies applying to each property in the district can be unambiguously defined. To change a District Plan map is to change the plan itself, a task which entails consultation, public notifications, submissions, hearings etc.

When dealing with a complex topic such as seismic hazard this requirement leaves little scope for statements about margins of error, scale of mapping, location of specific profiles etc.

The second key factor is the time frames within the district plan process. The research, survey, consultation and procedure necessary for the production of a district plan, or a change to a district plan, generally takes a number of years (three to four being common). In addition to this, the statutory processes of submissions, hearings, decisions and appeals can add another two to three years onto the end of the initial development stage.

These time frames have a number of relevant effects:

The information contained in the district plan is already a number of years old before the plan becomes operative. Since the requirements for amendment of the maps is the same as for the finalisation of the original plan there is an ongoing constraint on the updating of information, including seismic hazard information.

If there is no conscious decision made to amend or update the District Plan maps, they can remain in effect for up to ten years before the Resource Management Act requires a review of the Plan. The District Plan is a fixed snapshot of the layers of data which it contains - whether they be subdivision (the cadastral layer), reserves, hazards etc.

3. INTRODUCING PIM'S AND LIM'S

A PIM is a Project Information Memoranda produced in accordance with the Building Act 1991, and a LIM is a Land Information Memoranda produced in accordance with the Local Government Meetings and Official Information Act 1977.

PIM's and LIM's are snapshots of the information held by Council which is relevant to a particular proposal and/or property. A new PIM or LIM is issued each time a request is received, or in the case of a PIM, each time a building consent is sought. This can be for such minor building changes as the installation of a log burner, or for the construction of a new commercial building. The principal difference between the two is that a PIM is issued in relation to a particular building proposal while a LIM is related to the land itself. The relevant sections of legislation have been included as an appendix to this paper to illustrate the types of information which Council is required to provide on a daily basis.

In a PIM or LIM, unlike the District Plan, Council is required to provide all the available information (of the kinds specified in the legislation). In some cases this may mean that information is provided in one PIM which was not available at the time a prior PIM was issued for an earlier development on the same land. PIM's and LIM's are effectively snapshots of the available information, dipping into layers of geographic information which are potentially constantly changing.

Interestingly, Council is not required to include in a PIM or LIM information which is contained in the operative District Plan (this is already available public information). If however, council possesses more up to date or accurate information e.g. on natural hazards, than that which was included in the District Plan at the time when it became operative, it would be required to include this in a PIM or LIM.

4. COUNCIL RESPONSE TO SEISMIC HAZARD INFORMATION IN THE DISTRICT PLANNING PROCESS AND THROUGH PIM'S AND LIM'S

The key component of the Council's response to the requirements of District Plan, PIM and LIM is the Corporate GIS system. In setting up the GIS, Council sought to create a single geographic database, accessible for a range of uses, and maintained in the most up to date form possible. The issue is how to manage an up to date geographic database while at the same time administering legislation which is based on snapshots of geographic data.

The response of Council to this issue is as follows:

4.1 Ensure clarity of data used in Council documents.

This has led to a change in the nature of the District Plan Maps:

One of the traditional approaches to District Planning was to create a new zone where there was significant variation to one factor or geographic layer affecting the planning equation. For example, a fictitious plan might include four residential zones, representing low density, high density, deferred pending the availability of services, and flood prone.

The explanation of the differences between these zones would traditionally be contained in the text of the plan rather than on the maps.

The approach now being taken by the Porirua City Council is to identify a single residential zone with overlying constraint layers for hazards, and for landscape protection. The advantages of this method include:

- The reason for the provisions in the plan are immediately apparent to the user.

- It is relatively straightforward to generate overlays which show any changes to the layers of information since the plan was notified (even though these overlays will not be part of the district plan).

- It provides a common point for the integration of broad land-use planning with the building requirements of the Building Act 1991, in the forms of PIM's.

4.2 Avoid the unnecessary use data which is the subject of change in "locked" documents.
The District Plan has traditionally included a considerable amount of information which was not strictly necessary for the administration of the relevant statutory functions. This information has been provided in recognition that the District Plan is a key, and often the first, source of public information on land-use constraints in the district.

With the changes brought by GIS e.g. the ability to build maps for particular purposes, and the ability to print small runs of maps as needed, the need to include this information in a document such as the district plan which is "locked" has diminished.

Partly in response to the costs of changing a District Plan, and partly in response to the ability to produce geographic output which is directly tailored to the client's needs, there are advantages in reducing the public information function of the District Plan and including in the plan only those layers of information which are necessary for the council's statutory resource management functions.

This approach enables the other layers of information to be updated as the information becomes available. This reduces the potential for conflicting information and provides consistency in the information being used in Council's various functions.

4.3 Use triggers to provide simple access to complex data.
Wherever possible Council is using the same information for all relevant functions.

For example, the City Council's seismic hazard database is sourced from the Regional Council. This database is comprised of the available seismic information - fault line traces, liquefaction zones and ground shaking and areas of slope instability.

Council uses the database directly in the design and location of public works, preparation of emergency management plans and as input into a "further investigation required" layer, used in the District Plan and for PIM's and LIM's.

The "further investigation required" layer has been constructed by extending the seismic hazard area for each of the layers of information to the nearest appropriate cadastral boundary and then compounding all of these individual layers of information on seismic hazard: ground shaking, fault rupture, slope failure etc. A given property is thereby either completely in, or out of this "further investigation required" area.

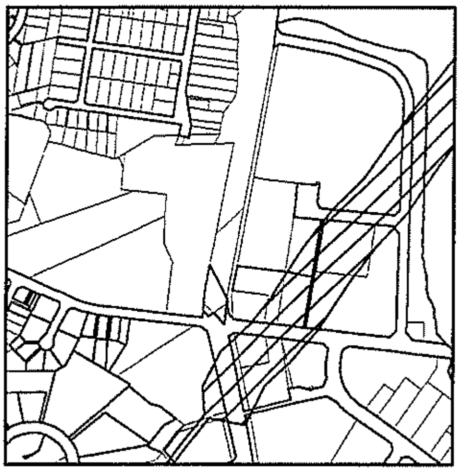
This constructed layer is used within the District Plan, and for the purpose of PIM's and LIM's. It is the early warning trigger to ensure that further investigation of the site is undertaken. Figure 1 illustrates the nature of theis constructed map layer.

The District Plan meets the statutory requirements of certainty while ensuring that the most up to date information is used in assessing the suitability of a site for a particular activity.

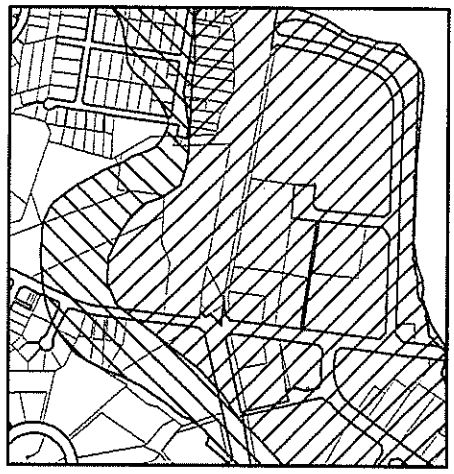
This has been achieved by including the "further investigation required" layer in the planning maps with a rule which requires that activities which are essential to the community require a resource consent before locating within that area. In order to obtain the resource consent the applicant must demonstrate the means by which the risk has been managed. This resource consent process ensures that Council is able to feed into the decision making process the most up to date information on the hazards which might exist on that site, regardless of whether that information was available at the time the plan became operative.

EVOLUTION OF THE PORIRUA CITY COUNCIL FURTHER INVESTIGATION REQUIRED AREA

PRIMARY DATA

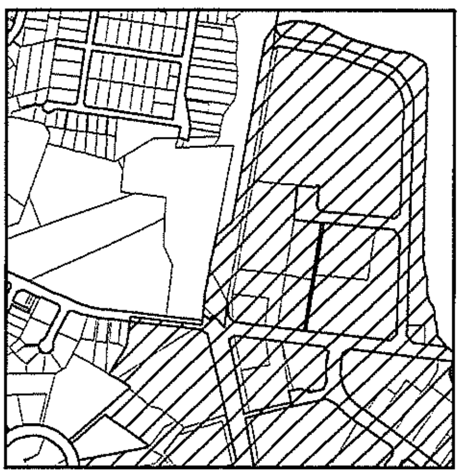


FAULTLINE WITH UNCERTAINCY BUFFER
WELLINGTON REGIONAL COUNCIL.

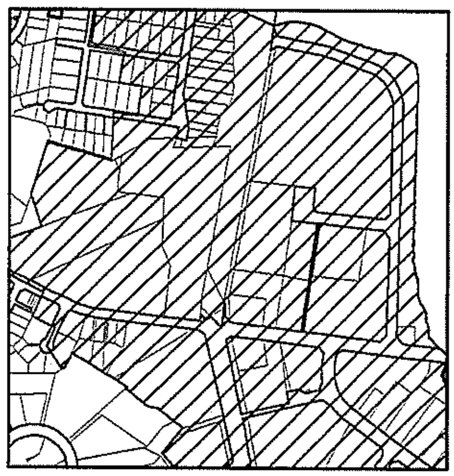


MODERATE & HIGH LIQUEFACTION POTENTIAL
WELLINGTON REGIONAL COUNCIL.

AREA BY AREA EXTENSION TO CADASTRAL BOUNDARIES

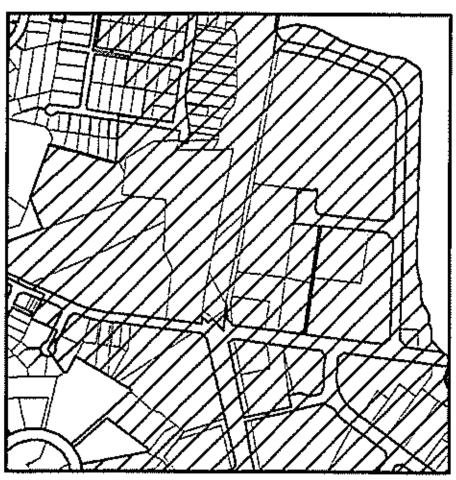


FAULTLINE AREA
WORKS CONSULTANCY SERVICES.



LIQUEFACTION AREA
WORKS CONSULTANCY SERVICES.

COMBINED FURTHER INVESTIGATION REQUIRED AREA



FURTHER INVESTIGATION REQUIRED AREA
WORKS CONSULTANCY SERVICES &
PORIRUA CITY COUNCIL.

In the case of PIM's and LIM's, the same "further investigation required" area provides a window into the complex layers of the seismic hazard database. This allows Council staff with little or no professional experience in hazards are able to issue PIM's and LIM's with confidence where these relate to properties outside the "further investigation required" area. Where a property for which a PIM or LIM is sought is inside the "further investigation required" area. the responsibility for drilling down into the seismic hazard database is left to those qualified to interpret the information.

In addition to the need to meet statutory obligations and to do so in a manner which is professional and technically sound, Council has a responsibility to ensure that information is presented in a manner which is useful to the user. This has been achieved through the preparation of a brochure which provides a common English introduction to the issue of hazards, sets the City in a regional context, and sets the hazards which exist in the City in the context of the standards e.g. building standards, which deal with the management of those hazards.

4.4 Develop detailed archival procedures:
Both the District Plan and individual PIM's and LIM's represent a snapshot of the state of knowledge at the time that these documents were approved, or issued. It is essential that the storage systems for seismic hazard information is able to recreate the state of knowledge at the time such a document is produced. At present this is achieved through a mix of methods from the locking and archival storage of relevant plot files on the GIS system, through to the storage of photocopies of individual PIM's and LIM's within the paper based property filing systems.

5. CONCLUSION

The legislation within which Council's operate imposes certain challenges for the management of geographic data including information on seismic hazard.

Technical information is not easily understood by people unfamiliar with the data. Porirua City Council has taken the approach of creating a "further investigation required" area. This enables Council staff who are unfamiliar with the seismic data, to make decisions on properties that are unaffected by the hazard. Only the properties affected, are passed on to staff familiar with the data for further investigation of the hazard.

Porirua City Council's District Plan contains a reduced set of information, and introduces policies that force requests for information to use the most up to date information available. This reduces the conflict between the fixed nature of the District Plan and the current information that may be supplied as a PIM or a LIM.

As the Council's implementation of more advanced information systems proceeds it is expected that the Council's ability to store and retrieve complex information will improve. At the same time the arrangements for ensuring that the information held is accurate, up to date, and that the "further investigation required" areas are appropriate will require ongoing review.

It should be noted that the time for appeals to the Planning Tribunal on the matters included in the Proposed District Plan is still open at the time of writing and the approach outlined above, and/or its specific application within Porirua City may become the subject of appeals.

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Note:
The facts in this paper are from the Porirua City Council. The opinions are those of the author. The author is a planner. Any comments in relation to statutory requirements are based on a planner's working understanding of these matters. They are not the opinion of a lawyer, or other expert in the field of planning law.

Regional Hazard Identification & Risk Assessment – The Insurance Company Perspective

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SYNOPSIS: Insurers and reinsurers in New Zealand have been placing great importance in the last four or five years on risk assessment, particularly earthquake vulnerability and seismic risk. The paper sets out the background to this. It discusses some of the theoretical and practical issues which need to be taken into account to build up a premium rating table for earthquake risk and describes means by which insurers might assess potential losses from portfolio exposures in different regions.

1. INTRODUCTION

This paper is presented in the first year that the Earthquake Commission in New Zealand no longer accepts the risk of earthquake damage to commercial property. They remain the prime Insurer for residential buildings and residential contents on a first loss basis. The phase-down of earthquake insurance from the EQC to the private insurance market has influenced insurers and reinsurers to pay much more attention to seismic hazard and vulnerability in order that a premium pool is developed for the increased exposures which endeavours to reflect some equity between owners of different buildings and businesses operating in different regions or in different areas within the same region.

2. BACKGROUND

Government took a decision which became effective from 1993 in order that over a period of four years they would gradually phase themselves out from the insurance of commercial risks for earthquake. The philosophy was determined by a need to ensure that residential building owners and occupiers could be adequately housed after a major earthquake event and an assumption that commercial enterprises could manage their own risks either by purchasing insurance or by internal funding so that they would not become a direct burden on the Government, through the Government guarantee given to the Earthquake & War Damage Commission as it was called then.

As insurers became more heavily involved in material damage earthquake risks in the commercial sector they placed more importance on obtaining a spread of premium rates throughout New Zealand that went at least some way to addressing the problems of inequity that can be caused by using too narrow a rating scale.

At the same time the assessment of maximum losses that could be expected to occur across a portfolio was given more attention, these changes occurring at a time when the worldwide reinsurance capacity was being affected by large natural event occurrences, mainly in the northern hemisphere.

3. RISK ASSESSMENT

In looking at assessment on a regional

basis it is appropriate to first consider the full rating or assessment exercise and how the various inter-locking factors, including regional ones, go to make up the premium or loss equation.

Although it varies from insurance office to insurance office a common basis of deriving a premium rating scale is based upon the year of construction, type of construction, and ground conditions.

3.1 Period of Construction

An insurer may group risks into year bands following the main changes in design criteria in New Zealand i.e. pre-1935 buildings, 1935 to 1965, 1965 onwards and 1972 onwards (certain buildings only).

3.2 Type of Construction

The categories used vary from a simple division of buildings into timber framed and other, to a more detailed building split which would take into account also whether load bearing walls form part of the construction or they are framed buildings, under or over four stories in height.

The main reason why some insurers will use a more simple two category construction factor is the difficulty insurance surveyors can have at times, and even engineers have this problem, of correctly allocating a building into its construction type from an external visual inspection.

3.3 Sub-Soil Conditions

The most common divisions used are simply "hard" ground and "soft" ground. For the purpose of applying an appropriate damage ratio.

In some ways these divisions mean just that "soft" is softer than "hard" and "hard" is harder than "soft"! It is probable that these terms will not appeal to geologists who would prefer a greater number of classifications.

There are reasons however for the two divisions. The main one is simplicity of operation because there are difficulties, most of the time, for insurers in precisely categorising sub-soil quality applicable to a particular building. There are enough difficulties at times putting the risk into the appropriate classification when there are only two soil categories to consider let alone three, four or five categories which engineers might otherwise prefer. But with the two categories which are mostly used there is a greater likelihood that the risk will be placed in the most appropriate category within the parameters of the rating tables themselves and therefore there is a far greater chance that the intent of the rating tables will be followed correctly.

The other reason for the two sub-soil categories in common usage is the relationship in the rating formula (see section 3.7) of the damage ratios and return periods or annual probabilities. The formula requires a damage ratio for the risk or group of risks. The chart, Figure 1, forming the base of the calculation provides damage ratios by construction and by ground quality ("hard" or "soft") [1]. To move further from this basis insurers will require similar charts with damage ratios and return periods or probabilities for three, four, five or however many ground quality indices are desired. But this will still require insurers to accurately categorise the ground quality for the risk or risks being rated which is a difficulty that exists now, although may not in future years.

For Wellington and Christchurch most insurers have regional maps for the city areas differentiating the "soft" ground from the "hard" ground. It is well known how difficult it would be in Christchurch, for example, using more than two categories when, we are told, the sub-soil quality can vary within 100 metres.

Damage to buildings "in resonance" with the predominant frequency of ground shaking may be, say, ten times that experienced by buildings not exposed to such frequency bands.

The most common understanding of what is "soft" ground in terms of most insurance rating tables is that "soft" means loose sediment, reclaimed land, artificial fill and land subject to liquefaction.

3.4 Sub-Soil Data

In the last few years and as insurers have become more experienced in the use of sophisticated earthquake rating and assessment techniques there have been a number of enhancements to traditional rating methods brought about by more extensive data becoming available, or being more easy to access.

An important feature of this is the availability in some regions of computer mapping of sub-soil quality enabling insurers to more easily identify the most appropriate index to use and to load or discount the technical rate accordingly.

In addition the availability of computer modelling programmes has enabled underwriters to apply the more extensive regional data to both the construction of rating tables and portfolio assessment calculations.

3.5 Rating Zones

Insurers sub-divide their rating areas into groups of cities or towns. Not all use the same groupings but the majority use five groupings as follows:

The first one known as Zone "A" would comprise of the main cities Whangarei, Auckland and Dunedin.

In Zone "B" Hamilton, Tauranga, New Plymouth and Invercargill are included.

Zone "C" includes Rotorua and Christchurch.

Zone "D" which is the most highest rated zone comprises Gisborne, Napier, Hastings, Masterton, Palmerston North, Wellington, Nelson and Blenheim.

Zone "E" has Wanganui and Greymouth.

Other smaller centres are allocated into one of these five zones from consideration of expected earthquake frequency and relative position within the design seismic zones. The adoption of five zones or any more than five enables the regional seismic hazard to be reflected in the rating.

Theoretically every town in New Zealand could have its own unique rating factor but in practice the market finds that relative simplicity of operation has a better chance of correct application [6].

To arrive at a premium rate for a risk reference would be made to the appropriate rating zone from which construction and sub-soil quality is then considered for the risk in question.

The insurer in doing this is taking into account the average expectation of loss corresponding to a particular return period or in other words the annual event probability expressed as a percentage.

Figure 1 shows a table containing vulnerability and hazard data from which risk may be assessed and a premium rate built up.

The use of computer modelling programmes by several insurers has enabled a greater number of regional differences to be allowed for. As an example a major insurer uses a programme which contains in its database information for 38 zones with geo-technical hazard being based upon sub-soil quality, liquefaction potential and landslide potential. This programme allows for the actual location of a specific risk or an area unit level which is a sub-section of the 38 zones to be used and the regions can be broken down to a street address level if necessary. At that stage the sub-soil specific to the actual risk can become the integral part of the calculation.

SITE: WELLINGTON, GISBORNE, NAPIER, MASTERTON, PALMERSTON NORTH, BLENHEM, NELSON

		STRUCTURE	Return Period of % loss or more: 5	20	50	Max Loss %	Return Period	Probability (%) Of Given % Loss or More in Specified Period (years): 1 year: 5	20	50	max.	10 years: 5	20	50	max.	100 years: 5	20	50	max.	1000 years: 5	20	50	max.
Soft Ground	Pre 1935	Load Bearing Walls Framed	20	40	80	80	250	5.0	2.5	1.3	0.4	39	22	12	4	H	92	71	33	H	H	H	H
		Timber	40	150	1000	80	I	2.5	0.7	0.1	L	22	7	1	(0.5)	92	48	10	(5)	H	H	86	(40)
	1935-65	Load Bearing Walls (4 Storeys or less) Framed (4 Storeys or less) Walls (Over 4 Storeys)	40	75	250	70	4000	2.5	1.3	0.4	L	22	13	4	0.5	92	73	33	5	H	H	H	39
		Framed (Over 4 Storeys)	40	70	200	70	3000	2.5	1.5	0.5	L	22	14	5	1	92	75	59	5	H	H	H	39
		Timber	70	450	I	70	I	1.4	0.2	L	L	14	2	(0.5)	(0.5)	75	20	(5)	(5)	H	89	(40)	(40)
	1965 on	Load Bearing Walls (4 Storeys or less) Framed (4 Storeys or less) Walls (Over 4 Storeys)	40	180	I	60	I	2.5	0.6	L	L	22	6	(0.5)	(0.5)	92	43	(5)	(5)	H	H	(40)	(40)
		Framed (Over 4 Storeys)	40	80	500	60	1000	2.5	1.3	0.2	0.1	22	12	2	1	92	72	13	10	H	H	86	63
		Timber	130	1500	I	60	I	0.8	0.06	L	L	8	6	(0.5)	(0.5)	54	7	(5)	(5)	H	48	(40)	(40)
	1972 on	Framed (Over 4 Storeys)	40	350	I	60	I	2.5	0.3	L	L	22	3	(0.5)	(0.5)	92	25	(5)	(5)	H	95	(40)	(40)
Hard Ground	Pre 1935	Load Bearing Walls Framed	40	70	180	80	450	2.5	1.4	0.6	0.2	22	14	6	2	92	75	42	20	H	H	H	89
		Timber	60	190	1250	80	I	1.7	0.5	0.08	L	16	5	0.8	(0.5)	81	42	8	(5)	H	H	55	(40)
	1935-65	Load Bearing Walls (4 Storeys or less) Framed (4 Storeys or less) Walls (Over 4 Storeys)	60	150	400	70	1000	1.7	0.7	0.25	0.1	16	7	2.5	1	81	48	22	10	H	H	92	63
		Framed (Over 4 Storeys)	60	130	350	70	1000	2.0	0.8	0.3	0.1	16	8	3	1	81	54	25	1	H	H	H	63
		Timber	90	600	I	70	I	1.1	0.2	L	L	11	2	(0.5)	(0.5)	67	17	(5)	(5)	H	81	(40)	(40)
	1965 on	Load Bearing Walls (4 Storeys or less) Framed (4 Storeys or less) Walls (Over 4 Storeys)	60	350	1000	60	I	1.3	0.3	0.1	L	16	3	1	(0.5)	81	25	10	(5)	H	H	63	(40)
		Framed (Over 4 Storeys)	60	130	500	60	1000	1.3	0.8	0.2	0.1	16	8	2	1	81	54	18	10	H	H	86	63
		Timber	160	I	I	60	I	0.6	L	L	L	6	(0.5)	(0.5)	(0.5)	47	(5)	(5)	(5)	H	(40)	(40)	(40)
	1972 on	Framed (Over 4 Storeys)	60	350	I	50	I	1.3	0.3	L	L	16	3	(0.5)	(0.5)	81	25	(5)	(5)	H	H	(40)	(40)

NOTES:

I means Indeterminate but in excess of 2000 years
H means a high probability, in excess of 95%
L means a low probability, below 0.05 %
( ) means that a return period of 2000 years is assumed

Fig 1

3.6 Damage Ratios

A premium rating table is operated by allocating a risk into a category which measures the equivalent annual probability of a certain mean damage ratio being exceeded.

For example if an earthquake event has a return period of 100 years there is therefore an annual frequency of 1% and if the expected loss by that earthquake is 20% of its replacement value then the theoretical net rate required is 20 divided by 100, a 0.2% per annum premium for this one event.

3.7 Premium Rating

If we look at just this one event a rate can be calculated using the following formula [5]:

$$X = \frac{LE \cdot f \cdot v \cdot P \cdot 100}{SI \cdot R}$$

In this formula:

X = The gross rate in percent for the period P (for a single event).

LE = The loss expected for an

event which corresponds to the return period R used in the calculation.

f = A factor which covers deductions (commission or brokerage) insurers costs, profit.

v = A variance or safety factor to cover the uncertainty in the determination of the return period and expected loss combination. The insurer needs to try and provide a buffer in case the return period does not turn out to what it would be, particularly when it will not do that over a short observation period or a short insurance period. Tiedemann [7] in his excellent book provides (at 670-672) discussion on the application of uncertainty factors to a rating formula but in practice in New Zealand a more simple flat loading is applied.

P = Period of exposure. Nearly always 1 being one year.

100 = A factor to obtain the rate X in % of the insured value.

SI = Sum Insured either as a amount if the loss has been expressed as a sum of money or as 100% if the LE is given in percent.

R = The return period of the event liable to cause the damage equivalent to LE. The probability of the damaging event could be used as an alternative, for example, the annual probability might be 5% in which case R would be 20 years.

The formula would work correctly if the return period is many times longer than the insurance period. Insurance periods are normally for 12 months and return periods of damaging events are considerably longer. Therefore the insurer must make an allowance for the exposure of a risk to earthquakes of varying magnitudes or for damage produced by various earthquake intensities. In considering annual policies the return period factor could be replaced by the less ambiguous annual event probability.

In a small market like New Zealand no premium is high enough if the event being rated happens tomorrow!

3.8 Several Events

In allowing for more than one event the formula would be adjusted to take the sum of a series of several events. For example, using data from the chart in Figure 1, a formula may be constructed using return periods for losses which have an expected damage ratio of 5%, 20%, 50% and the maximum percentage expected. Similarly it would be possible to use variable percentages for several different MM intensities although information on damage ratios for varying MM intensities is not readily available.

The purpose of the rating calculation is to try and allow for the fact that the vulnerable buildings will suffer damage if intensities are comparatively low but the damage will reach severe proportions at intensities which might only cause moderate losses to earthquake resistant buildings, and the damage might amount to a total loss at high intensities.

The more vulnerable a structure is to earthquake damage the greater necessity there is to perform the calculation over a wide range of intensities or mean damage ratios.

3.9 Contents & Business Interruption

The base rates are normally applied to buildings and there are additions or deductions for contents and with business interruption being at +50% or +100%.

3.10 The Practical Problems

The above section sets out the

theoretical basis for constructing a rating table.

Insurers can calculate theoretical technical premium rates required for a given risk or across a given portfolio of risks which over a long period could be expected to produce a balanced result. (Technical surplus equalling the profit expectation built into the rating formula). However most of the time insurers are issuing policies for 12 months and need to stabilise their balance sheet within that 12 month period. The purchase of reinsurance is one means used to stabilise the balance sheet, i.e. smooth the results.

If their costs, including reinsurance costs, are too high to enable the normal technical rate to be charged over that 12 month period then that technical rate has to rise to cover these actual costs not just expected costs in a normal year. Insurers want to balance their book across New Zealand, reinsurers are balancing their book globally so events outside New Zealand such as northern hemisphere storms and earthquakes can significantly affect earthquake rating of risks within New Zealand.

Reinsurance capacity and pricing can be quite volatile from year to year depending both upon the extent of claims worldwide and the amount of risk capital looking for reinsurance business.

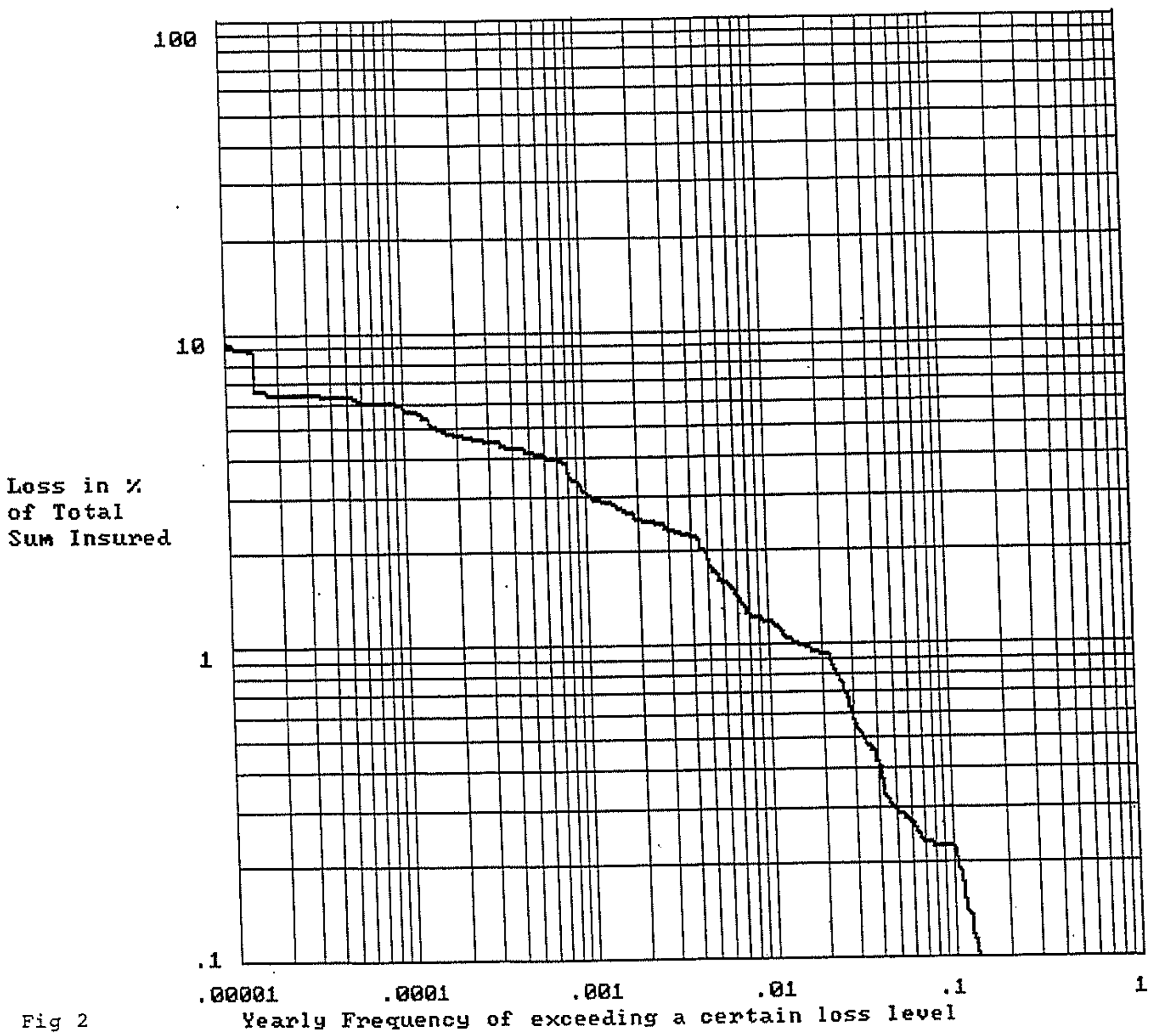

Fig 2

Figure 2 shows what a Loss Frequency curve might look like for the estimated commitment the New Zealand insurance market might have in the commercial sector only by the end of 1996 [2]. The loss expectancy for a 1 in 500 year event including the domestic portfolios and before the purchase of catastrophe reinsurance could be about $1,500 mio, against an expected earthquake premium pool at December 1996 of about $200-$250 mio. The difference is more than the combined reserves of all the companies therefore it is necessary that the risk be managed by the purchase of reinsurance and to some extent the reinsurance costs can have as equal an influence on premium charges as regional seismic hazard variations can have. That is the reality of matching long term probabilities with short term cash-flows.

In mentioning reserves it is relevant to mention that reserves can only be created from tax paid surplus. Earthquake premiums are collected on a year to year basis but large events have long return periods. The New Zealand insurance market has been pushing to be able to set up specific catastrophe reserves on a tax-free basis but this idea has not yet been accepted by the politicians or officials.

4. ESTIMATED MAXIMUM LOSS ASSESSMENT

Insurers need to evaluate the potential loss a single risk is exposed to and the potential losses that a portfolio of risk is exposed to.

It is necessary to have confidence that when the earthquake occurs the insurer has bought enough secure reinsurance to enable the remaining net loss to the insurer to be met from reserves and the current years premium. Also to have enough left over to reinstate the reinsurance programme for the remainder of the year without causing any serious downgrading of the insurers solvency margin and claims paying rating.

Similarly reinsurers themselves need to assess the expected losses from a number of reinsured portfolios to ensure that earthquake capacity is not allocated beyond their capacity to pay.

4.1 Cresta Zoning

Reinsurers worldwide collect exposure data from insurers on a CRESTA zone basis (Catastrophe Risk Evaluation and Standardising Target Accumulations), the zones in New Zealand being roughly equivalent to what are recognised as provinces. The zones are not intended to be equivalent to one or more seismic zones but are convenient boundaries into which various main cities or towns fit and when devised were zones into which most insurers were able to code individual exposures with a minimum of difficulty i.e. little doubt which zones most risks would fall into.

4.2 Assessment Techniques

Techniques used to assess loss in a portfolio vary from simple percentage estimates in key cities to calculations performed by complex computer modelling programmes.

The more modern scientific approach to loss estimation has its origins in a technique pioneered over 20 years ago by Dr Don Friedman from Travellers Insurance Company in the USA [3]. This approach is based on simulating the occurrence of a hazard of specified magnitude in a particular location using maps of insurance exposure. In his early studies Friedman used either the characteristics of actual historical extreme events or postulated extreme events but today the most sophisticated studies randomly simulate the events based on the estimated statistical characteristics of their occurrence in the particular locality. At the simplest level these approaches can be used to obtain rough estimates of maximum credible event losses by superimposing estimated isoseismals for extreme earthquakes on maps of the insurance exposure. The more sophisticated approach is to randomly simulate hundreds of years of earthquake occurrences and calculate the losses for each occurrence to produce data that can be used to give estimated losses as a function of return period. If the information is available the effects of soil properties on local intensity can be included [8].

All techniques rely on advice from the engineering fraternity who can provide sets of calculations based upon risk samples. There are a number of good computer modelling programmes in use owned by consultants and by insurers and reinsurers (e.g. Munich Re, Swiss Re).

The key factor is that in all cases full recognition is given to variable hazard factors for different cities or regions even though the result may be expressed as a percentage of the total New Zealand wide exposure and therefore not obvious to the outsider that regional hazard has been considered.

Importance given to regional variations in seismic risk is, quite understandably, the reason why earthquake insurance for some risks in the Wellington area is becoming increasingly difficult to obtain, or obtain at a economic price. Wellington being both high value exposure and high hazard has a very significant effect on the amount of reinsurance an insurer has to purchase and therefore, indirectly, on the total costs that have to be recovered from the consumer through premium charges.

The estimated loss assessment will be made by the insurer on management judgement taking into account the return period of the type of loss that the insurer believes they need to be able to stand without suffering any serious diminution of their solvency margin. A problem all insurers have is that sums insured will often have an insufficient allowance for post-event inflation.

There will be some insurers who would be comfortable funding, or buying reinsurance protection, based on a 1 in 100 year event but the majority would probably look at protection based upon events with a return period of 250 to 500 years. In saying this it follows that a 1 in 10,000 year event in New Zealand, if it happened, would likely exhaust the reinsurance purchased and free reserves of most insurers.

5. THE FUTURE

There is little doubt that earthquake risk assessment by insurers in New Zealand will continue to be of great importance especially now that all commercial risks are being placed into the private insurance sector. It has been seen, particularly in the last couple of years, that some commercial organisations have been having difficulties in getting adequate or even any insurance on Wellington risks where because of either the period and type of construction or the sub-soil quality there has been a reluctance by insurers to grant insurance. No matter what premium rate may be able to be charged and often the true technical rate is not affordable. Obviously the pre-1935 buildings or old buildings on "soft" ground are the ones that have the difficulty but this difficulty might extend into anything constructed before 1965 as insurance capacity gets rationed out and insurers look to allocate a higher percentage of it to the less hazardous areas.

There have also been many instances where it has not been easy to obtain business interruption or loss of rents cover for long indemnity periods, these having been pulled back from three or five years to two years or less. Again more in the regions of highest seismic hazard.

Insurers and reinsurers funds are not unlimited. Solvency margins can only be protected by the purchase of reinsurance or retrocession covers or other risk transfer techniques or by capping the exposures.

We will surely see in the future some further increases in deductible levels, which have already increased at the start of this year from that prevailing during the early years of the phase-down, and now commonly vary with seismic hazard areas.

The regional differences in hazard will always be taken into account and form an integral part of earthquake risk rating and expected loss calculations.

Geo-technical engineers will be able to assist the insurance industry by continuing research which will enable better or easier identification by non engineering people of sub-soil quality and also by providing reports either for individual risks or regional reports for portfolio assessment.

It is most likely that the major change to occur in the medium term will be the greater availability of digitalised soil mapping software which will assist insurers to more easily apply a sub-soil index to a specific risk. Already we have data collection by insurers on a street address basis (insured values) and the next step is to be able to more easily identify the sub-soil quality specific to that insured value which will lead to more accurate risk assessment than applying an average index for the general area.

As continuing research is done on regional seismic hazard the revision of damage ratio estimates by region, by type of construction, and by sub-soil quality will enable modification to current assessment methods to be undertaken thus reflecting current knowledge.

6. ACKNOWLEDGEMENTS

Graham Byrnes, John O'Hara, Philip Robinson and Alex Robertson kindly provided updated information on current assessment methods and reviewed the draft making some thoughtful suggestions.

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Local Authority Perspective On Subdivision Consent In Hazardous Areas.

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Synopsis
The following is a discussion of administration by the Dunedin City Council of subdivision applications processed in accordance with the Resource Management Act. Specifically, the procedure is discussed where the land is subject to instability or where coal mining is known to have occurred. Council's Technical Services Engineer is engaged to advise the Consent Applications Sub-committee on the suitability of applications submitted and upon relevant geotechnical issues.

1. Introduction
The Dunedin City Council has since the introduction of the Act established procedures whereby Council Departments provide comment to the Council's Surveyor on matters relevant to each Department. The Council's Surveyor reports to the Consent Applications Sub-committee which then considers the application for land subdivision. Council's Engineer reports upon any geotechnical issues relevant to each application, subsequently following up with a review of any additional report(s) submitted by the applicant's Geotechnical Consultant. When notified of site remedial works and development works the Engineer (or a staff member) also inspects the subdivision site to confirm the nature of these works.

A significant percentage of applications have in the last decade been reported upon by the Engineer because of the presence within the City of extensive areas which are subject to instability or which are situated over old coal mine workings. Researchers in the geotechnical field have reported upon the instability of soils on the Otago Peninsula (D M Leslie), the presence of coal mines under Fairfield (A R Mutch, P J Glassey, D L Stewart) and the instability in the south west Dunedin area centred around Green Island (I C McKellar).

The territorial authority which administered land to the west and south west of the Dunedin metropolitan area prior to local authority amalgamation had instigated a minimum lot size of 2.0 hectares for land zoned for rural residential purposes. Much of this land has been the subject of subdivision applications during the last five years and of comment by Council's Engineer because of the land instability risk.

2. Legislative Requirements
Land subdivision consent is subject to the requirements of the Resource Management Act. The purpose of the Act is to promote the sustainable management of natural and physical resources (Sec.5). Specifically the Act emphasises the need to protect the natural environment while enabling communities to provide for their own social and economic wellbeing.

The functions of Territorial Authorities are stated in general terms in Sec.31 of the Act.
They include responsibility for protection of the land and control of natural hazards (their remedy and mitigation). The Act states that subdivision consent shall not be granted where any land or any structure on the land is likely to be subject to material damage by erosion, subsidence, etc. or where subsequent use is likely to accelerate, worsen, or result in material damage to the land (Sec.106 (1) (a) & (b)). Consent may however be granted where provision can be made to the satisfaction of the

Territorial Authority for the protection of the land. (Sec.220(1)(d)).

The Territorial Authority is therefore required to act as guardian of the land, whilst providing for the social, economic and cultural wellbeing of the community.

Contrary to popular belief the Act does not place any emphasis upon nor define the term "building platform", so that although provision of a satisfactory building location may be one objective of any subdivision, the Act's focus is upon protection of the land.

Building Consent is subject to the requirements of the Building Act 1991. The criteria for consent where land is subject to a natural hazard are stated in Sec. 36 of this Act. The criteria in that clause of the Act apply regardless of whether the application relates to building upon a pre-existing site or upon recently subdivided land. Building Consent shall be refused where the land is subject to, or is likely to be subject to erosion, alluvion, etc. or where the building work itself is likely to accelerate, worsen, etc. the hazard (Sec.36(1)). The Consent may however be granted where the Territorial Authority considers that the land can be protected. Where the Territorial Authority considers that building will not worsen any hazard, then consent may be granted subject to an entry being made on the certificate of title to the land (Sec.36(2)). The entry remains as an advisory statement that a hazard exists and absolves the Authority of civil liability.

The Building Act also provides a comprehensive Building Code complete with "Verification Methods" (or means of compliance). Method B1/VM4 in "Foundations" provides a criteria for stability assessments of permanent slopes at prospective building sites. The stated factor of safety is 1.5. This criteria therefore impinges upon the subdivision process, requiring consideration of this standard by the Territorial Authority prior to issuing a subdivision consent. This sweeping requirement has already attracted considerable debate because it ignores the intangibles in any slope stability analysis.

3. The Engineer As Advisor

In reviewing subdivision applications Council's Engineer, Dunedin City Council has adopted the following principles relating to geotechnical hazards present, the ability of the applicant to avoid, remedy, or mitigate the hazards, and ultimately the ability of the landowner to effectively maintain such works.

Principles include;

1. Subdivision is seen as a long term effect, with the proposed buildings remaining in place and at minimal risk from natural hazards for in excess of 150 years.

2. The Act identifies the land as a natural resource to be afforded long term protection from inappropriate development or change of use.

3. Council should consider the broader picture in regard to hazard assessment at any site. Where the applicant's land is adjacent to extensive areas of slope instability then the investigation should determine whether that land could suffer the same fate.

4. Modification of the proposed subdivision at the application stage may effectively reduce the subsequent impact on the land. A reduction in lot density or realignment of proposed boundaries for instance, may result in access roads clearing marginal slopes rather than attempting to cross them.

5. Boundary locations within a subdivision should permit individual landowners to maintain and manage those areas which might otherwise, if neglected, represent a hazard to themselves.

6. Council must assume that future landowners will have only a rudimentary understanding of the hazards and the impact of their own development activities upon the land.

7. Remedial measures if required by Council for subdivision consent should be constructed by the subdividor prior to subdivision seal, rather than by future lot owners.

8. Where deep drains or other remedial measures are considered essential to long term stability the Council should question whether consent is appropriate. Inspection and maintenance of these works by the owner may lapse with time resulting in marginal conditions arising and may result in failure.

9. The Council's approach is generally to assess slope stability in non-analytical terms, only requiring mathematical analysis where design of remedial measures for an active landslide dictate otherwise or where a subdivision applicant wishes to subdivide land adjacent to a high risk area.

10. Applicants are invariably reluctant to fund geotechnical investigations, but in the final analysis the Council must be satisfied that subdivision is in the community's long-term interest. Informal meetings with Council's Engineer prior to lodging an application may assist in identification of those problem areas requiring detailed investigation.

Council's Engineer also has responsibility for the maintenance of the hazards register and has provided advice on hazards as part of the District Plan Review. These tasks are considered complimentary to the subdivision review process.

Council's Engineer is also directly involved with administration of known unstable areas within existing residential areas of the City. This is invariably a difficult task because of the expectations of residents that the problem will immediately be solved by Council (the East Abbotsford Landslide of 1979 was an exception as all dwellings were demolished or relocated within months of that event).

4. Assessment Of An Application

At the Dunedin City Council the subdivision application along with any geotechnical report appended to it, is reviewed by Council's Engineer. Previous records of instability, including geological, soils and hazard maps and aerial photographs are reviewed. A site walk-over inspection is also carried out prior to the Engineer's report being prepared and forwarded to Council's Surveyor.

The report may call for further investigation by the applicant's Geotechnical Consultant, may advise in favour of the application proceeding subject to specific remedial works being undertaken, and/or may advise that a consent notice be placed upon the certificate of title. This legal notice on the title will specify the obligations of the landowner(s) to carry out works and their ongoing responsibility for maintenance of remedial measures. Such remedial works may include drain construction and/or conversion of land use from pasture to forest.

In theory an applicant may at any time submit results of further investigations in an effort to satisfy Council that subdivision consent is appropriate. Council not the applicant has the duty to make the correct decision and even when the decision is imposed by a Planning Tribunal will be considered responsible when for example, slope failure subsequently occurs.

The figures (1 & 2) included below give an indication of the staged process which an application to subdivide must pass through on it's path to final consent. This process may be drawn out where geotechnical issues are debated. The Territorial Authority is however expected to meet the deadlines stated in the Act.

Council's Engineer has on occasion called for an independent review of the geotechnical report appended to a subdivision application, however this action has been the exception not the rule.

5. Provision of Geotechnical Reports

In presenting a report to Council in support of a subdivision application one may reasonably ask a number of questions including;

1. Who is a "suitably qualified person" from the Territorial Authority's point of view to submit a geotechnical report in support of an application? The Dunedin City Council does not have a short list of individuals nor any stated criteria such as membership of IPENZ or the Geomechanics Society for selection. It would in theory accept a report from any individual, relying upon the internal review to assess the merits of the submission presented. However those involved in the field are well known to Council staff so that questioning of an individual's credentials has not been necessary.

2. What standard of investigation is required? Council has no predetermined criteria as to the extent of site mapping, subsurface investigation, monitoring or testing required at a proposed subdivision site.

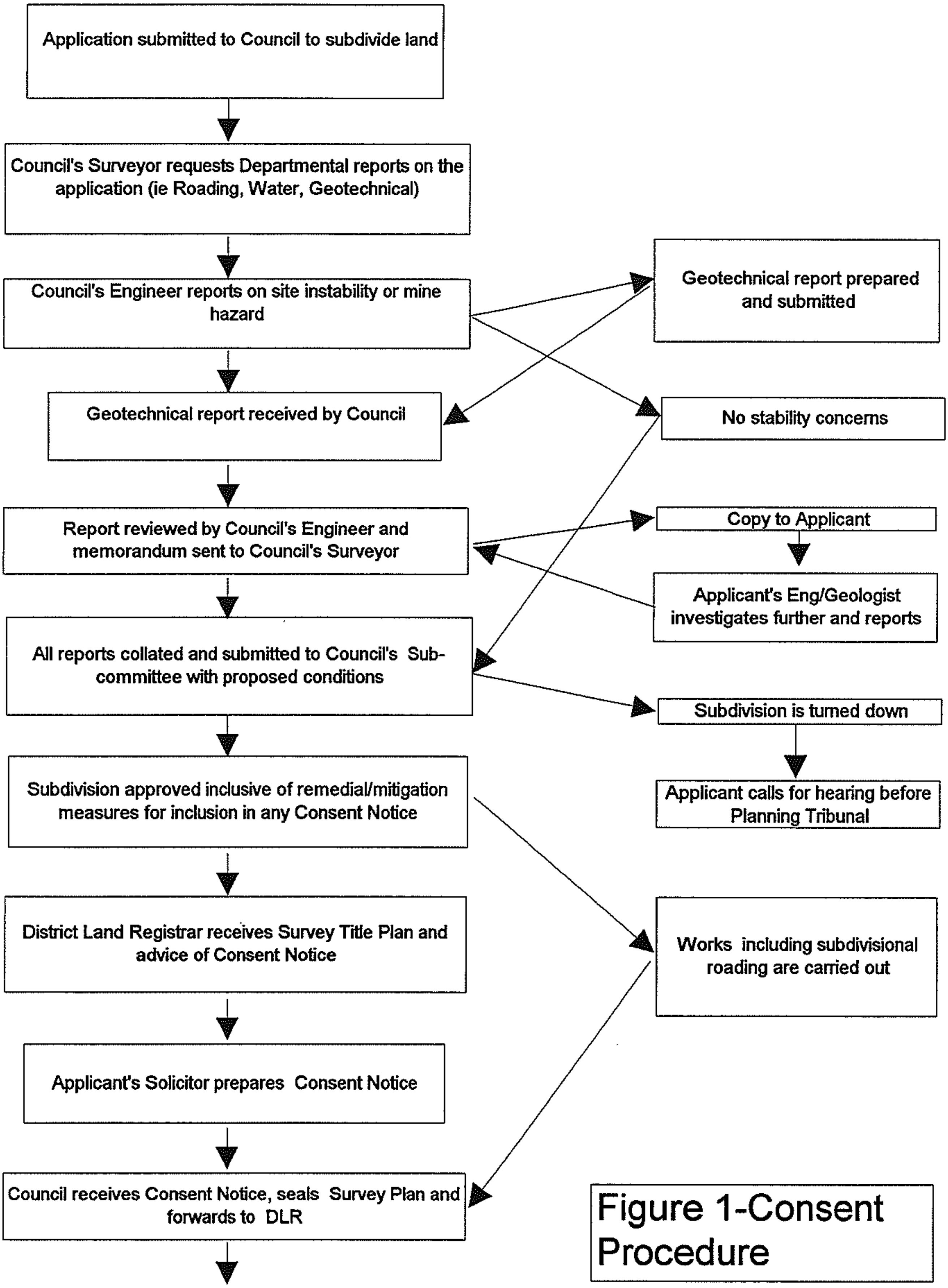

Figure 1-Consent Procedure

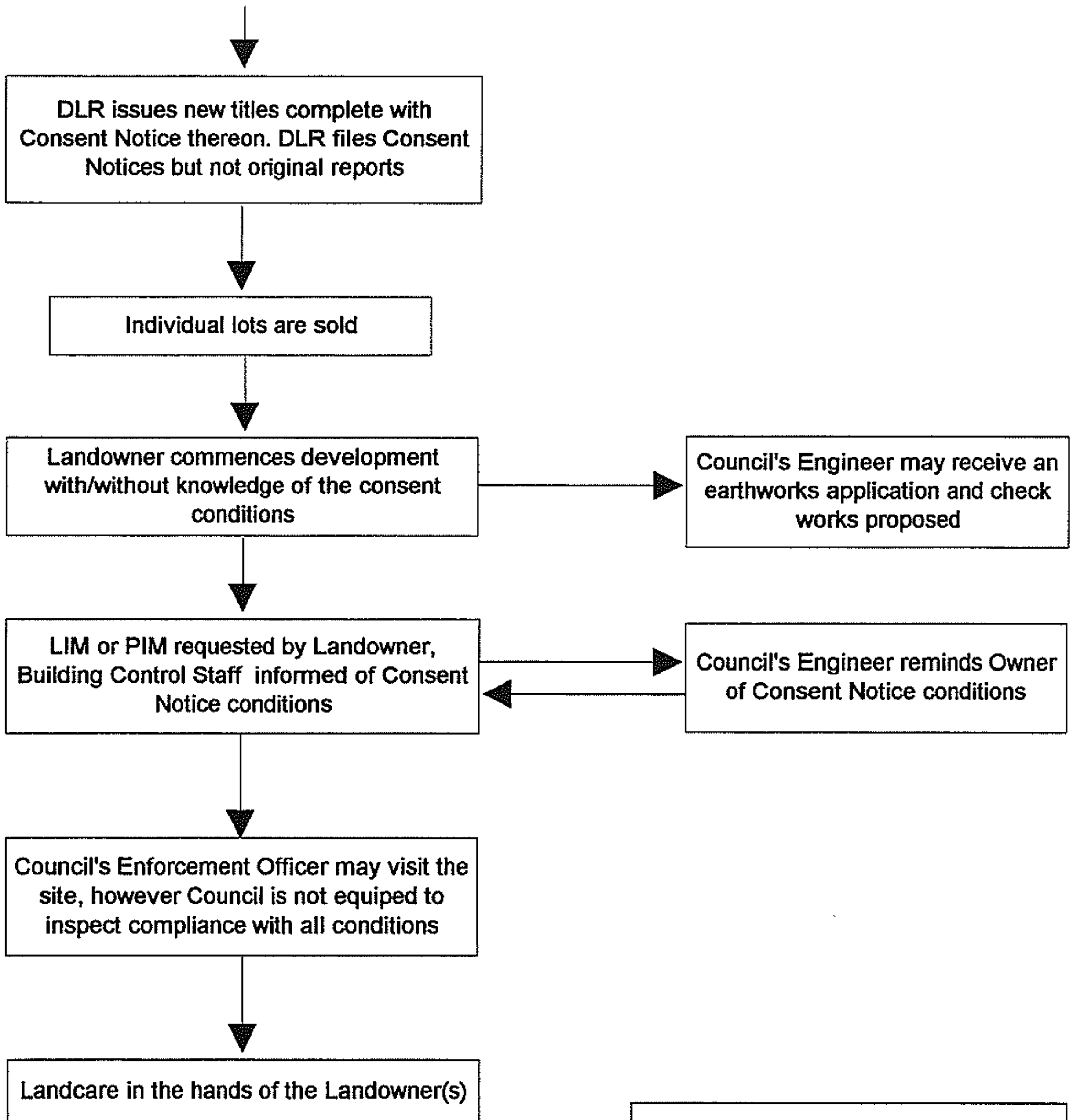

Figure 2 -Consent Procedure

3. How extensive a report is required? This subject should ideally be discussed with Council's Engineer prior to report preparation. Council's Engineer in reviewing the whole application determines the relevance of the report received in the context of the application and cross references those investigations with his own observations, knowledge of the regional land stability, and research. In regard to the presence of coal mines Council is particularly dependant upon the Mines Department records (dating back to the 1870's) and the research of others.

4. What has Council's Engineer stated in his report? The internal report from Council's Engineer to Council's Surveyor is generally made available to the applicant so that misunderstandings are minimised, and so that any further investigative works can be discussed informally. The extent of further investigations are generally a reflection of the regional stability, and the extent of the subdivision proposed. Localised sheet erosion features are likely to be of less concern than deep seated earthflows or slumps. The relevance of factors of safety would only be considered where remedial works involving significant landslides were contemplated. The Engineer would probably recommend the consent be refused where such a risk existed and where such close scrutiny was necessary.

6. Post Consent Issues

Immediately following the consent to subdivide the landowner has Council's approval to proceed with such matters as fencing and formation of access roads, all based upon the survey title plan. Only following the seal of the plan by Council and issue by the District Land Registrar of new certificates of title to each lot can the purchaser(s) obtain title.

In practice much of the development related earthworks are carried out without an earthworks permit (as is required by Council) and therefore without the knowledge of Council's Engineer. The first indication that site work has been undertaken is when the PIM (Project Information Memorandum (see Building Act)) application is applied for and this is generally concurrent with the building consent application. This application provides Council's Engineer an opportunity to remind the landowner of the consent notice requirements, but has in some cases arrived too late to prevent damage to the land.

The Act requires the Territorial Authority to have primary responsibility for land use management including natural hazard mitigation. However Council's inspection resources are limited and are unlikely to be greatly increased. A Building Control Officer will inspect the building site prior to foundation construction, but is not trained to assess compliance with most of the consent conditions of the subdivision.

There is generally no follow up inspection by Council of slope drainage works, conservation planting or other subdivision consent conditions. The landowner has in theory read the "Consent Notice" conditions and recognised the need to maintain these works etc.

7. Conclusions

The Resource Management Act provides a legal framework for Territorial Authorities in assessing applications for land subdivision. In the author's opinion the review of all applications received is an essential part of the land management and hazard mitigation duties required of Territorial Authorities. Council should refuse consent unless it is satisfied that the land will be protected and that approval will be in the long-term interest of the community.

Because of the nature of natural hazards in the Dunedin area it is considered appropriate for Council to retain staff with sufficient knowledge of the issues and who are in a position to oversee all stages of land development in this territory. Subdivision consents in potentially hazardous areas require careful attention to detail in consent notice preparation, and in administration of the associated land development. Even with careful attention to detail by Council during the consent process the eventual landowner(s) may well lack the skills or knowledge to develop potentially hazardous land without incident.

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A GIS-based Hazard Information System: Dunedin pilot project

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SYNOPSIS: A GIS-based Hazards Information System (HIS) has been developed by the Institute of Geological and Nuclear Sciences in partnership with local territorial authorities and the University of Otago. The system is designed to assimilate data on natural hazards from a wide range of sources in different formats, to integrate these data with location information (topographic and cadastral), and to make them easily accessible. The HIS consists of two subsystems: site-specific register of natural hazards, and zonation of hazard risk. The system is intended to help local and regional authorities to supply hazard information, as required under the Resource Management Act and the Building Act, as well as meet planning needs. The HIS has been developed using the software package Arc/Info®, and was tested using data from part of Dunedin City.

1 INTRODUCTION

The Resource Management Act 1991 (RMA) requires local authorities to establish policies for integrated management of the land and natural and physical resources; and to implement rules to avoid or mitigate natural hazards (sections 30 and 31). They are also required to gather information relating to these matters, and make it available to the public (section 35). Territorial authorities have further responsibilities to identify and assess land at risk of erosion, flooding, subsidence and landsliding under section 36 of the Building Act 1991.

To meet these requirements, planners and decision-makers need timely access to information about natural resources and natural hazards. Members of the public also want natural hazards information, and expect this to be supplied by local authorities. However, such information tends to be scattered among government departments, consultants, local authorities, landowners and specialist scientific and interest groups.

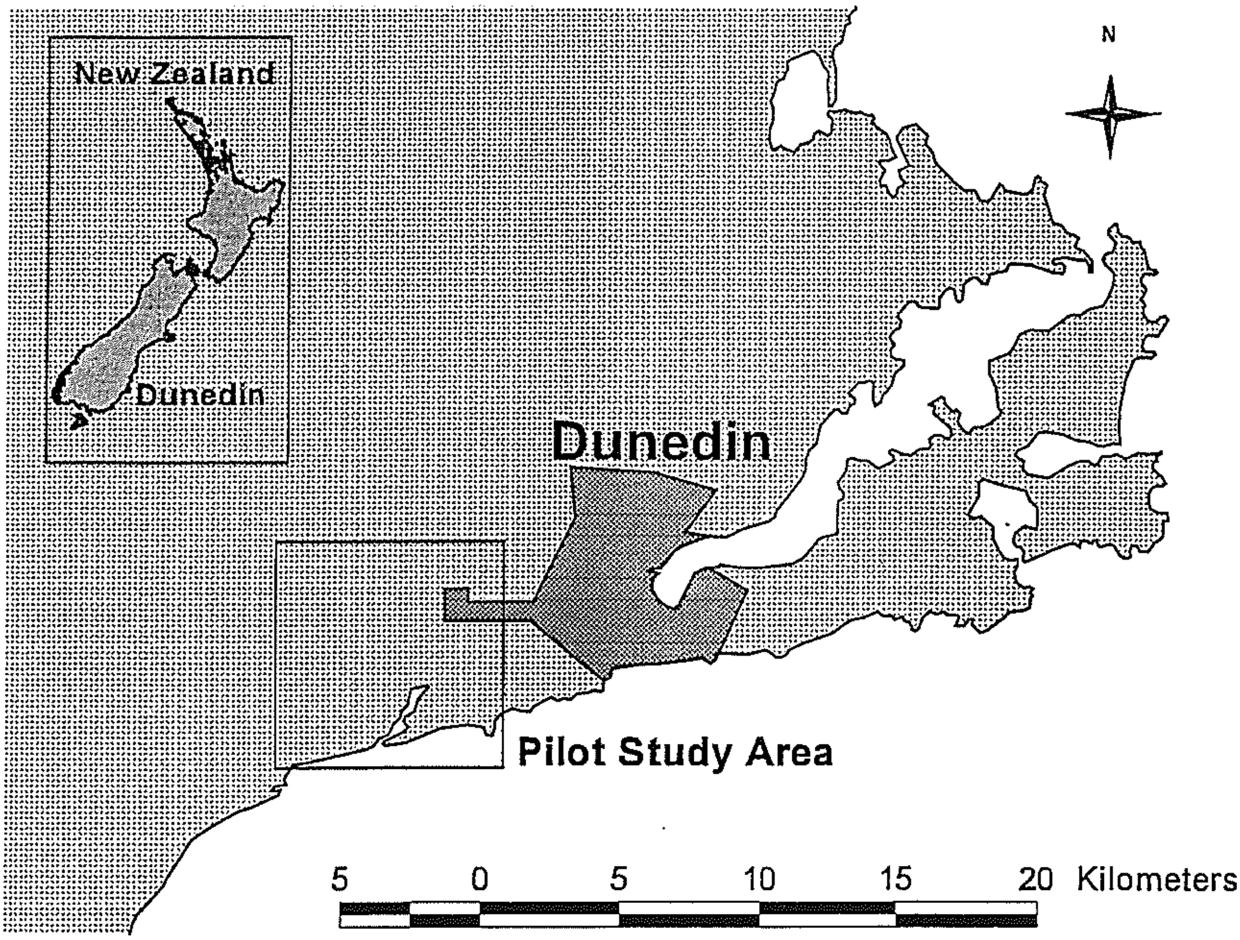
In 1993, the Institute of Geological & Nuclear Sciences Ltd (GNS) initiated a pilot project, with the aim of developing an information system which could:

- Contain all available data on hazards (both natural and human-caused) within a study area, in a systematic fashion;
- Record the source of the hazard information so original data can be located;
- Analyse various layers of data, individually or in combination, and to produce a zonation for any particular hazard;
- Produce maps, tables or text reports, on specific natural hazards and hazard zonation;
- Relate all this information to specific street addresses, property descriptions, or geographic locations.

The pilot study was funded by the Foundation for Research, Science and Technology (FRST), and developed at the Dunedin Research Centre of GNS.

The pilot study area, comprising 64 km^2 of the southwestern urban part of Dunedin City (Figure 1) was selected for its range of

Figure 1: The pilot area, located southwest of Dunedin City.



hazards, and the existence of a modern detailed geological map covering the area at a scale of 1:25000 (McKellar 1990). There was also known to be a wide range of unpublished data available from numerous sources. Finally, there is pressure for urban/rural development within the study area.

2 HAZARD INFORMATION SYSTEMS

Hazard information and zonation systems, often based on geographic information systems (GIS) technology, have been developed overseas (for example, Brabb 1984; Mejia-Navarro and Wohl 1994) and for other areas in New Zealand. Examples of GNS hazard evaluation work include seismic hazard and tsunami evaluations for Auckland (Hull *et al.* 1995; de Lange and Hull 1995); an earthquake and slope instability hazard evaluation for Tasman District (Coote and Downes, 1995); assessment of earthquake induced landslide potential in the Wellington Region (Hancox *et al.* 1994) and earthquake hazard reports for Bay of Plenty and Hawke's Bay (Hull *et al.* 1994; Begg *et al.* 1994). Wellington Regional Council has developed a landslide hazard zonation, based primarily on occurrence of landslips and slope angle (Hastie 1989; Kingsbury *et al.* 1992).

The Dunedin system differs from those mentioned above because it is designed specifically to store *hazard information* and its *sources*, to provide *hazard zonation*, and to integrate this hazard information with *locational information* that is directly relevant to the public and to planners under the RMA and the Building Act. One of the most important features is that enquirers can get back to the source of the information in the system - the actual map, record or report that refers to their property or street.

3 THE DUNEDIN HAZARDS INFORMATION SYSTEM

The system specifications and design (Aldridge and Benwell 1993) were carried out at Otago University (Aldridge *et al.* 1993; Glassey *et al.* 1994). The basis of the Dunedin system is a GIS which stores hazards information - a "library". There are two "shelves" or subsystems of data. Information about the location and nature of natural hazards, and some hazards resulting from human activities, comprises the *hazards register* sub-system. Analysis of the data in various ways yields zones of susceptibility to particular hazards - the *hazard zonation* sub-system. Within these shelves are reference "books": the topographic, hydrological, cadastral, transport, drainage, geological, and other data.

The system was developed using PC Arc/Info® but it could also be adapted to other GIS software. A customised user interface and menu system have been developed in PC Arc/Info® (Figure 2). Viewing and querying the data can also be carried out using the software package ArcView®.

3.1 Data capture

Finding the data and getting it into the HIS is time-consuming and labour-intensive (Mackaness 1989). Most of the information is not in digital form, is incomplete, has been collected for other purposes and is at various scales - it usually has to be interpreted by suitably qualified people before it can be entered. Information may be collated from different sources such as government departments, SOEs, territorial authorities, universities and consultants. Historical records, drill logs, geological and soil maps, and hydrological information had to located, assembled, transcribed and digitised (Figure 3) in order to complete the landslide hazard register and zonation. Cadastral, street and topographic maps were also needed in digital form. However, once all this information is in the system, it can be used in many different ways and updated relatively easily. The data entry is much easier where information has been collected in a standardised way. It is recommended that anyone monitoring, researching and collecting data on any natural features and hazards, keep in mind the possibility that the information will be used for planning purposes, and be as consistent as possible in recording the data. A landslide data sheet has been developed by GNS, to help with the collection of consistent data onlandslides; it could be used by territorial authorities, engineers and geological researchers.

3.2 How it works

The system is not a truly relational database (in information science terms); layers of data are graphically overlaid in various combinations, allowing interpretation of the relationship between the factors by the observer. These data can be analysed to show how susceptible areas are to certain hazards.

For example, the register of known coal mine subsidence may be combined with the topographic and street maps to show where this hazard has been noted in the past (Figure 4a). The next step, taking account of the distribution of old mines and the overburden to seam thickness ratio, is to derive a zonation of the likelihood of subsidence over mined areas (Figure 4b).

3.3 Landslide hazard register and zonation

For landslides in the area, as much information as possible about the dimensions, materials, cause, timing and type of failure, has been collected and the source of this information recorded (the files of GNS, DCC and ORC).

Figure 2: The user interface of the HIS is menu-driven. Examples of the QUERY and UPDATE options are shown.

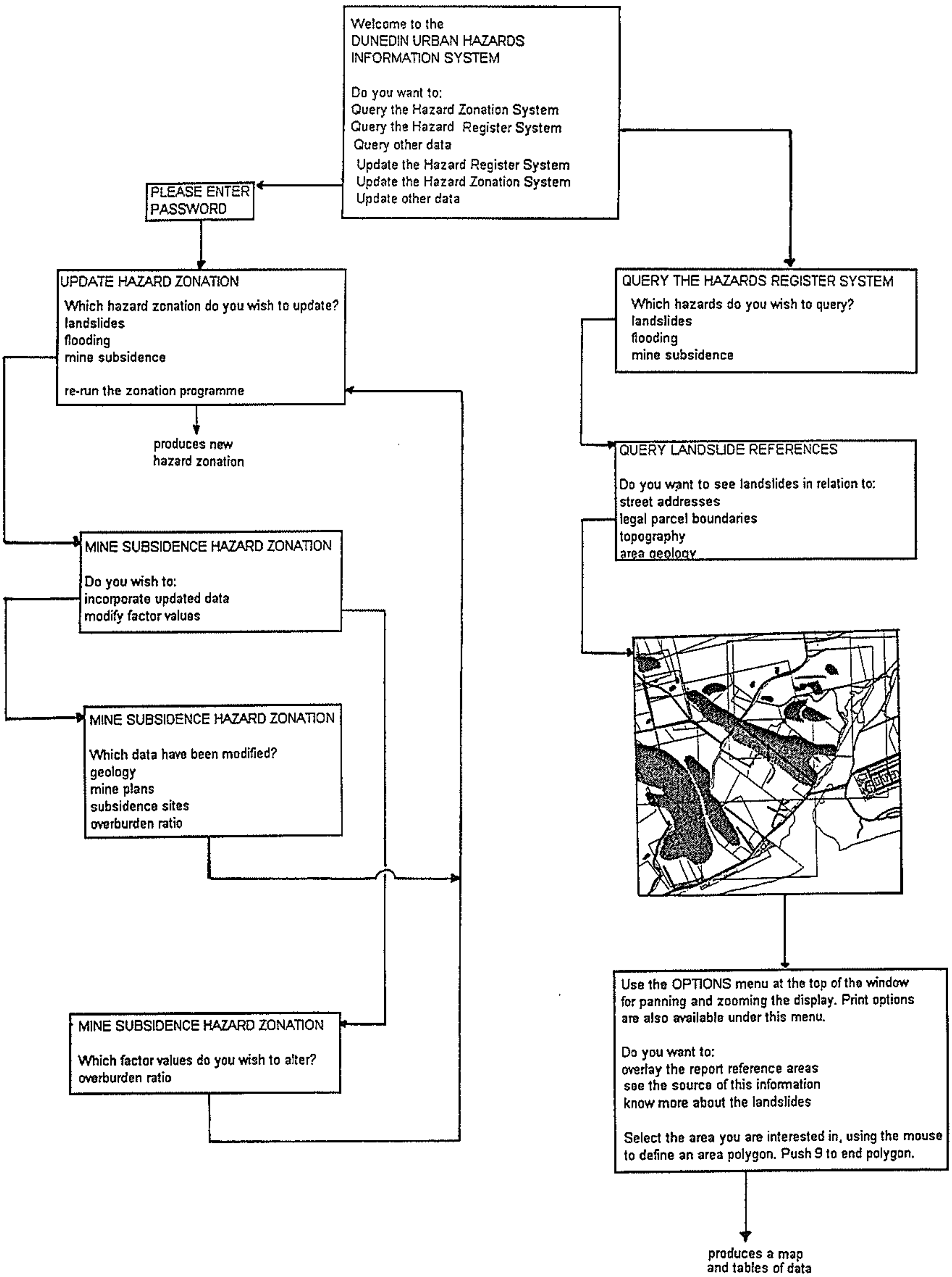
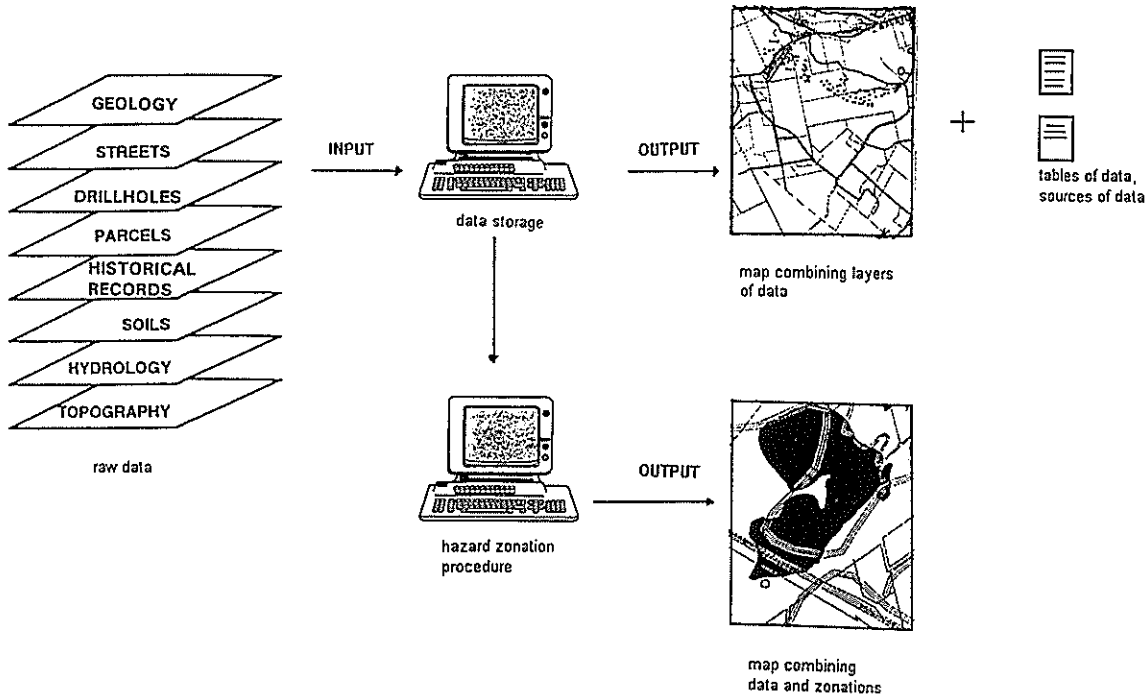


Figure 3: Schematic diagram of the elements of hazard storage and analysis



These data form the site-specific landslide hazard register, which can be usefully combined for presentation purposes with topographic and street maps (Figure 5a).

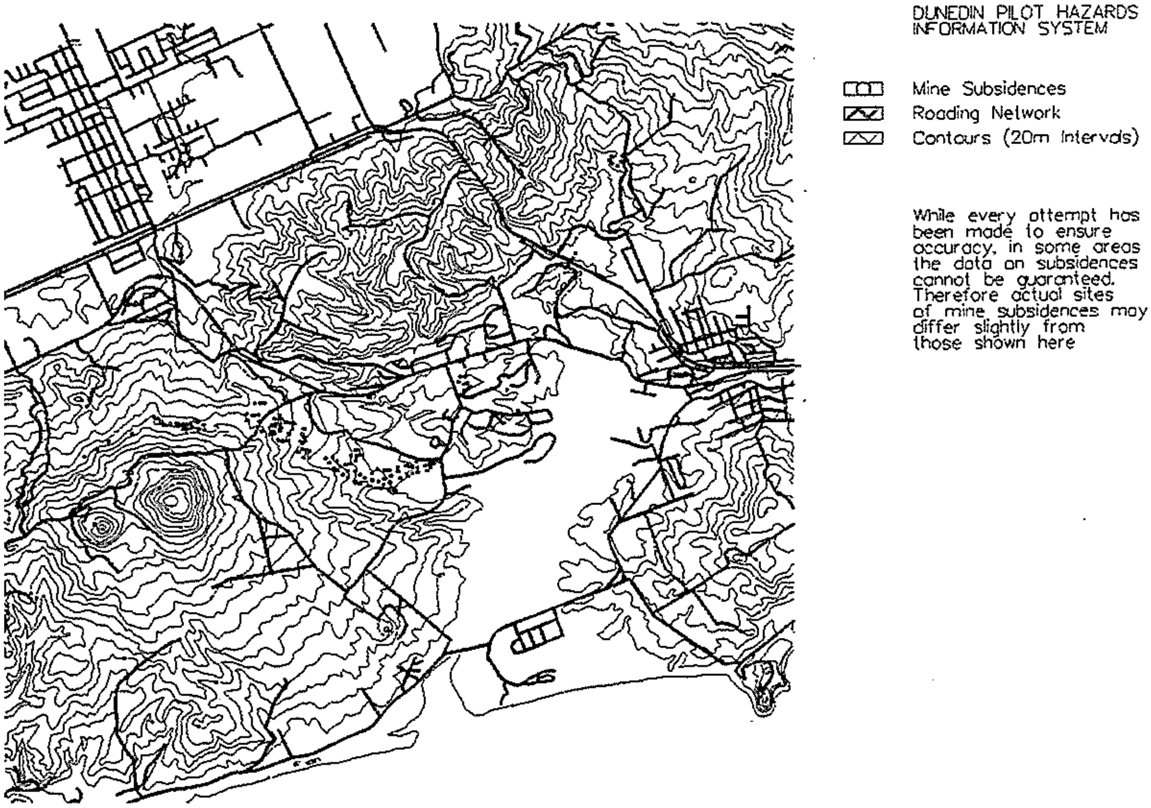
To zone susceptibility to landsliding, factors such as underlying rock type, slope angle, slope modification, groundwater, and known landslide distribution, have been considered and assigned subjective weightings on the perceived degree of influence on landsliding. A high weighting is assigned to *rock type* and *slope angle* because they are known to have a major influence on landsliding.

Groundwater data are considered necessary for modelling landslide distribution and predicting future failures, but no detailed information is available for the pilot area. General assumptions are therefore made from the rock type and hydrology, classifying the areas as either well drained, poorly drained, or saturated. Factors such as vegetation, and aspect are thought to be relatively less-important.

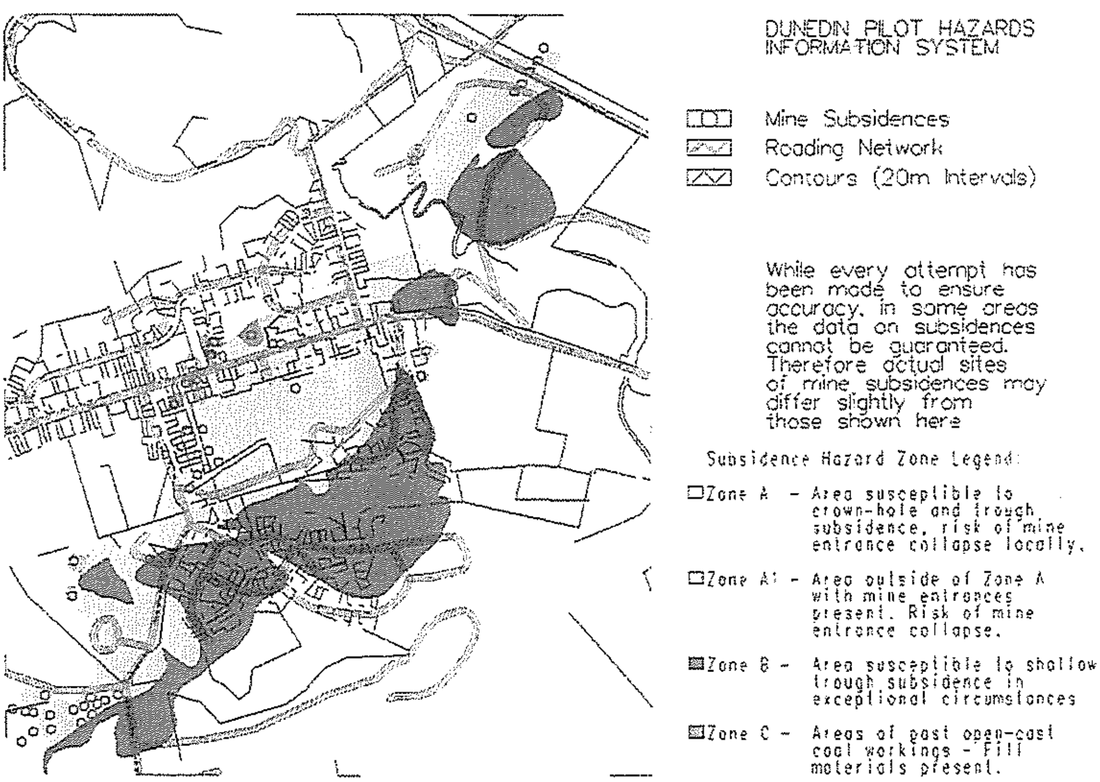
Combining data layers and running the analysis results in a landslide susceptibility map (Figure 5b). The analysis method is described in more detail by Glassey *et al.* (1994). However more research is needed, utilising the capabilities of GIS, to rigorously test the influence of factors relevant to landslide distribution and determine how the various factors should be combined to derive a valid landslide susceptibility zonation.

Additional factors could be taken into account to refine the landslide zonation further. These include thickness and strength of the surface layers (soil and weathered rock) in which many landslides occur; and landslide-triggering mechanisms such as ground shaking, high intensity rainfall events and slope modifications. Some of these factors have been used in other studies (for example Kingsbury *et al.* 1992; Begg *et al.* 1994; Hancox *et al.* 1994, Coote and Downes 1995; Hull *et al.* 1995). The Dunedin system is flexible and capable of growth - relevant information can be added as it becomes available from landslide studies or research projects, and we hope to build the acquisition of standard data into local authority monitoring procedures.

Figure 4: Mine subsidence hazard

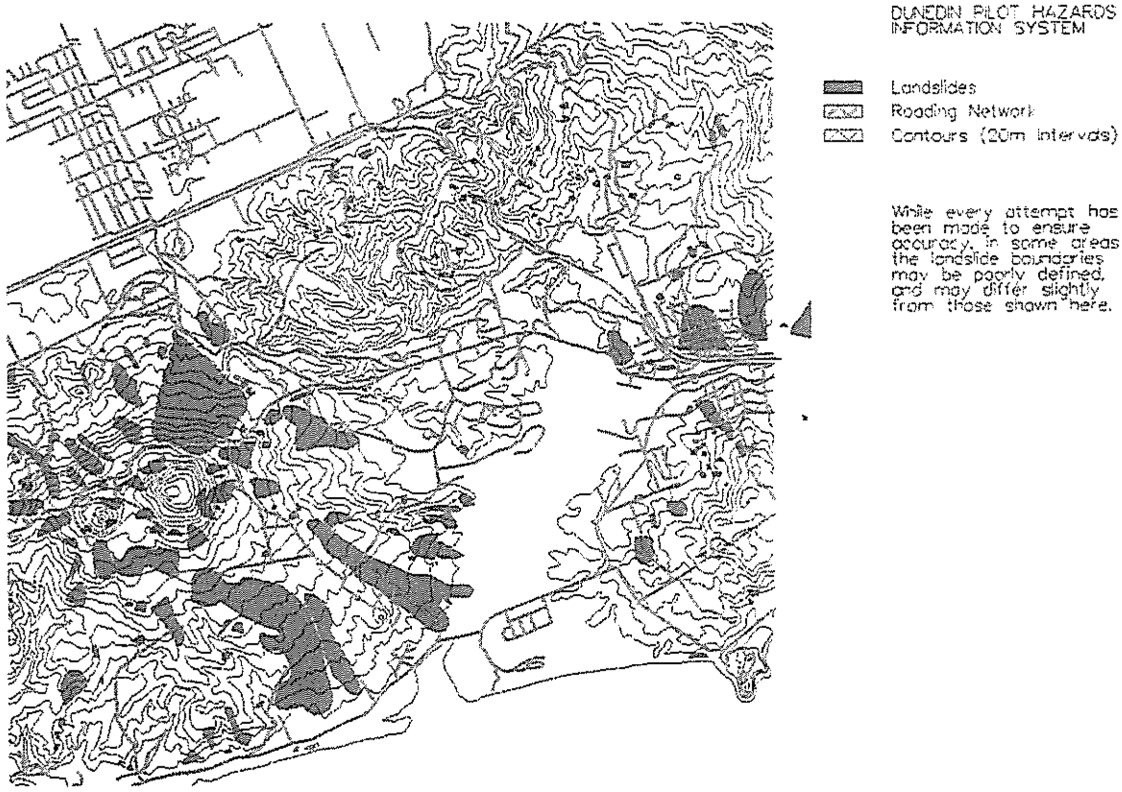


a) known occurrences of hazard



b) susceptibility to hazard (note that this shows only part of the area covered by 4a)

Figure 5: Landslide Hazards



a) known landslides

b) susceptibility to landsliding hazard

Glassey *et al.* "A GIS-based Hazard Information System: Dunedin pilot project"

3.5 Reporting from the system

All the layers of data in the system can be interactively interrogated using Arc/Info® modules, or via the Windows-based ArcView® packages, which are effective reporting tools (see Figures 4 and 5). ArcView® is the easiest for most purposes and could be customised to provide a "user-friendly" icon based query interface. Text and graphic data can be printed either from Arcplot®, ArcView® (see Figures 4 and 5), or from spreadsheets such as Excel®.

In setting up the HIS, the functions of *querying* and *updating* the system have been separated (Figure 2). The QUERY option allows public access to hazard information, and it is envisaged that such a system could be installed in local authority offices, giving both staff and the public access to all the hazard information that is known for the region. Subject to confidentiality arrangements, anyone could then request information on any property: the presence of known natural hazards; the susceptibility of the area to those hazards; the development constraints imposed on the land by the local authority; and any other constraints which may exist, such as the requirement of a site-specific investigation. Enquirers could also find out the source of the information, which would be important if they wished to dispute it.

The UPDATE option should only be available to those responsible for compiling and maintaining the data, such that the integrity of the data is not compromised. In addition, it is considered important to have one central database to maintain reliability and accuracy.

3.6 Caveats

Some warnings apply to the hazard register and hazard zonation as they stand. Much of the information collected from the various organisations and entered into the system is of a technical nature, and it must be examined and interpreted by people with appropriate skills, before being entered into the GIS. In order to maintain data integrity, we suggest that the specialists who have collected and entered the data into the GIS, also be contracted to update it and carry out any modifications to the system. It may be more efficient for local authorities to buy these services from the specialists than to bring their own staff up to the standard of expertise required to interpret technical data.

Secondly, the hazard zonation methods are based on generalised data. This is appropriate at a regional scale for regional planning and broad assessment purposes, but is not suitable for the evaluation of specific sites. It can provide a realistic basis for an initial hazard assessment of a particular site and identify areas where detailed investigations may be needed, but should not be used as the only means of assessing a specific site.

It is also stressed that boundaries between hazard zones, although appearing on the map as lines, are gradational at both data capture and representation scales. A "fuzzy boundary" concept has yet to be built into the system. This problem is important to property owners, as land values may fall and insurance premiums rise in areas of known hazard susceptibility, and development costs may be higher where remedial or preventive works have to be undertaken. Site-specific evaluations will usually be needed to overcome this type of problem.

4 LOOKING AHEAD

For local authorities which have not installed a GIS, the hazards information system could be the starting-point of a comprehensive data bank for the region. It could be extended for use as a planning tool, enabling data on biological, historical and recreational features, as well as hazards, to be combined and analysed. The many authorities which already have GIS (such as the Banks Peninsula Resource Information System, Loveridge *et al.* 1994) will be able to acquire hazards coverage in an appropriate form for their existing system.

Future research directions will include the testing and refinement of the landslide zonation methodology to develope a generic zonation method as opposed to a number of area specific methodologies. This will involve using conventional statistical analysis as well as case-based reasoning and artificial intelligence techniques.

5 CONCLUSIONS

We have tested GIS as a platform for storing and retrieving hazard data by developing an information system, beyond the conceptual stage, which allows users to integrate and query data on hazards, and hazard zonation, on local and regional scales. The system can store information on natural and cultural features, hazards, cadastral and topographic maps, and so on, so that:

- the various sorts of data can be combined and queried;
- the data can be traced back to source; and
- hazard information, located in terms of cadastral and topographic maps, can be extracted from the system.

ACKNOWLEDGEMENTS

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Institute of Geological & Nuclear Sciences Contribution Number 772

Identification and analysis of landslides in an area of steep land and complex geology

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SYNOPSIS: Aerial photographs and geotechnical field surveys are used to identify landslides in folded, faulted and crushed sedimentary rocks with steep slopes and moderate to high relief. Slope morphology is integrated with rock defects and rock type using maps, sections and stereoplots. This allows the various types of slope movement to be determined.

Wide belts of crushed shale give rise to debris flows. Thin beds of crushed shale provide basal ruptures for rockslides or flexural slip zones in complex topples. Fractured limestone either topples or slides, depending upon the amount and direction of dip of the penetrative defects.

Mapping of slope deposits provides a measure of the magnitude of landslide hazard. Stratigraphy of the slope deposits is poorly known but with historic records allows an estimate of the hazard frequency.

Land development in the area needs to take account of the hazard style in source areas, override zones and debris depocentres. Damage is different, but severe, in all three zones.

1. INTRODUCTION

Limestones and shales form prominent strike ridges and dip slopes along the eastern coast of Marlborough, in the Northeast of the South Island, New Zealand. This area is noted for its spectacular mountain ranges (Campbell and Johnson 1982) a high rate of uplift (Walcott 1978) and active faults. It also includes the southern end of a belt of highly deformed rocks (Sporli 1980) which extend from East Cape of the North Island, along the East Coast and across into coastal Marlborough. Faulting and folding of these rocks has produced a variety of structures, most of which are defects in the geotechnical sense. These include imbricate thrust faults through the whole pile of sedimentary cover rocks, bedding fissility in the shales, pressure solution cleavage in the limestone, as well as fractures, shear zones, crush zones and seams of gouge (Prebble 1980, 1987 and 1995). In the limestones, classical landslides of the translational type are very few. In the shales, debris flows are very numerous and many are active.

The apparent stability of the limestones is deceptive. A lack of prominent headscarps and generally smooth convex profiles suggest that the limestone dip slopes are not subject to slope failure, except in one or two special cases where low dips occur.

However, upon closer examination and using an integrated field mapping approach (geomorphology, structure, rock type and defects are blended) a deep seated form of toppling is recognised in nearly all the limestone dip slopes of the study area. The toppling overturns the beds and is referred to as *overtoppling*. It also creates through-going rupture surfaces and rock mass bulging (Prebble 1995). This in turn leads to rock mass loosening gully erosion and debris flows. A downstream consequence is the damaging accumulation

Table 1 Mineralogy and microfabric of the intact rock

Rock unit	Rock type	main minerals (80 to 90%)	minor minerals (10 to 20%)	micro-fabric
Whales Back Limestone	micrite (fine grained limestone	calcite and quartz	clay and sericite	mosaic
Ben More Shale	shale	calcite and clay (smectite)	quartz	turbulent
Ben More Limestone	micrite	calcite	clay and quartz	mosaic
Isolated Hill Shale	shale	calcite and clay (smectite, illite, and kaolinite)	sericite	turbulent
Isolated Hill Limestone	micrite	calcite and silica (chalcedony)	sericite and clay	mosaic
Mead Hill Flint	chert	silica (chalcedony)	sericite and clay	mosaic
Whangai Shale	shale	Quartz and kaolinite	smectite and sericite	mainly turbulent

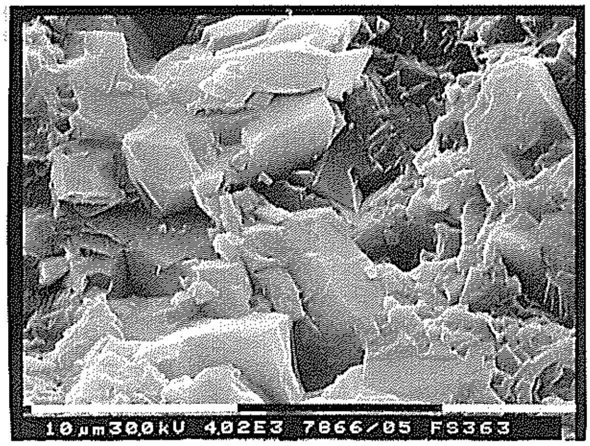


Fig 1. Mosaic microfabric in limestone.

Fig 2. Turbulent microfabric in shale.

of debris of the kind referred to by Bowring Cunliffe MacKay and Wright (1978).

Previous studies (eg Prebble 1980) deal with rock stratigraphy, structural development and overall tectonics, using data obtained from rock exposures in the deep gorges of the main rivers and streams. The broad interfluves of the dip slopes were largely ignored and contain the critical areas of strata overturned and dislocated by toppling.

An important part of the present study is to distinguish between tectonic structures and deformation created by slope movement. Parameters, such as defect condition and geomorphology assist in making the distinction.

2. ROCK MATERIAL PROPERTIES

A wide variety of sedimentary rocks from conglomerate and sandstone, through to shale, limestone and chert abound in the Eastern Marlborough region. This study confines itself to the shales and limestone which make up the prominent dip slopes. The sequence of rock types is siliceous shale overlain by chert, limestone and interbedded calcareous shale and limestone.

The siliceous (quartz-rich) shale is known as the Whangai Shale and the other units are referred to collectively as Amuri Limestone. These rocks are widespread in the southern East Coast of the North Island and in coastal Marlborough.

The steepest, highest and most extensive slopes in the Amuri Limestone are found in Marlborough. To assist geotechnical mapping the limestone is subdivided into 6 lithologic units. From lowest to highest, stratigraphically, these are:- Mead Hill Flint (chert), Isolated Hill Limestone, Isolated Hill Shale, Ben More Limestone, Ben More Shale and Whales Back Limestone. The limestones are all fine grained micrites and the shales are calcareous clay shales. Other rock types such as volcanics and sandstones are less abundant and not significant in the present study.

2.1 Rock petrographic properties

Mineralogy and microfabric of the rocks are shown in Table 1. The limestones are dominated by microcrystalline calcite, derived from the shells of microscopic organisms such as coccoliths. However, silica (either as quartz or as chalcedony) is also abundant in some limestone units. The shales of the Amuri Limestone are rich in both calcite and clay. Main minerals such as calcite and silica in the limestones, make 80 - 90 per cent of the rock, minor minerals 10 to 20 percent.

Microfabric is the geometric arrangement of the mineral grains and clay microaggregates. Mosaic microfabric of the limestones is a tightly interlocked, almost non porous, masonry-like packing of grains of calcite, quartz or chalcedony. Clay is not sufficiently voluminous to form a continuous network and occurs as isolated microaggregates jammed between the grains. Mosaic microfabric is isotropic (Fig 1).

In contrast, turbulent microfabric in the shales forms when clay exceeds 15 per cent. This appears to be the threshold value, above which a continuous network of clay microaggregates form, enveloping the grains (Fig 2).

2.2 Physical properties of the rocks

As a result of the change in microfabric, porosity in the shales increases slightly, anisotropy develops, strength drops dramatically and slaking commences. The shales are flakey, or splintery with a well developed foliation. The change in physical properties from non porous, non slaking, isotropic, strong rock material in the limestones to weak or extremely weak,

Table 2 Microfabric and physical properties of the intact rock

Rock type	Microfabric	strength	porosity	slaking
micrite (fine grained lime-stone)	mosaic	strong to very strong 50 t0 160 MPa	essentially non porous 1% or less	Do not slake
chert	mosaic	strong to very strong 50 t0 160 MPa	essentially non porous 1% or less	Do not slake
shale	turbulent	extremely weak to weak 1 t0 15 MPa	slightly porous 2 to 12%	slake readily and disinte-grate
Notes: 1) Strength (Approximate unconfined compressive strength in MPa) 2) Slaking (as determined by jar slaking test, immersion in water)				

Table 3 Relationship of rock type and defects to slope failure

Rock type Rock mass	Dominant Defects	Slope failure	Subsequent Slope movement	Topography
Strong lime-stone tabular rock mass	Crush zones. Extremely closely spaced fractures Dips 30° to 80° (slope angle 15° to 42°)	Overtopples (flexural) leading to rock mass bulging	Stony debris flows. Debris avalanche	Convex slopes. Bulges screes. Ravines with stream like debris lobes
Strong lime-stone tabular rock mass	Crush zones. Extremely closely spaced fractures Dips 15° to 25°, parallel to slope	Rock slides	Debris flows from toe	Head scarps Block fields pull aways, ponds and swamps
Very weak shale. Fissile rock mass to clay gouge soil.	Wide clayey crush zones	Debris flow	Debris flow	Tongue like stream like glacier like lobes

anisotropic, fissile, slightly porous and very slake prone shale is marked by a consistent change in microfabric (Table 2).

Essentially, the limestones (including chert) are strong, non porous and durable. The shales however, are very weak, foliated, fissile and slake readily.

3. DEFECTS

The rocks are folded and faulted by a complex array of thrust faults, strike-slip faults, steeply plunging folds and a regional anticline. A wide belt of tectonic crushing and mixing of the rocks is wrapped around the nose of the regional anticline and another belt of crushing and mixing is found in the core, where the cover beds have uncoupled from the undermass greywacke in a shear belt-driven decollement (Prebble 1976 and 1980).

On an outcrop scale, the limestones are extremely fractured by several sets of tectonic joints and pressure solution cleavage. The shales are usually sheared and crushed. Limestone interbeds within the shales have been attenuated to sausage-like lenses and dislocated by shearing into small isolated lozenge-shaped fragments imbedded in a matrix of crushed shale. Much repetition of the rock units is caused by the numerous low angle reverse thrust faults which form an intricate array through the sedimentary rock mass and which are also folded by the regional anticline.

The end product, as a result of uplift, is a curved sweep of limestone dip slopes in which the bedding and crush zones of the thrust faults dip in the same direction as the slope, but at a steeper angle. The crush zones vary between being parallel to bedding or 15 degrees steeper.

3.1 Crush zones

These consist of randomly oriented angular fragments of rock, usually 1 to 5 mm in size, in a matrix of clay or sandy clayey which is very soft, wet and extremely weak. Microfabric examination shows that the matrix is highly angular rock particles, and clay. Crush zones are soils in the geotechnical sense. Some show a tendency to develop fabric, by orientation of particles in a sub parallel fashion, and may be referred to as shear zones. Many crush zones are faults, of the imbricate system in the sedimentary-cover strata. Others are part of the basement cover decollement fault, and yet others are probably the result of flexural slip between beds as a result of regional folding.

All crush zones (and shear zones) in the area are potential basal ruptures for landsliding or potential flexural slip zones in areas of deep seated toppling.

The geotechnical mapping has established that their continuity is throughout the whole region.

The crush zones vary in thickness from several metres to tens of metres and are either parallel to or at a low angle (15°) to bedding.

Thin crush zones, containing clay seams are also found within the shales. These zones and seams are 0.2 to 3.0 cm thick and are continuous for at least several tens to a few hundreds of metres. Mapping indicates that they may be more or less continuous throughout the shales. Clay seams also abound in the thicker crush zones.

3.2 Fractures

Extremely closely spaced (20 mm) to very closely spaced (60 mm) pressure solution cleavage is found in the Ben More Limestone. Similar cleavage, mainly very closely spaced, is typical of the other limestones. The cleavage has developed into fractures, with bedding parallel fracturing being dominant (ie more continuous) and disjunctive fractures (at a high angle to bedding) being the minor (truncated) set. This results in a markedly tabular rock mass in all these limestones. Similar fracture sets prevail in the Mead Hill Flint.

3.3 Variation in defect condition

All fractures are tight at stream bed level, resulting in a very tightly interlocked to cemented rock mass at that topographic level. On slopes, especially in the Ben More Limestone, the fracture blocks are progressively loosened with altitude by dilation and transposition along fractures and crush zones. In the toppling masses, the block interlock strength is minimal and the near surface toppled rock behaves like a gravel rather than a rock mass. Similarly, crush zones in the toppling masses are wider and more distorted than at stream bed level. Some have spread into very wide zones of soft, extremely weak clay gouge. It is possible that swelling of the smectite clay has added to the deformation in the crush zones.

4. SLOPE MOVEMENT AND GEOMORPHOLOGY

Detailed geomorphic mapping shows a distinct correlation with both defects and rock type.

4.1 Slopes in shales and crush zones

The slopes in shales generally are hummocky and irregular, as a result of the prevalence of crush zones. The wide crush zones, are marked by generally trough-like and irregular hummocky slopes, both lower and more irregular than adjacent slopes in limestone.

Typically the hummocks are arranged in tongues or lobes, many of which are long and glacier-like to stream-like. These features indicate debris flows.

4.2 Slopes in limestone

In contrast, the limestone slopes are broad, convex and more or less equidimensional to rectangular shaped interfluves, separated by deep gorges and subdivided by the troughs which mark the shales and crush zones.

Head scarps are conspicuous by their absence in all but a few limestone slopes. Most have a subtle to reasonably well marked head bench, or ridge-top trench, but not a true scarp. Most are also crossed by faint to well developed reverse scarps (uphill facing scarps). The larger reverse scarps follow crush zones and are trough-like. The relationship of scarps to crush zones is interpreted from the geotechnical mapping. In a few cases, where deep ravines are eroding into the limestone slopes the relationship can be directly observed.

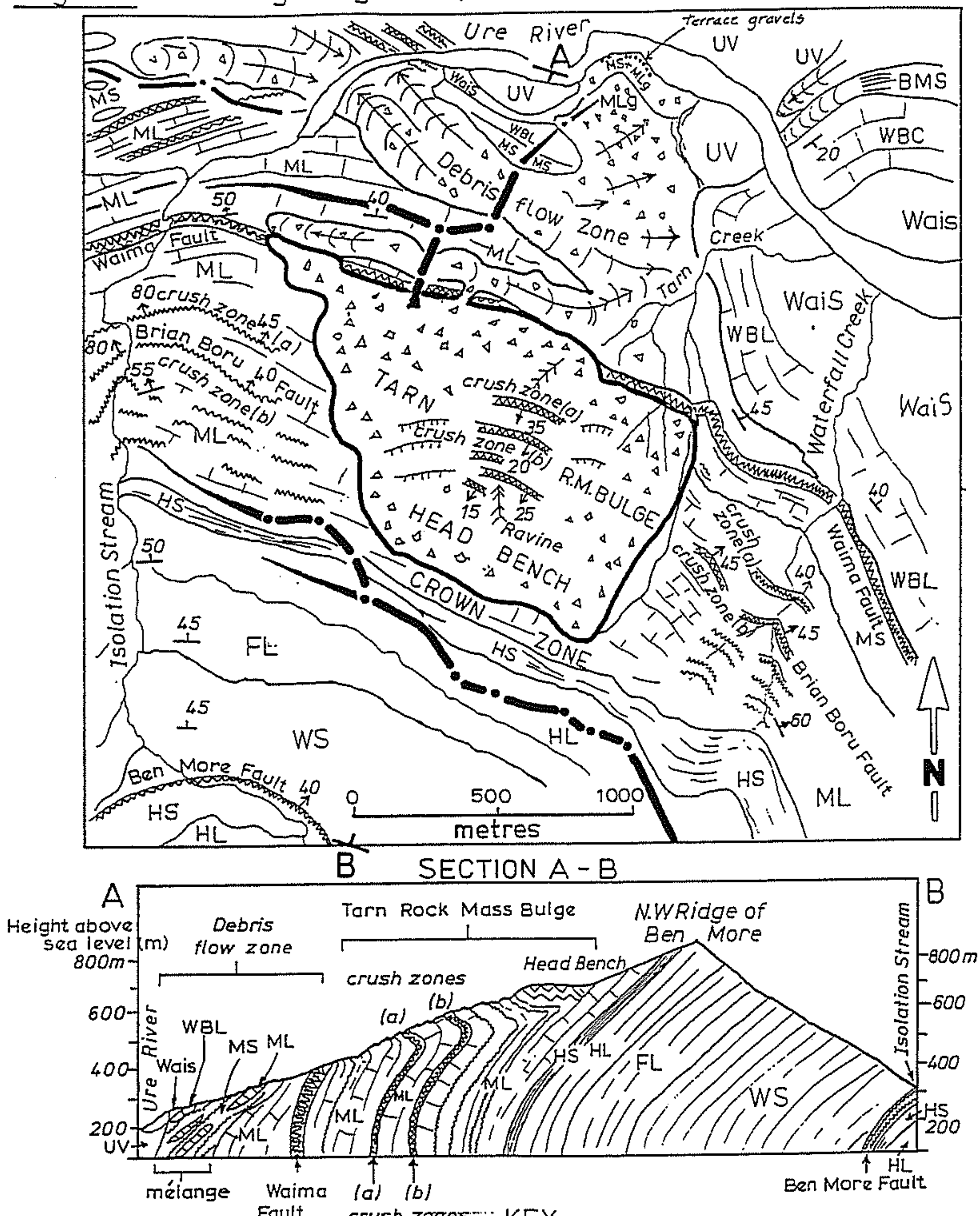
4.3 The distinction between toppling and tectonic folds.

Tectonic folds are found on several scales, with different styles and different relative ages. Many are directly related to thrust faults, melange and crush zones. Those of a similar size to the bending over caused by toppling differ in that they are plunging, many of them very steeply. They have no consistent orientation with respect to topography and are most frequently seen in tightly interlocked rock in the stream gorges.

In marked contrast, the bending over in the topples creates synclines open towards the valley, with horizontal axes, parallel to the slope contour. They are always confined to the loosened, dilated rock in limestone slopes.

In some limestone slopes the convex shape is well developed and forms a bulge. Previously described as rock mass bulges (Prebble 1987 and 1995), these features are large, deep-seated topples in which the

Fig.3. Outline geologic map, TARN ROCK MASS BULGE.



KEY

WaiS	Waima Formation	HL	Isolated Hill Limestone	ridge, Peak, scarp face, ravine	
WBL	Whales Back Limestone	FL	Mead Hill Flint		
MS	Ben More Shale	WS	Whangai Shale		
UV	Ure Volcanics		Bedding		
ML	Ben More Limestone		Fault		Debris
HS	Isolated Hill Shale		Crush zones		Debris flow

bedding, fractures and crush zones are bent over valleywards by flexural toppling (Fig 3).

4.4 Debris flows

Clay matrix debris flows are widespread in the shales and crush zones. Stony debris flows arise on the topplng masses.

The clay matrix debris flows have a highly plastic, very soft extremely weak clay rich matrix which makes up 20% of the debris and angular rock fragments which make up the rest. Where debris flows originate in the Isolated Hill and Ben More Shales, smectite is common in the matrix. Debris flows arising in Whangai Shale are kaolinite rich.

The flows vary in size from several tens of metres to several hundred metres in length and are usually 5 to 10 times as long as they are wide. They are tongue-shaped to stream-like or glacier-like in overall form and usually a few to several metres thick, at least. Some accumulations of debris in the larger flows are probably a few tens of metres thick.

The surface of the flows is usually highly irregular, on both a large scale and a small scale. Blocks, ridges, ruts and minor scarps from 1 to several m in height abound. Side levees up to several m high are common. The toe of the flows is usually wet, and unstable. Many show signs of recent movement such as fresh scarps, angular blocky surfaces and side shears against levees. Local farmers report damage to fences, vegetation, vehicle tracks and watercourses, more or less continuously during prolonged wet spells.

The stony debris flows are similar, except that the material is almost entirely limestone fragments 0.5 to 2 cm in size. These flows arise in the ravines of large topples and are markedly stream-like in form. They are generated in high intensity rainstorms and can deliver huge quantities of gravel to streams and rivers, causing serious aggradation.

4.5 Topples (Fig. 3)

These are the most common and extensive type of slope movement in the study area. thirty two out of 34 limestone dip slopes examined are subject to toppling. Unlike the other slope movements, topples create convex, slightly bulging slopes, not hummocky trough-like slopes. Topples lack the arcuate head scarp typical of slides and flows. Topples also have no overide zone. Ultimately toppling creates bending surfaces, rock mass dilation, loosening and through-going ruptures on which sliding can take place. Loosening and bending promote collapse and the development of fall line ravines, which give rise to stony debris flows.

The topples are in the order of 0.5 to 2.0 km across and 0.5 to 1.0 km from head to toe (Fig. 3 Map). Bending surfaces (ie pivot points for toppling) are found as deep as 50 m into the rock mass (Fig 3, Section A-B). Within each topple, bedding, fractures and crush zones are bent over valleywards by flexural toppling which involves slip along the dominant fractures and in the crush zones. This creates reverse scarps and a head bench (Fig. 3 Section A-B), where the toppled rock pulls away from in situ rock. Crush zones at the toe of the topples are subject to debris flow and are the likely cause of initial removal of support which allows toppling to retrogress up the slope.

The valleyward bending results in a horizontal fold with an axis parallel to the slope and confined to the topple. Bending in some topples produces angular chevron-style folds, collapse zones and complex multistage toppling.

The loosened rock in the topples is a source of large scree fans and stream-like

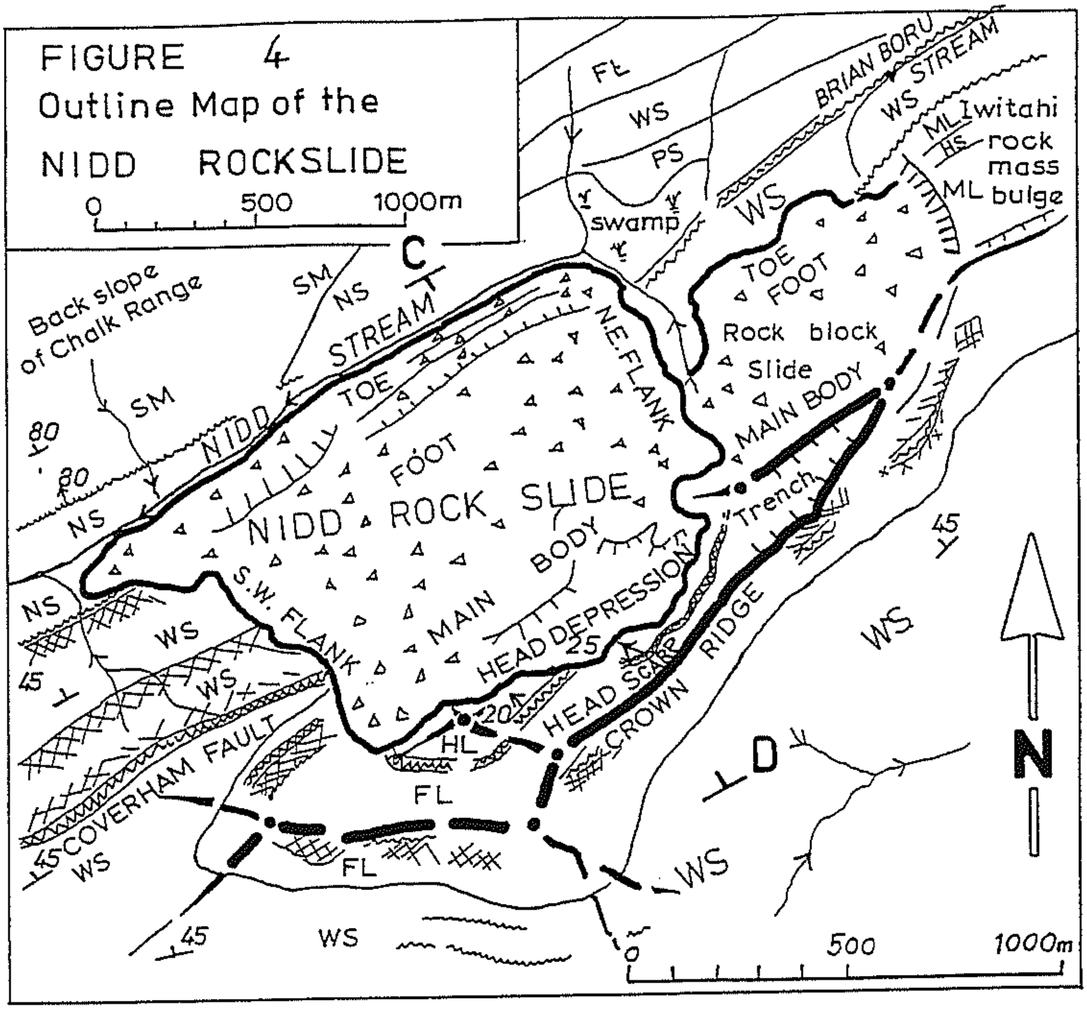


FIGURE 4 Outline Map of the NIDD ROCKSLIDE

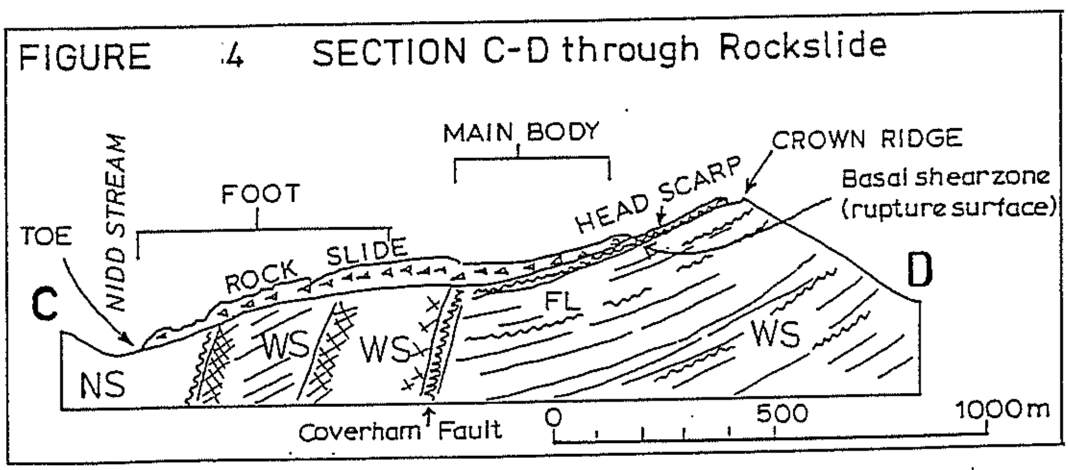


FIGURE 4 SECTION C-D through Rockslide

KEY

				(symbol)	Rock Slide
				(symbol)	Crush zone
ML	Ben More Limestone	WS	Whangai Shale	(symbol)	fractured zone
HS	Isolated Hill Shale	PS	Paton Sandstone	(symbol)	Scarp (teeth = face)
HL	Isolated Hill Limestone	NS	Nidd Sandstone	(symbol)	ridge / stream
FL	Mead Hill Flint	SM	Swale Siltstone		

stony debris flows which spread out below the topples and feed debris into the streams.

Even larger debris aprons are found downslope of some topples, indicating that catastrophic collapse and debris avalanches have been produced. Toppling may then retrogress upslope or extend along the slope to a new sector.

4.6 Rock slides (Fig. 4)

Where the bedding, dominant fractures and crush zones dip at 15° to 25° rock slides develop, in preference to topples. The critical defects are the bedding parallel clayey crush zones, which form the basal rupture surfaces for rock slides (Fig. 4 Section C-D). The defects can be sorted out geometrically by mapping, cross sections and stereoplots (Figs 4 and 5). Only 4 rock slides are found in the limestone dip slopes. They are comparable in size to the topples and but give rise to different topography such as steep head-scarps, pull away trenches, swamps and ponds, blocky irregular slopes and toes which override rock units not involved in the slope failure itself (Fig. 4). All the toes produce active debris flows. One rock slide has dammed the upper reaches of a stream, creating a large swamp (Fig. 4 Map).

5. SLOPE FAILURE IN RELATION TO ROCK TYPE AND DEFECTS

Table 3 shows the relationship of rock type and defects to slope failure. Most dip slopes in limestone fail by overtoppling. The slopes are generally in the range 15° to 42° with major defects dipping 30° to 80°. Consequently, most limestone dip slopes are buttressed against sliding. The friction angle along dominant defects is in the order of 30°. Dips steeper than 30° allow slip to occur but this gives rise to toppling, assisted by defect dilation and rock mass loosening generally.

Toppling produces bending surfaces, where the beds break in flexure along minor defects such as cleavage and fractures oriented at a high angle to bedding. Transposition of bedding and fractures, in combination with dilation, rock mass bulging and partial collapse produces a very loose mass of limestone debris. This behaves more like gravel than a rock mass. It is easily eroded by ravines, and produces large screes and stony debris flows. Therefore, these slope failures in the limestone are a consequence of the initial toppling.

Wide crush zones, irrespective or orient-ation, are also a soil mass and the clay-rich finely fractured and crushed material produces debris flows.

6 MAGNITUDE AND FREQUENCY OF HAZARD

6.1 Magnitude

Individual topples contain in the order of 75 x 10^6 m^3 of limestone debris. The rock slides have a similar volume. Areas of 1 km^2 are common. Debris flows range up to several hundred metres in length, but may be grouped into coalescing masses of debris which cover up to 1 km^2, and are up to several m or a few tens of m deep.

Several of the clayey debris flows are actively creeping, and accelerate after prolonged infiltration during winter or high intensity rainstorms.

Further debris flow activity is generated during high intensity rainstorms by mobilisation of stony debris from ravines on rock mass bulges (topples). These produce rapid debris flows and accumulations of debris in stream channels. The rate of aggradation can be in the order of a few metres in several hours, over several hundred metres length of stream channel and adjacent small flood plain terraces. Areas of up to 1 km^2 of flood plain and channel can be buried with limestone debris. These are usually the few strategic low altitude flatland areas used for stock yards and shed sites. They are also usually alongside the main highway and railway corridor, so that the "excessive" aggradation is a threat to roads railines and bridges.

6.2 Frequency

Frequency is difficult to assess, in the absence of long records or a framework of dated deposits. Two radiocarbon dates and comparative geomorphology indicate that most of the slope movements are no more than a few thousand years old (3,500 - 5,000 yrs being an approximate age for initial movement of the present slope failures). However, activity of the toes of rock slides, of several debris flows and of ravines, and screes on topples has probably been continuous since the initial movement.

Reverse scarps on bulging topples are probably 100 to 500 years old and some as young as 40 years, by comparison with scarps developed on dated screes elsewhere in the South Island.

Stony debris flows and severe downstream debris aggradation has a return period of around 200 years or less, as judged by the 1975 Cyclone Alison event.

Successive aerial photographs over the last 50 years and comparative geomorphology and vegetation indicate the following debris flow activity from the Tarn rock mass bulge (topple) this century:-

Pre 1964 (probably 1920's) :- 212,000 m^3
1969 :- 108,000 m^3

These volumes are only a fraction of the total debris produced over this time, much more will have discharged to the river bed where a fan of at least 240,000 m^3 still exists. The 1975 Cyclone Allison storm did not seriously affect the Tarn ravine but did result in serious and damaging aggradation on others closer to the coast of Marlborough.

A return period of 50 years for voluminous debris flow activity on eroding topples appears possible. Similar return periods may characterise serious movement of clayey debris flows sited on crush zones or at the toe of rock slides. These figures remain somewhat speculative until more research of historic records and of datable deposits has been carried out.

7. DISCUSSION - IMPLICATIONS FOR LAND USE AND DEVELOPMENT

The nature of the hazard from slope movement varies according to the topographic zones (source areas, overrides and depocentres).

In source areas, where the slope failure originates, there is severe disruption to the ground surface as a result of scarps, blockfields, troughs, hummocks, screes and ravines. Currently this is manageable in terms of stocking, in many cases. However some ravine and scree development severely restricts stocking, or has forced retirement of large blocks of land.

Override zones of debris flows and rock slides are highly disrupted, boggy and unstable which gives continual problems of fence and track maintenance, stream channel blocking and at least one on-going highway and railine maintenance problem. Active override zones are virtually unmanageable and are fenced off or require earthworks. Override zones of stony debris flows are extremely rough gravel fields which, even more than clayey debris flows, take decades to revegetate and "soften".

Gravel depocentres are debris fans, stream beds and some low lying small terraces. Here the damage is from the burial of pasture, roads, buildings, bridges and lifelines such as water pipes, power lines and communication links. Additional problems arise from raising of stream bed levels and stream deflection. Considerable channel clearing and realignment has been necessary.

Geotechnical mapping has identified areas of slope movement and established geological models for their failure mode and further movement. A consistent relationship with rock type, defects and topography has allowed prediction and recognition of slope failures over large areas previously not well understood or even thought to be stable. In particular identification of overtoppling masses is an addition to our understanding of topples and parallels similar research in the Canadian Rockies (Cruden 1989 and Cruden and Hu 1994).

The geotechnical maps can form a basis for risk assessment in that land at risk from movement in source areas, overrides and depocentres can be identified. The existing maps provide an explanation for the previously enigmatic discharges of debris from ravines on smooth convex slopes in normal pasture.

Although historic records indicate a return period of approximately 50 years for significant events, further research on frequency is needed. Large catastrophic events such as collapse of a sector of a toppling mass or a large debris avalanche are not well dated. Recurrence intervals of these events is dependent on further research into terrace deposits, slope deposits and geomorphology.

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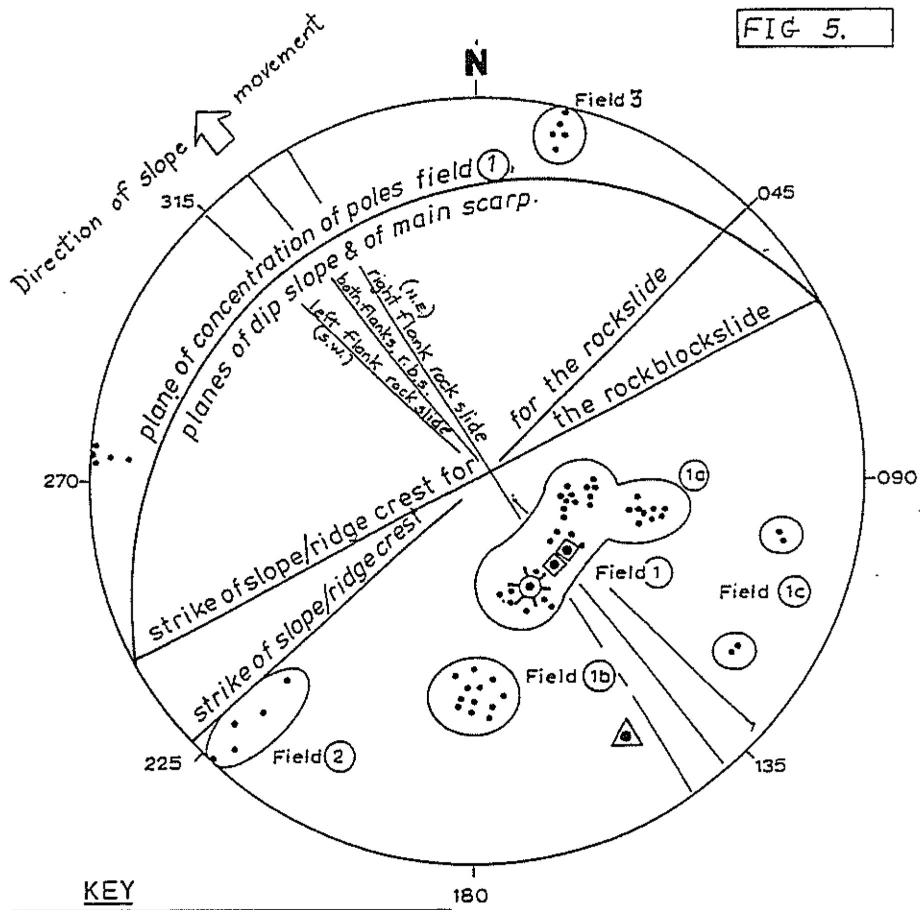

KEY

Poles to slope and defects
▣ dipslope of rockblock slide
⊙ Head scarp and dipslope of rockslide.
✱ dominant clayey crush zone between the Mead Hill Flint & Isolated Hill Limestone.
• clayey crush zones in Mead Hill Flint & Whangai Shale.
▲ crush zone of the Coverham fault and of parallel crush zones in the Whangai Shale beneath the foot of the rock-slide & rockblock slide.

Figure 5. Nidd Rock Slide

Equal area plot of poles to clayey crush zones, and to the head scarp, crown ridge and dip slope.
(Lower hemisphere plot)

BUILDING ON MARGINAL LAND

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SYNOPSIS: Marginal land is defined as a building site (or sites) affected by one or more geotechnical hazards with a frequency or severity such that during its design life damage may occur to the structure and/or injury may result to its occupants. Marginal land is often suitable for residential purposes provided that adequate investigations are undertaken to define the nature and extent of hazards affecting the site, and that the owner accepts a degree of risk to the property with or without implementation of specific remedial/protection works. Examples of successful building on marginal land include dormant landslide complexes, coastal areas, and flood-prone sites; whilst land subjected to rockfall or erosion may similarly be occupied if appropriate protection measures are implemented. Professional advisers have important obligations to clients in advising on development options for marginal land, and administering authorities should be encouraged to make greater use of s36(2) of the Building Act 1991 as this ensures that the geotechnical problems associated with a particular site are clearly identified.

1. INTRODUCTION

New Zealand has a history of building on land that is subject to geotechnical hazards including erosion, subsidence, landsliding, debris deposition and/or inundation. The scale of the problem may vary from the inundation of a township by floodwaters to the impact of a debris flow on a single house site in a remote rural setting; and from the threat to a cliff-top dwelling from ongoing toe erosion and face retreat to the movement and destruction of dozens of houses in a major landslide such as the Abbotsford Landslip of August 1979. Because of the dynamic nature of much of the New Zealand landscape and the continuing use of such hazardous land for residential purposes, legislation has long recognised the need for identification and mitigation of specific hazards at both the subdivision and individual section stages of development (Bell & Pettinga 1985).

"Marginal land" is here defined as a building site affected by one or more geotechnical hazards with a frequency or severity such that during its design life damage may occur to the structure and/or injury may result to its occupants. This definition is not meant to imply that such damage or injury will necessarily occur within the specified time-frame, that the land in question is unsuitable for residential development, nor that realistic remedial and/or protection measures cannot be put in place.

This review of building on marginal land therefore addresses the acceptability of geotechnical risk in an urban or rural context, the role of the professional adviser in such situations, and the obligations of administering authorities in approving such developments. Important philosophical, technical and professional issues are raised, and the adequacy of current legislation is considered in relation to both existing and future residential use of "hazard-prone" land.

2. GEOTECHNICAL HAZARDS

A hazard may be regarded as "the potential or actual danger (= threat) to human life or property which is posed by a natural process having a particular (often large) magnitude" (Bell 1994). A very similar definition of "natural hazard" is given in the Resource Management Act 1991 as "any atmospheric or earth or water related occurrence .... the action of which adversely affects or may adversely affect human life, property, or other aspects of the environment". An alternative usage of the term "natural hazard" is given by Varnes (1984) as "the probability of occurrence of a potentially damaging phenomenon within a specified time period and area"; and the term "risk" is defined similarly by both Varnes and Einstein (1988) as "the product of hazard times potential worth of loss, where loss includes death or injury, capital losses, or non-monetary environmental effects."

In the present context the term "geotechnical hazard" is used in the sense of both natural and human-induced phenomena "which may pose a danger to life, property, or engineering works, or which may otherwise seriously impact on a local community" (Bell 1994 p3388). Following Bell (1987; 1994) these hazards can be grouped under seven major headings (settlement; landslide; erosion; flood; seismic; volcanic; loss of resources), and with the exception of the last of these ("loss of resources") reflect respectively the terrain-, water- and tectonic-related components of landscape development processes. The distinction between geological and geotechnical hazards is that the former involves only natural triggering events, whereas the latter may be initiated by human activity, but in either case it is the impact on people or property that defines the particular process as a hazard. Again, whilst it can be argued that loss of resources is not of itself geotechnical in nature, the economic impacts on communities and the resultant planning implications can be highly significant (Alfors et al 1973; Bell 1994).

3. RELEVANT LEGISLATION

Subdivision of land is subject to a consent process in terms of s106 of the Resource Management Act 1991, and approval shall not be granted if "any land ...., or any structure on that land, is or is likely to be subject to material damage by erosion, falling debris, subsidence, slippage, or inundation from any source" unless "sufficient provision has been or will be made" to avoid, remedy or mitigate the effects of the specific hazard(s). There is thus a clear obligation on the part of the consent authority to ensure that specific geotechnical hazards are identified and appropriately addressed at the subdivision stage of planning, and in many respects the current legislation is similar to that which previously existed under s274 of the Local Government Act 1974 as amended. Some Councils, however, appear to have adopted a policy of requiring specific design details for individual building lots at the subdivision consent stage when this is clearly a matter that should be addressed at the building consent stage, although certainly this could be argued as prudence when dealing with marginal land.

Section 36 of the Building Act 1991 deals with building on land subject to erosion and other geotechnical hazards, specifying in addition to those listed under s106 of the Resource Management Act 1991 "avulsion" (= sudden change in channel position) and "alluvion" (= sediment or debris deposition on adjacent land). Under s36(1) territorial authorities shall refuse a building consent if the land is subject to one or more of the specified hazards, or if the building work is likely to "accelerate, worsen or result in" any of the identified hazards either on the land itself or any other property, unless satisfied that adequate provision has been made to "protect the land or building work" or "restore any damage" caused as a result of the work. In relation to marginal land s36(2) is particularly relevant because it provides for the granting of building consents in situations where the land is subject to one or more of the specified hazards but the building work will not "accelerate, worsen, or result in erosion, avulsion, alluvion, falling debris, subsidence, inundation, or slippage of that land or any other property". In such cases the certificate of title is to be annotated by the District Land Registrar, s36(3) provides for removal of any such entry when it is no longer required, and s36(4) states that territorial authorities and their employees or agents shall not be liable for any approval under s36(2) where damage to the building subsequently results "directly or indirectly" from one (or more) of the specified hazards.

It is important to note that s36 of the Building Act 1991 essentially followed s641A of the Local Government Act 1974 as amended in its approach to building on marginal land, although certainly there was a requirement in the previous legislation for any such buildings to be relocatable. It is therefore somewhat surprising to find that the performance-based Building Code, introduced after the Building Act 1991, specifies that "permanent slopes shall have a factor of safety against instability of no less than 1.5" which clearly is contrary to the intent of the Act itself and would preclude many building sites on marginal land. Also relevant to the administration of urban development are 1) the requirement under s35 of the Resource Management Act 1991 for local authorities to maintain "records of natural hazards"; 2) the issuing of Project Information Memoranda by territorial authorities under s31 of the Building Act 1991 to include data on natural hazards and hazardous contaminants; and 3) provision under an amendment to the Local Government Official Information and Meetings Act 1987 for Land Information Memoranda to be issued with similar data on specified natural hazards and contaminants affecting any land. The adequacy of the existing legislation is discussed later in this review following a consideration of selected case studies which exemplify the range of hazards and geotechnical problems associated with building on so-called "marginal" land.

4. SELECTED CASE STUDIES

4.1 Pompolona Hut Snow Avalanche

Pompolona Hut is one of several accommodation complexes on the Milford Track, Fiordland, and about 23 September 1983 a large snow avalanche triggered a series of events which resulted in extensive damage to the facility and led to its relocation at a cost of approximately $0.5M (Bell 1987; 1994). The Hut complex had been built on a post-glacial fan surface in the valley of the Clinton River and was surrounded by mature beech forest, but previous studies had identified a large snow avalanche runout to the immediate west of the site for which the recurrence interval was estimated at about 100 years (Fitzharrris & Owens 1985). The triggering storm of 18 to 23 September 1983 produced heavy snow falls on the upper slopes and heavy but not extreme rainfalls at lower altitudes, the recurrence interval for the event being estimated at between 5 and 10 years (Bell 1987). However, the damage to Pompolona Hut was the result of the abnormally large runout distance of the snow avalanche (but within the 100 year hazard zone), which caused temporary damming of the Clinton River and subsequent breaching in an new channel position, with flood scour and undermining of the Hut foundations by debris falls and topples. From the perspective of geotechnical hazards it would seem that no one ever asked the key question about possible consequences from a snow avalanche occupying the maximum historic runout zone, because a more suitable building site for Pompolona Hut could obviously have been identified within the mature (100 year+) beech forest nearby where the Hut has now been relocated (Bell 1994).

4.2 Construction on Landslides

Many dwellings have been, and continue to be, built on landslides in New Zealand, one of the better known cases being the Tahunanui Slump in Nelson City where some 120 houses are located on a well-defined pre-historic landslide having an area of 26 ha (Johnston 1979). Movement was first recorded in 1893 during construction of a road; approximately 2ha was reactivated by the Murchison Earthquake in 1929, with local displacements of up to 5m and two houses wrenched off their foundations; and again in 1962 nine houses were damaged when 1 ha moved following an exceptionally wet period. Since 1962 Nelson City Council has installed and maintained an appropriate stormwater system, and has implemented strict controls on earthworks, which together have effectively stabilised the Tahunanui Slump although it is clear that much of the land must have only marginal stability. Whilst the long-term security of properties on such a feature cannot be guaranteed under all geotechnical situations, the owners and occupiers of these dwellings obviously must have a reasonable expectation of stability given that the landslide has not moved significantly for more than 30 years and that strict development controls are being maintained. In such circumstances the properties will be clearly marketable, despite possible limitations regarding mortgage finance and/or insurance cover, and a key question is whether such building sites would warrant approval in terms of s36(2) of the Building Act 1991 if development on the Slump was being proposed at the present time.

In the present context emphasis is clearly being placed on the construction of residential housing on dormant or relatively inactive landslide features, rather than on sites subject to rapid or obviously ongoing movement (eg debris flows generated within gullies) or areas involving first-time slides such as the 1979 Abbotsford Landslip in Dunedin. The latter event has been thoroughly documented (see, for example, Coombs & Norris 1981; Bell 1987; Smith & Salt 1988), and whilst there is debate over the various geotechnical controls on failure it is generally agreed that progressive failure occurred on a low shear strength bedding plane as a result of elevated pore pressures and partial excavation in the toe area (Bell 1994). What is also important in the Abbotsford case study is that excavation of Harrison's sand quarry was to provide buttressing fill for the Motorway Slide further to the west, this latter movement involving reactivation of part of the pre-historic West Abbotsford Landslide on which close residential development had been permitted for many years. Whilst it may be technically and administratively sensible to limit (or prevent) further residential development on dormant landslide features, it is much less easy to deal with existing dwellings on such marginal land

and there is also a very valid counter argument that s36(2) of the Building Act 1991 permits house construction in these "hazardous" situations.

In the Queenstown area concerns about possible slope instability in steeper areas covered by glacial till led to the adoption in 1981 of a by-law requiring engineering geology evaluation of certain land zoned accordingly in the then-current District Scheme (Bell & Pettinga 1985), and this requirement has since been extended to other parts of the District where residential development has either taken place or is proposed on dormant landslides (Bell & Riddolls 1992; Bell 1994). A condominium development was proposed in 1988 and subsequently approved on part of the toe area of the Coronet Peak Landslide, a major foliation-controlled feature having an estimated volume of c.10^9 m^3 and on which is located the Coronet Peak Skifield and associated facilities. Assessment of the proposal, which included engineering geology mapping, air-photo interpretation and limited trenching (Figure 1), concluded that there was no evidence for ongoing instability at the site and that the development was feasible geotechnically provided that the dwelling units were relocatable (a requirement in terms of s641A of the then-current Local Government Act 1974) and that certain measures such as drainage were implemented. On the nearby Arthurs Point Landslide some 12 houses were approved and built before recognition of the feature, and further development has now occurred on more stable parts where measures to maintain (or preferably improve) the present state of marginal stability include heavy compaction of the blocky schistose debris, extra reinforcement of foundation slabs and/or the use of pole frames, retention of cut and fill batters, piping of stormwater off the site, and deep cutoff drains to control any perched groundwater.

The above examples demonstrate that it is feasible to develop on dormant (or relatively inactive) landslides provided that the building work does not reduce the factor of safety (which must already be at or close to unity), and many more New Zealand case studies of successful construction on landslide areas could be cited. This is clearly a situation where approval is appropriate in terms of s36(2) of the Building Act 1991 (and previously under s641A of the Local Government Act 1974) because, whilst the land may be subject to "slippage", "the building work itself will not accelerate, worsen or result in .... slippage". The intent of both present and past legislation is thus met by permitting house construction on slopes or sites having marginal stability (ie a factor of safety much less than the 1.5 specified in the Building Code), although considerable care is required in ensuring that long-term stability is maintained and the owner must accept that a risk of renewed movement remains even though the geomorphic evidence may indicate stability for hundreds or even thousands of years. Many territorial authorities appear reluctant to issue consents under s36(2) of the Building Act 1991, however, and such a form of approval may, of course, have other implications for owners or potential purchasers including an inability to raise mortgage finance, difficulties with insurance for the asset, and/or a negative impact on market value.

4.3 Erosion in Loess Soils

Loess soils consist predominatly of silt-sized particles with varying amounts of clay and fine sand, and form by direct airfall deposition or by subsequent downslope transfer as slope-wash to produce loess-colluvium (Bell & Trangmar 1987). Loess soils are extensively developed in the South Island and the southern part of the North Island, and are characterised by both surface (sheet and rill) and subsurface (tunnel-gully) erosion. The processes involved in erosion include clay mineral dispersion, slaking and physical entrainment of sediment, and laboratory methods to identify loess erodibility include the Pinhole Erosion Test and the Emerson Crumb Test (Bell et al 1990). Residential development has taken place on thick (>10m) loess deposits in the Timaru area without geotechnical problems, but Banks Peninsula (Canterbury) and the Wither Hills (Marlborough) are well known for both tunnel-gully formation and surface rill erosion in the loess soils present there, as well as for shallow landsliding on the Port Hills of Christchurch (Bell & Trangmar 1987; Bell 1994). The geotechnical properties of erodible loess soils have been studied in detail because of their potential impact on urban development in the Christchurch area, and lime and other forms of chemical stabilisation have been utilised in order to minimise the effects of sub-cutaneous erosion (Bell & Trangmar 1987; Bell et al 1990).

Residential development on the Port Hills of Christchurch involves much land that is "marginal" in that both erosion and landsliding can occur either under natural conditions or as a consequence

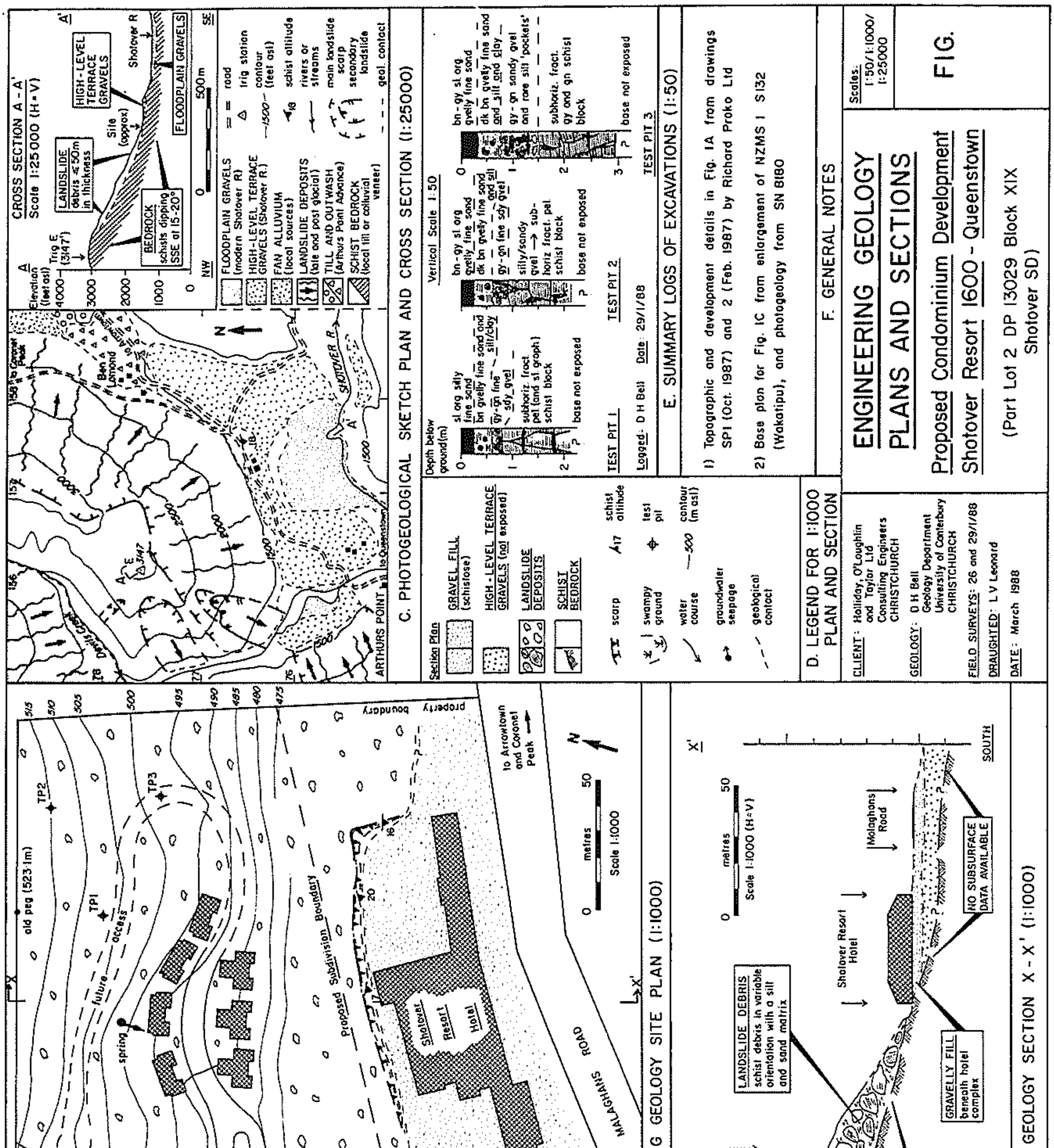

Figure 1 Engineering geology data for proposed Shotover Resort 1600 Condominium development on Coronet Peak Landslide, Queenstown (from Bell 1994).

of construction on the generally steeper (15°+) side- slopes. Geotechnical requirements to minimise the impacts of such development work are well documented (Evans & Trangmar 1977; Bell 1981; Bell & Trangmar 1987; Bell et al 1990; Bell 1994), and an engineering geology evaluation is normallly specified as part of the subdivision or building consent process (Figure 2). Typically an investigation would involve engineering geology mapping of a site, subsurface data from auger holes or trenching, and testing of samples under laboratory conditions in order to characterise the soil materials and establish remedial options. Increasingly Christchurch City Council requires the geotechnical adviser to assume responsibility for the design and implementation of appropriate erosion protection measures, and it is now common practice for reporting and site inspection to be required prior to, during and following completion of works in order to ensure that all issues are addressed. It is certainly reasonable to conclude that the state-of-the-art with regard to erosion in loess soils is now such that close residential development of marginal land on the Port Hills is both geotechnically feasible and administratively well controlled.

4.4 Rockfall Hazards

Current legislation specifies "falling debris" as a particular geotechnical hazard requiring evaluation at both the subdivision and the building consent stages of development, and it clearly involves falls of soil and/or rock materials. In rockfalls the movement may by free-fall, bouncing, rolling and/or sliding in part as a function of slope angle (Ritchie 1963; Varnes 1978), and specific failures can range from individual boulder release on a hillside to significant cliff collapses of 100 m^3 or more in volume. Geotechnical evaluation of potential rockfall hazards is often more difficult than for rotational or translational landslides because of problems in identifying the trajectory and/or runout zone characteristics, whilst cliff-face inspection for individual loosened blocks of rock may require the use of climbing ropes or alternative methods of access. Rockfalls initially involve joint-block release from faces or outcrops, and subsequent triggering may result from earthquake shaking, high joint-water pressures in the face, preferential erosion or failure of a weaker unit, or cultural disturbance (eg by blasting or excavation). It is extremely difficult to predict the timing of rockfall events, and remedial or prevention measures typically involve one or more of scaling of loosened blocks, buttressing with concrete, anchoring of individual blocks, protection fences or barriers, and slope revegetation.

Rockfall hazards have assumed greater importance in Christchurch as more marginal building sites are developed, even though the historic record suggests that there have been continuing small- and large-scale failures in the past 100 (+) years from both natural and human-induced causes. In 1987 a building permit was issued for a site in the suburb of Redcliffs that was located on the talus apron below a 50m (±) high cliff in basaltic lavas, and the house was subsequently damaged by minor rockfalls sourced from the cliff face. Some 50 m^3 of rock failed from the cliff face onto the adjoining vacant section in June 1992, and the present owner of the house then sued Christchurch City Council on the grounds that consent should have been refused as the site was unsuitable for a dwelling. The case was decided in late 1995 and endorsed the geotechnical evidence that appropriate rockfall protection works (ditch, bund and fence) should be installed at the rear of the house for long-term occupancy of the site, but the main claims for damages and compensation were rejected.

In Kaikoura the University of Canterbury's research building was located within 4m of the base of a 45m high cliff in closely fractured limestones, and following an intense rainstorm in July 1992 two limestone blocks each of 100-150 kg mass fell through the roof of the building causing minor damage but rendering the rear half of the building unsafe for occupancy. The roof of the building was immediately covered with hay bales as a form of temporary protection, and more than 60 t of fractured limestone removed from the face by hand using a crane with an extension jib as a means of access. A canopy protection structure has since been cantilevered over that part of the roof within the rockfall trajectory zone, and this consists of cable-supported wire mesh which can deflect up to 1m vertically and absorb impact energy from 150 kg blocks. Regular scaling of the cliff face will be carried out every 5-10 years as a preventative measure, and a wire mesh canopy has also been placed at the rear of the building to deflect rockfall debris onto a catch-bench area. This case study higlights the fact that the designers of the building did not consider rockfalls as a potential hazard despite its location at the foot of a cliff, and that the local Council did not require

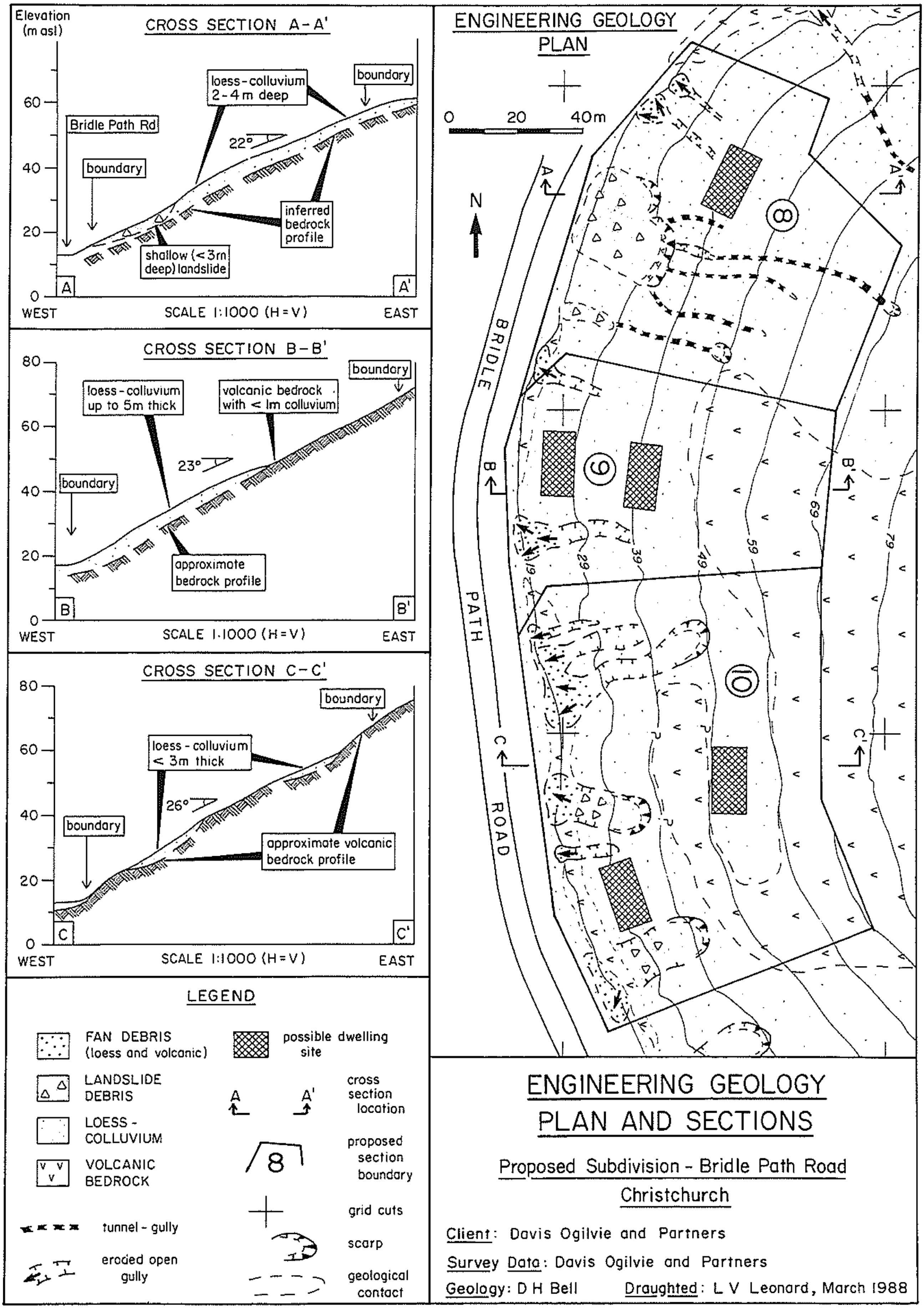

Figure 2 Engineering geology data for proposed subdivision on erodible loessial soils, Port Hills, Christchurch (from Bell 1994)

appropriate investigations as part of the consent process (although in the latter case it is true that "falling debris" was not specifically mentioned in the then-current Local Government Act 1974).

4.5 Developments in Coastal Areas

Many residential subdivisions in New Zealand are located in close proximity to the sea, either within dune complexes or on cliff tops, and experience would suggest that in general coastal lands should be regarded as "marginal" for development purposes. Geotechnical problems such as erosion and instability have arisen in relation to a number of these properties, and a variety of approaches to coastal hazard zonation and mitigation have been adopted (Gibb 1981; Bell 1987). On South Brighton Spit in Christchurch 12 dwellings are presently located seawards of the 1950 shoreline position on a dynamic geomorphic feature which has migrated more than 100m since the first surveys in 1849 (Kirk 1983). Further development of this area is strictly controlled within a designated Residential Coastal Zone, but because the coastline is essentially prograding it has been decided to allow these dwellings to remain within the foredune area despite the risk of short-term storm-induced retreat. Further north along the shoreline at New Brighton a minimum 20m hazard zone has been adopted for dwellings, and the foredune area is both preserved and actively managed to maintain a suitable vegetation cover.

At Motunau Beach, North Canterbury, some 20m of cliff-top retreat has occurred in the last 20 years following a period from about 1890 to 1970 when no significant erosion occurred. One house has already been relocated, a second is under threat from cliff-top failure, and a coastal hazard zone has been adopted by the local Council within which further building activities can be closely controlled. The 30-30m high cliffs are developed in relatively unbedded Pliocene mudstones, and the failure mechanism involves multiple shear fracturing near the base of isolated mudstone columns with subsequent removal of failed debris by slaking of the uncemented weak rocks (Figure 3). Construction of a gabion basket wall some 15m out from the base of the cliff to partially buttress failed debris and allow revegetation proved to be unsuccessful, principally because of a lack of maintenance of the baskets following storm damage. In the Tauranga area cliff failures within volcanic ash and derived soils has resulted in potential damage to properties at a number of sites (Houghton & Hegan 1980), and on Maungatapu Peninsula several houses were threatened by cliff retreat in mid-1995 following an abnormally wet period, with failure initiated in Tauranga Group sediments at a depth of some 10-12m below the top of the cliff.

5. GEOTECHNICAL CONSIDERATIONS

5.1 Building on Marginal Land

The preceding examples illustrate clearly that there are significant geotechnical issues in residential development on marginal land, and that these must be addressed as part of the consent process in the same manner as for any other engineering site investigation. The identification of geotechnical hazards and the provision of data on magnitude-recurrence interval relationships are fundamental to any development project, and an engineering geology evaluation should therefore form the first stage of any geotechnical assessment (Bell & Pettinga 1984). A systematic approach to the evaluation of land for residential subdivision was developed as a consequence of the Abbotsford Landslip (Bell & Pettinga 1985), and this is directly applicable to all land whether or not it is considered to be "marginal" as defined in this review. The methodology involves interpretation of aerial photographs flown at different times and scales (where available), engineering geology mapping (typically at scales of 1:500 to 1:2000), subsurface data collection using hand augering or trenching, and limited laboratory characterisation of material properties. The result of such investigations is the formulation of engineering geology site models and the identification of geotechnical constraints to any proposed development, with specific recommendations for subdivision layout and access requirements, suitable building sites or envelopes, and further geotechnical and/or foundation design investigations. The approach has been adopted in various parts of New Zealand and an engineering geology assessment is frequently required as part of the consent process, although clearly it is not a substitute for detailed site-specific geotechnical investigations if or where necessary (Bell & Pettinga 1985; Bell 1987, 1990, 1994).

As defined in this review building sites on "marginal land" are affected by one or more geotechnical hazards that <u>may</u> cause damage or injury during the design life of the structure, which can be nominally taken as 50 years (although it is

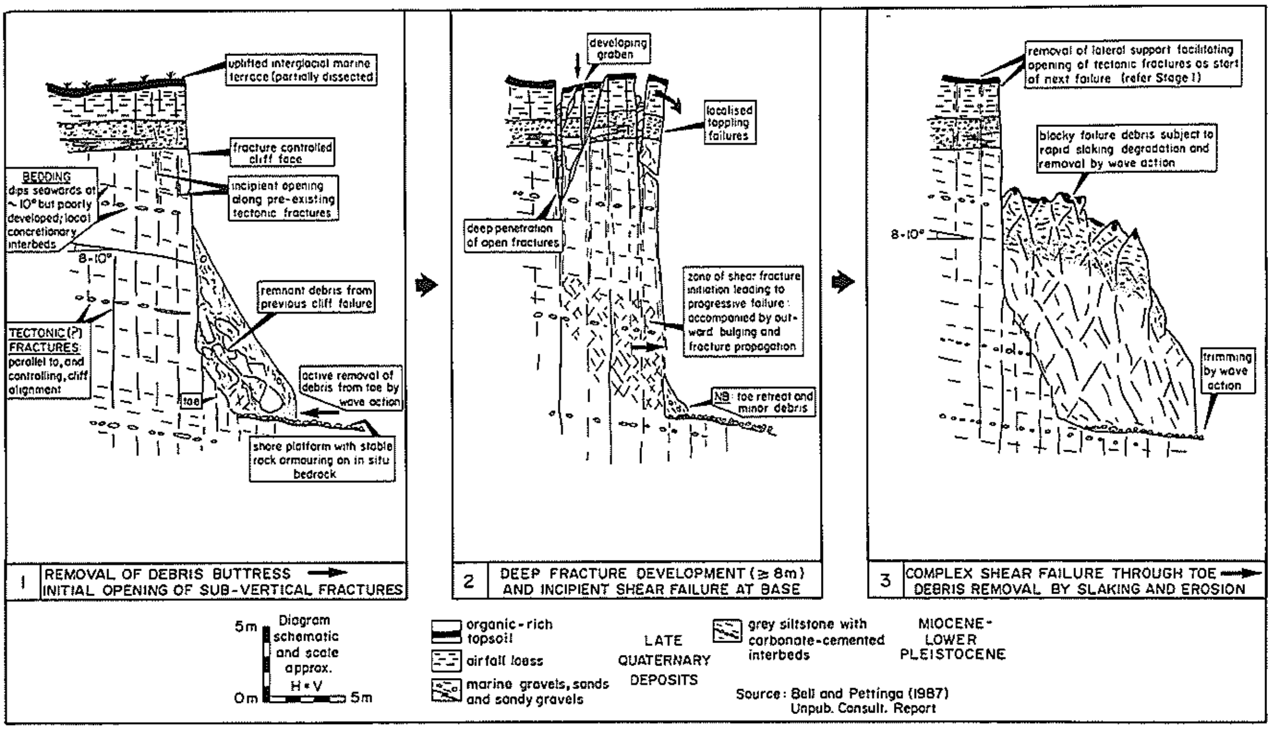

Figure 3 Cliff failure mechanism for residential development site, Motunau Beach, North Canterbury (from Bell 1994)

often considered to be 100 years for the purposes of hazard analysis). It is therefore strictly land for which approval should be given in terms of s36(2) of the Building Act 1991 (or s641A of the Local Government Act 1974), because although the site is subject to one or more specified hazards the act of building will not of itself increase the degree of risk. Obviously, however, the owner and/or occupier must accept the consequences of building on hazard-prone land, and it is clear that a significant number of dwellings in New Zealand are in fact sited on land that is "marginal" without a great deal of community concern. The perception of what is a hazardous building site varies considerably, and the fact that many older areas within towns and cities are at risk from, for example, flooding or landslip, is often ignored by the market. Whilst territorial authorities and the geotechnical profession have obligations to ensure the safety of building sites, it is also clear that the current legislation permits residential development on so-called "marginal" (ie hazard-prone) land and that this practice has continued for many years. The engineering geology approach outlined above enables the recognition and evaluation of land that may be considered "marginal", as well as land with no significant geotechnical constraints to residential development, and continuing pressure for building on these more difficult sites must be anticipated for a variety of reasons.

5.2 Specific Issues

The preceding discussion has highlighted a number of specific geotechnical issues that have to be considered in evaluating and controlling development on so-called "marginal" land, including:-

A. Hazard Recurrence Interval Data: The determination of magnitude-frequency data for estimating recurrence intervals of damaging events (or geotechnical hazards) is at best an inexact science, and the available records are often of inadequate length or acccuracy to be statistically reliable. As suggested above an appropriate consideration in most cases is the 100 year event, which can be expected to recur on average once every 100 years, as this is a realistic maximum design life for a dwelling. There can be no doubt that a satisfactory determination of landscape development over time, and the recognition of active geomorphic processes affecting a particular site by using an engineering geology approach, will provide a realistic basis for geotechnical evaluation but that it will not necessarily yield quantitatively useful data on which to base remedial design. For residential development on marginal land there has to be prior recognition of its potentially hazardous nature, and a judgement based on local knowledge and experience as to the advisability of building construction and/or implementation of hazard mitigation measures.

B. Construction on Dormant Landslides: Although it would be rare to recommend construction of dwellings on landslides that are actively moving, there are in fact many residential areas in New Zealand located on inactive (or dormant) landslide features where there is no evidence for ground movement or property damage after many years. Provided that due care is taken in the design of foundations and the control of both surface and subsurface water, some residential development on dormant (or inactive) landslides is an acceptable risk if careful engineering geology assessment can demonstrate realistic long-term stability of the feature. Certainly there may be concerns with financial or other aspects, a fact that owners and intending purchasers should be aware of, and it would probably be unwise to permit subdivision of such marginal land at traditional densities. From a legal point of view the issue is whether approval should be given under s36(1) or s36(2) of the Building Act 1991, whilst in terms of the Building Code it is quite clear that a factor of safety of 1.5 cannot be achieved for "permanent slopes" (and hence the development should presumably be refused even though long-term stability can reasonably be assumed).

C. Construction in Coastal Areas: Geotechnical hazards in coastal areas include rapid erosion of shorelines by storm-wave attack, longer-term changes (ie over tens to hundreds years) in response to the wave climate, and episodic cliff retreat. Recognition of the 100 year coastal hazard zone (following the methodology of Gibb 1981) is one technique for managing the development of such marginal land, and using site-specific geotechnical data it may also be possible to recommend appropriate setback distances for building on cliff tops. The coastal environment is in many ways unique, however, and requires long-term monitoring of shoreline profile changes as well as wave climate data for appropriate planning and engineering decisions. Given the relatively high population density in the coastal fringe there is obvious scope for close geotechnical involvement with the development of such "marginal" land, and interdisciplinary studies are clearly appropriate in order to obtain the requisite database.

D. Rockfall Hazards: Rockfall hazards are important geotechnical constraints in urban development, but may be difficult to analyse quantitatively because of uncertainties regarding source, block size and trajectory. Whilst computer simulation programmes now exist to determine such parameters as bounce height and runout distance for highway slopes (see, for example, Pfeiffer & Bowen 1989), there are a variety of problems in assessing rockfall hazards because of the geological complexity of particular situations and the fact that prediction as to timing of failure is generally impossible. The recognition of the importance of rockfall hazards in cities such as Christchurch has been somewhat belated, and the state-of-the-art has changed dramatically in the past 5-10 years with requirement for site-specific investigations now as part of the consent process. As a consequence the remedial and protection measures implemented have been significantly upgraded for new building sites, but concerns must remain about older sites where no such work was carried out at the time of house construction.

E. Setback and Runout Distances: One of the most difficult geotechnical issues for building sites on top of cliffs or banks is that of appropriate setback distances, whilst in gully areas and at the base of cliffs the question of runout distance for failed debris (either as falls or flows) has to be considered. The fundamental consideration with cliff-top development is the rate of retreat that can be expected over a reasonable design life (say, 100 years), and also whether the cliff or bank is undergoing active erosion (eg by sea or river). A degree of judgement is required in evaluating setback distances, as well as a good knowledge of historical changes that have occurred, and in Tauranga a zone defined by 2H:1V is used to control cliff-top building (based on the observations of Houghton & Hegan 1980). With regard to development at the base of cliffs any building within the talus apron is clearly at risk, as this represents the accumulated debris from past failures and future falls have to be anticipated, and site-specific investigations and protection measures must clearly be undertaken. The location of dwellings on fan surfaces at or near the mouths of gullies is a related geotechnical problem, especially in areas such as the Marlborough Sounds where flatter building sites are generally restricted, and the potential for damage from rapid storm-generated debris flows (with or without avulsion from the present stream bed) is often high. Considerably more work is required to establish appropriate geotechnical guidelines for the control of such developments, and in the interim continued reliance is required on precedent and professional judgement.

F. Existing Urban Areas: Within existing towns or cities there are often areas affected by specific geotechnical hazards with a severity or frequency that would warrant classification of the land as "marginal", for example large landslides or floodways on which residential development has already taken place. In such cases the costs of relocation or abandonment of the land are usually too high for community acceptance, even though the building sites and/or occupants may be at significant risk, and the approaches adopted by territorial authorities clearly vary. For example, in Nelson the Tahunanui Landslip is maintained in a state of marginal stability and strict building controls are applied, whilst in Greymouth a flood protection wall was built in preference to relocation of the central business district which had been repeatedly flooded since settlement of the area. The geotechnical issues associated with hazardous sites in existing residential areas are clearly greater than for land that has not previously been developed because of difficulties in undertaking further remedial measures and pressures to maintain property values. Again this is a matter where different decisions will be made by various territorial authorities depending on the nature of the problem(s), the costs involved, and the community perceptions of the risks involved: whilst geotechnical advice may well be to abandon the site, this will not necessarily be the outcome in practice and the "marginal" land that has already been developed may remain in residential use indefinitely.

6. PROFESSIONAL AND ADMINISTRATIVE CONSIDERATIONS

6.1 Professional Issues

The role of the geotechnical professional in the development of so-called "marginal" land is clearly to identify the nature of the site and the associated hazards, and to advise the client of the implications of building including the need for any remedial or protection measures. Quantitative risk assessment is unlikely to be feasible, although it may be possible to provide some crude probability estimates of future damage at the site, and a great deal of reliance will have to be placed on precedent and local knowledge. As previously discussed the geomorphic history of the site provides an essential component in the evaluation process, and a systematic consideration of the various hazards affecting the land will be necessary in terms of the relevant legislation for either subdivision or building consent purposes. Engineering geology therefore has a key role in the geotechnical assessment of marginal land, and should form an integral part of any investigation programme whether dealing with the evaluation of a previously undeveloped site or of problems associated with an existing residential area.

A particular concern for the geotechnical professional is whether or not to recommend approval of individual building sites in terms of s36(2) of the Building Act 1991, as this is directly relevant in terms of the current legislation and also may have significant implications for the owner or developer in terms of mortgage finance, insurance cover, and market valuation. The risks associated with building on marginal land have to be clearly understood by all the parties concerned, and care must be exercised in the wording of geotechnical reports so that all of the issues are identified and addressed in a balanced manner. A recommendation not to proceed with a proposed development on marginal land would clearly require strong justification given the wording of s36(2) of the Building Act 1991, and likewise any decision supporting a proposal would need suitable phrasing such that the geotechnical professional was not subsequently found negligent or liable in the event that an identified constraint materialised to the extent that the site was no longer considered safe. If real concerns exist about the suitability of a specific site or development proposal peer review is an option, although again the client will need to agree to the added cost: similarly involvement with a site where a serious geotechnical problem has occurred or is developing requires considerable skill on the part of the professional adviser given the emotional trauma likely to be experienced by the owners or occupiers of the property.

6.2 Administrative Matters

Territorial authorities seem at present reluctant to apply s36(2) of the Building Act 1991 in approving developments on marginal land, in part possibly because the legislation is relatively new and no legal precedent yet exists in this area. However, as previously discussed s36(2) is little different in intent from s641A of the Local Government Act 1974, and it is quite clear that building on marginal land has been occurring for some time with and without appropriate geotechnical advice. Some pressure may be coming from clients and legal advisers given that a s36(2) approval has potentially negative implications for financial aspects of a proposal, whilst there is definitely a profit motive in the closer subdivision of a marginal site that may be suitable for only 1 or 2 dwelling units per hectare. Although there may also be difficulty in deciding from a geotechnical point of view whether s36(1) or s36(2) is applicable, from an administrative perspective if significant hazards are identified affecting a particular site then it may be prudent to give approval in terms of s36(2) until such time as all remedial and/or prevention measures are in place and then invite the owner to apply for removal of the title annotation under s36(3).

It seems clear that the intent of the current legislation is to permit building on marginal land, and considerable precedent has already been established in this regard. It is therefore rather surprising that the Building Code specification of a factor of safety of 1.5 for permanent slopes should be introduced, as this would clearly preclude development on dormant landslides and many coastal cliff sites which might otherwise be approved under s36 of the Building Act 1991. The costs of obtaining sufficient site-specific data to conclusively establish such a safety factor may be prohibitive, even for sites that are not "marginal", whilst there is no specification as to the conditions (eg saturated with seepage; earthquake loading) under which the calculations are to be made. There are also many sound (ie s36(1) approval) building sites where such a high factor of safety cannot be justified in terms of long-term risk to occupiers, and if many of the existing slopes in closely settled parts of New Zealand were analysed correctly the factor of safety would probably be less than 1.5. If building consent approval is to be made by blind adherence to a code then the intent of s36 of the Building Act 1991 is being ignored, and the judgement of geotechnical professionals is being questioned (and possibly refuted) by persons with little or no technical knowledge on the subject.

7. PRINCIPAL CONCLUSIONS

1) "Marginal" land is here defined as a building site (or sites) affected by one or more geotechnical hazards with a frequency or severity such that during its design life damage may occur to a structure and/or injury may result to its occupants: marginal land is not necessarily unsuited to residential development nor is the risk to the occupiers unacceptable, but there are clearly significant geotechnical constraints that must be adequately addressed at the planning and construction stages and there may be a need for ongoing maintenance of remedial measures.

2) The term "hazard" is here defined in the sense of a danger or threat to human life or property, and geotechnical hazards can be grouped as settlement, landslide, flooding, erosion, seismic, volcanic, and loss of resources: current legislation requires the evaluation of hazards due to erosion, falling debris, subsidence, slippage, and inundation for subdivision consents issued under the Resource Management Act 1991, and additionally avulsion and alluvion for building consents under the Building Act 1991.

3) Examples of residential development on marginal land in New Zealand include construction on dormant (or relatively inactive) landslide complexes, building in flood-prone areas and on sites subject to rockfall, erosion or deposition hazards, and coastal developments such as cliff-top and foredune areas: approval of such building work should now be given in terms of s36(2) of the Building Act 1991, as this allows annotation of the property title with the relevant hazards or remedial information and transfers the responsibility for risk acceptance onto the owner or developer.

4) Building on marginal land may have significant implications for the availability of mortgage finance, insurance cover, and market valuation, especially if approval is given in terms of s36(2) of the Building Act 1991: construction of residential dwellings or larger complexes on marginal land is appropriate with sound geotechnical advice and evaluation of the issues involved, but there may still be significant risks of which the owner, occupier and/or future purchaser must be made aware.

5) There are important professional responsibilities for the geotechnical adviser when involved with

development on marginal land, and it is essential that an adequate assessment be made of the hazards associated with the site as well as careful reporting of the risks so that the client can make an informed decision: from an administrative point of view increasing use should be made of s36(2) approvals for building sites on marginal land, and it should also be noted that development at traditional densities is unlikely to be acceptable in such situations.

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Building Development on Marginal Slopes

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SYNOPSIS : Two design concepts are proposed which allow building development on slopes with marginal stability. The philosophy of the concepts is to protect the structure in the event of a land slip, either (i) retaining the ground beneath the structure while allowing the ground in front of the retention system to slip, or (ii) providing a self supporting floor, and supporting the edge of the structure on widely spaced strong piles which allow the ground around the piles to slip away.

1. INTRODUCTION

Building development on slopes with marginal stability is common in areas where relatively expensive remedial measures to improve stability are economic, eg cliff top sections along Auckland's waterfront and river bank sections along the Waikato River in Hamilton.

This paper proposes 2 simple design concepts which allow building development on such slopes. The concepts, while making certain simplifying assumptions, have been approved by some Territorial Authorities and used in practice.

2. PROPOSED DESIGN CONCEPTS

The philosophy of the concepts is to protect the structure from the effects of land slip in situations where it not feasible to improve the stability of a steep slope.

(i) Concept A

Protect the structure by retaining the ground beneath it, while allowing the ground in front of the retention system to slip.

Concept A is illustrated by the example of a cliff top site in Auckland shown in Figure 1. The chosen retention system is a closely spaced bored cast in situ concrete pile wall, which is often the most feasible system. The spacing of the piles (less than 3 pile diameters centre to centre) is chosen to ensure arching of the soil between the piles so that they act as a retaining wall.

The stability of the slope in front of the pile wall is analysed to determine the envelope of slip surfaces with a factor of safety of 1.5. To simplify analysis the effect of the piles on the slip surface geometry is modelled as a tension crack. For design of the piles as a retaining wall the slip surface envelope is used to determine both the design height of retained soil and the ground slope in front of the piles when they act as a retaining wall.

(ii) Concept B

Protect the structure by providing a self supporting floor, and supporting the edge of the structure nearest the slope on widely spaced piles. These piles are strong enough to allow the ground around them to slip away from beneath the structure while still providing support to the structure.

Concept B is illustrated by the example shown in Figure 2 with a widely spaced bored cast in situ concrete pile wall being used at the front edge of the building. The spacing of the piles (greater than 4 pile diameters centre to centre) is chosen to ensure that the soil slides past the piles and does not arch between them.

The stability of the slope beneath the building is analysed to determine the envelope of slip surfaces with a factor of safety of 1.5. To simplify analysis, the pinning effect of the piles on the slip surface is conservatively ignored.

The design height of sliding soil applying a force to the back of the piles during the land slip is determined using the slip surface envelope. Concept A is often more economical than Concept B, and both should be considered during the design process.

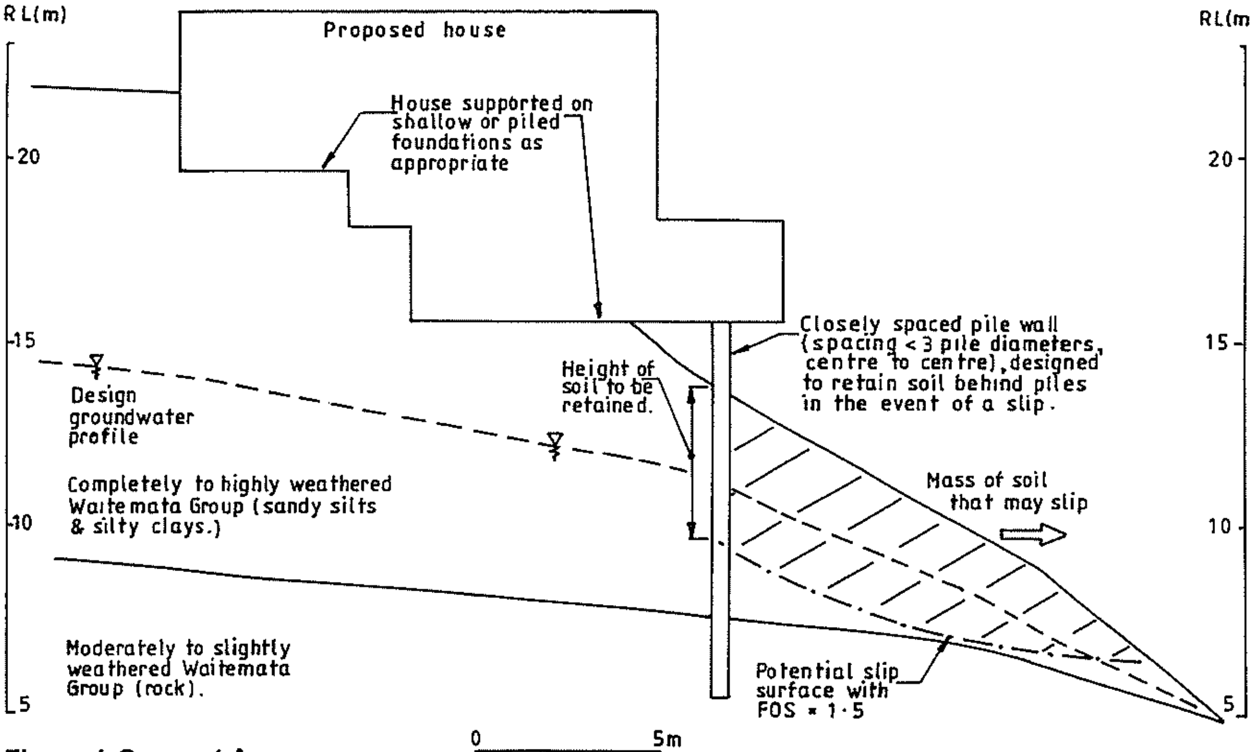

Figure 1 Concept A

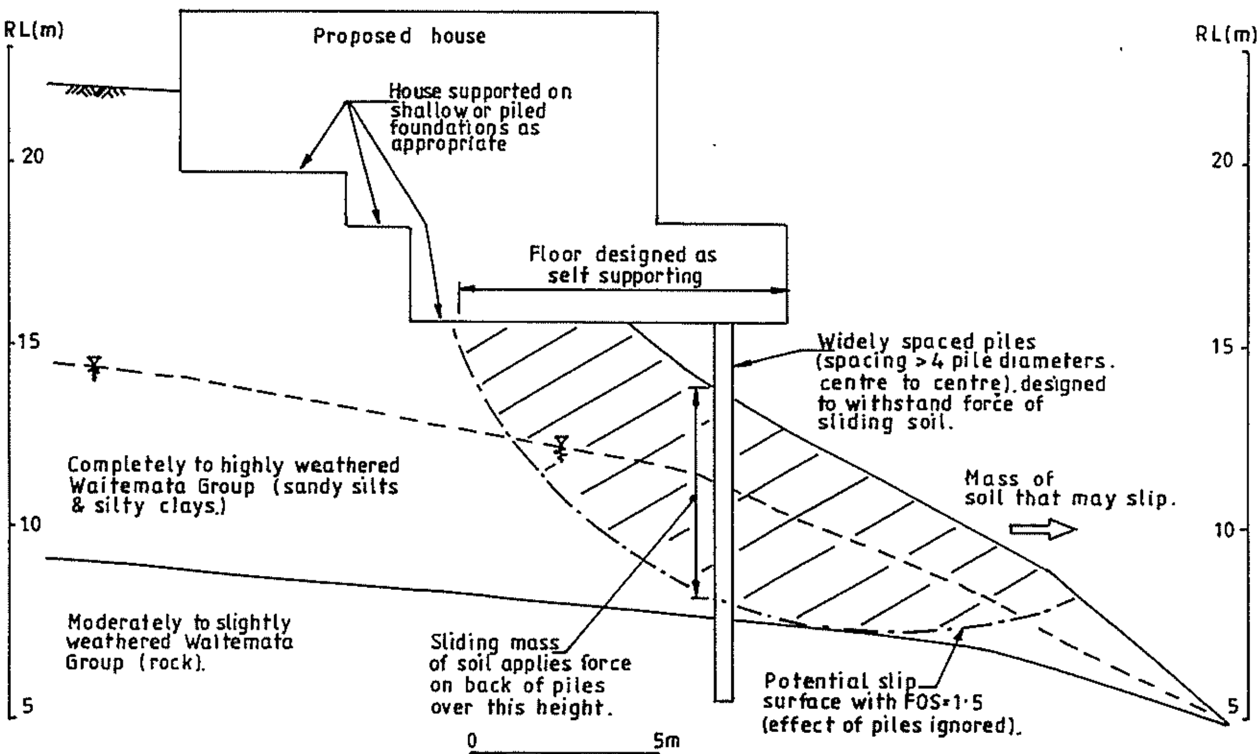

Figure 2 Concept B

Geotechnical Issues of Land Development on the North Shore - A Consultant and Council Viewpoint

Scott Vaughan, *Riley Consultants Ltd., Auckland NZ*
Brian Gunson, *Inspections Chief, North Shore City Council, Auckland NZ*

SYNOPSIS: Development of marginal land on the North Shore will continue to occur and be governed primarily by market demand. It is reasonable to expect that this will at least maintain or more likely increase the current level of geotechnical involvement.

Geotechnical input for such developments is variable and is governed by several factors, the most significant of which is the considerable subjective component involved in geotechnical work. This is a factor that has contributed to difficulties encountered in achieving consistency in the vetting of geotechnical aspects by Territorial Authorities.

The geotechnical profession should consider ways in which performance can be improved by way of approved practitioner lists or minimum standards and guidelines for geotechnical work. Failure to do this will ensure that variable standards of geotechnical work and development will continue to occur and will not improve the perceptions of territorial authorities, the public and the civil engineering profession toward Geotechnical engineering.

1. INTRODUCTION

Intensive development of the North Shore area has been ongoing for many years with an apparently increasing degree of infill and marginal land development undertaken. A combination of the geotechnical hazards encountered and the tightening of development control procedures has generally resulted in greater Geotechnical input being required.

Many of the blocks of land and individual sites being developed in recent years have required innovative geotechnical engineering solutions to provide suitably stable building platforms. The long term stability of these developments placing considerable reliance on the experience and expertise of the Geotechnical practitioner. This is not to say that some earlier developments did not require intensive geotechnical involvement.

Areas previously left untouched due to marginal stability and associated high development costs are now being developed as market pressures make them economically feasible. This is a trend that is likely to continue.

The approval for development of such areas is the responsibility of the territorial authority. The absence of standards that comprehensively cover geotechnical investigation, design and reporting, has meant that the vetting of geotechnical aspects of development has been inconsistent from Council to Council and within Council. This is a problem that is not uncommon to the North Shore City Council which has been faced with the amalgamation of five former Borough Councils since 1990 and a major restructuring of its staff resources.

Geotechnical engineering typically requires a considerable component of personal judgement. Standards for compliance therefore cannot be easily assessed. As a result of the absence of rigid standards and procedures, the quality of geotechnical engineering submitted to Council is highly variable. In some cases the work of some practitioners has been proven by failure to be inadequate and indicates they are not adequately experienced in the field of geotechnical engineering.

The following paper discusses geotechnical issues of development in the North Shore Area from the viewpoints of a Geotechnical Practitioner and Senior Development Control Engineer of the North Shore City Council.

2. MARGINAL LAND ON THE NORTH SHORE

The geology of the North Shore significantly influences site stability and includes sedimentary siltstone and sandstone formations, volcanic tuff and basalt flows, soft infilled alluvial valleys and Pleistocene deposits. Geological controls such as bedding plane attitudes within the sedimentary formations are of particular importance in assessing the long term stability of cliff top properties. Typically the greatest degree of geotechnical involvement in the North Shore area as elsewhere in NZ, is required for the development of land that falls into the following categories.

Steep Sites - not exhibiting signs of past movement
Steep Sites - with evidence of previous instability
Cliff Tops
Soft Alluvial sites

Filled and/or contaminated sites

For each of these site types there are specific investigation requirements for establishing sufficient information for stability and foundation assessments. The selection of appropriate investigation and analysis techniques will vary not only for each type of site but will vary from site to site.

These are reasonably basic considerations that would be taken for granted by most experienced Geotechnical Practitioners. As the assessment of these requirements is of a subjective nature there will typically be differences of opinion between Practitioners. The difficulty arises in assessing whether both opinions or methods are correct or whether one is correct and the other faulty or whether both are faulty.

As would be expected over a number of years, knowledge has been gained by local Geotechnical Practitioners and Council staff regarding areas of the North Shore that are stability sensitive. This information has in some North Shore Council City Area offices been compiled into hazard registers. This is however, not a consistent approach throughout the Council. These types of registers are of particular use to Council staff when vetting geotechnical aspects of development in these areas. They do not give indications of minimum geotechnical requirements.

3. GEOTECHNICAL INPUT FOR DEVELOPMENT

The input provided by Geotechnical Practitioners varies considerably and is dependent on several factors including the following:

A) Identification that geotechnical involvement is required

In our experience we have found that occasionally the need for geotechnical involvement is not identified or is ignored by engineers, architects and developers. Plans are accordingly submitted for consent approval at which point Council will either identify the need for geotechnical involvement or will process the application on the basis of the information provided. If the property is identified as being stability sensitive it will generally be by way of either a site visit or from knowledge of the area, each of which require a subjective involvement.

The potential exists for stability problems to go unchecked if not initially identified by the applicants, engineers or architects and then subsequently overlooked by Council processing staff who do not have local knowledge, geotechnical expertise or access to a hazard register.

B) Budget restrictions

The degree of geotechnical input for projects is often limited by cost constraints governed by budget restrictions. With several geotechnical consultancies in the Auckland area ranging in size from 1 to 2 persons to <20 persons, competition for geotechnical work for residential developments is very tight. In many cases residential geotechnical work is being undertaken for charges less than or equal to those 5 to 8 years ago. In order to undertake this work within these budgets the degree and quality of investigation, interpretation and reporting is being compromised. Reductions in the area of investigation would mean that more assumptions were being made about subsurface conditions. This could result in overconservative designs with unnecessary additional construction costs or at worst failures due to insufficient geotechnical information being obtained or incorrect assumptions being made. The market will generally govern the final price that will be paid for such services. It should be the responsibility of the Geotechnical profession as a whole to ensure that standards are not lowered in the course of meeting restrictive budgets. To do this it must be assessed what are the acceptable professional standards.

The subjective opinion of the Geotechnical Practitioner will also influence the degree of geotechnical input for development, as discussed earlier. This will be a function of their experience and expertise.

C) The level of expertise and experience of the Geotechnical Practitioner

In requesting geotechnical information for building consent applications, Councils including the North Shore City Council often require that the work be undertaken by an "engineer experienced in soil mechanics". Whether this has the same meaning as Soils Engineer or Geotechnical Engineer is open to debate. Whether as a direct result of this particular wording or not, some geotechnical work is undertaken by engineers who have had considerable experience in other aspects related to residential development such as structural and general civil design rather than geotechnical. Is it correct to say they are not Geotechnical Engineers? What are the requirements for an Engineer to call himself/herself a Geotechnical Engineer? It is apparent that there are differing perceptions within the civil engineering profession of the requirements for the Practitioners of geotechnical work.

From the perspective of a territorial authority it is difficult to know whether the author of a geotechnical report is a Geotechnical Engineer who practises predominantly within that field or is a Structural or general Civil Engineer with some knowledge of soil mechanics that he/she calls upon from time to time. This of course is not an issue if the work is of an acceptable standard. In the case of the North Shore City Council a list of several Geotechnical Practitioners whose work is generally deemed acceptable has been prepared some years ago. It is a list that is selectively used by the various area offices of the Council and is not regularly updated. The list has been compiled not so much on the basis of technical competence as the numbers of reports that pass through the Council office.

The present procedures for processing geotechnical aspects are heavily dependent on the Council officers local knowledge, technical capability and familiarity with geotechnical engineering. It is debatable whether these Council officers should have any geotechnical knowledge as they and the Council are reliant on the expertise and ethical responsibility of engineers presenting their work. In processing these aspects however, they are being involved as Geotechnical practitioners for the Council in a review capacity. In this capacity they should have a general knowledge of Geotechnical engineering, be able to recognise the more difficult developments and tag them for further input. This should also include requesting peer reviews if necessary.

In comparison, aspects such as planning and construction not requiring specific design are processed by Council staff with specific knowledge of these fields. They are assisted by policies and standards such as district schemes and building codes unlike geotechnical issues.

In summary, the geotechnical input for development on the North Shore is governed by many factors including:

- the geological setting
- whether geotechnical problems are identified
- the ability of persons undertaking these works
- the standard of the geotechnical work

4. VETTING OF GEOTECHNICAL ASPECTS OF DEVELOPMENT - A COUNCIL PERSPECTIVE

Since the amalgamation of five former Borough Councils in 1990, the North Shore City Council has embarked on a gradual trend towards centralisation of services associated with roading, stormwater, sewerage, water supply, environmental health, reserves, parking enforcement and property management. This has been extended over recent months by the formation of Development Services to centralise the processing of all building consents, inspections, customer services and resource consents in order to streamline the various processing functions which were previously undertaken by five regional area offices. The move strives for greater consistency in application of procedures, the interpretation of new building codes, regulations, Acts, resource management consents and town planning requirements, along with application of higher skill and training levels for staff. The service will integrate with a geographic information database being established to bring general information to a customer advisory interface, and technical information for staff involved with application processing.

Application vetting is a key function of the processing system. It starts by sifting through the documentation for administrative correctness, then follows through building, town planning and drainage issues, then on through technical checks on structural elements/civil engineering, fire and egress (where appropriate), heating and ventilating (where appropriate), environmental health (where appropriate), a hazards check and site visits, often involving more than one professional discipline.

4.1 Significance of the Geotechnical Overview

In terms of geotechnical input the vetting system is highly dependent on the experience and local knowledge of Council assessors and private engineering practitioners engaged by the land owners. There is use of information held by various divisions of Council including historical data held on property files, previous reports by consulting engineers on a specific site or adjoining ones, requisition content and hazard data.

Of fundamental significance is an appreciation of visiting the site to identify the key geologic sequences in relation to the terrain presented, and to distinguish between such sequences (including often localised main-made filled areas) and the proposed intentions of any developer or builder. The basic Miocene, Pleistocene and Holocene sequences are frequently evidenced throughout the North Shore City area, but they are dispersed with erosion sequences or artificial fills which can lead to quite demanding requirements in terms of geotechnical coverage and structural engineering content. In essence, the question of capacity between the geotechnical practitioner, Council assessor(s), and the structural designer arises, along with consensus in reaching agreement with the land owner, his architect and his bank balance.

Resolutions achieved without cross-referencing the findings of others invariably lead to unsuccessful or non-performing applications. We must remember that our Council interprets the useful life of any new building consent for a period of 50 years, but there are many examples where that vision of performance has been truncated by failure in various forms within 10 to 15 years of so-called completion. Practitioners can do better than that if they think about teamwork.

Investigations that are undertaken with obvious levels of technical comprehensiveness have a tendency to introduce controlling requirements and follow-ups. They condition their approvals with recommendations designed to prevent rather than cure and Council supports this. The move promotes the concept of a duty of care, and application of reasonable skill for the protection of parties involved.

4.2 Control Mechanisms

Geotechnical practitioners are well familiar with the classical load adjusting and drainage techniques controlling shear strength and pore pressure distribution, often modelled from subsoil water level approaching ground surface, down to a scenario approaching full drawdown over a period of years. In recent months our academic peers have expressed some reservations on the factor of safety approach to slope stability or other structures influenced by shear, bending moment or bearing capacity, even though the NZ Building Code approved document B1/Structure prescribes a factor of safety of not less than 1.5. I personally subscribe to the almost certainty of soil variability and moisture regime being two of the most influential characteristics requiring control for most sites, unless we are into more homogenous structures such as hydro dams or airport runways and the like. I therefore see no reason why practitioners should not continue to pursue the factor of safety method, provided that a conservative approach is taken on the adoption of variable soil parameters and assessment of the consequences of failure.

At Council we are beginning to take a further look at consequences in various directions. The planning division has introduced requirements for the mitigation of adverse consequences on people and the physical environment. North Shore has experienced significant growth in subdivision and building since 1991. All subdivision applications including cross leases and building consents must now include an assessment by applicants of effects under the fourth schedule of the Resource Management Act. The assessment must be in proportion to their nature - the more potentially adverse the effect, the more detailed the assessment and mitigation details must be.

A second approach implements measurement procedures. If we consider in geotechnical terms that lack of movement is proof of a performing earth structure, then measurement of height change (settlement) and horizontal displacement (shear) can be relied upon as a control system. These requirements are presented for sites with a history of instability or soil creep.

A third approach is one still evolving out of concern created by property owners indiscriminately altering dwelling structures or the landform or drainage system in such a way that damage occurs to either themselves or to adjoining neighbours. These actions invariably occur well after all producer statements and Council clearances have been given. Here I see the potential for geotechnical practitioners to proactively contribute to the production of simple advisory notices explaining the do's and don'ts of various situations, with support provided by Council in the form of distribution at advisory counters and in building consent documents issued, which is now reaching about 6000 per year. The news media would seem another alternative.

5. CONCLUSION

It is apparent from recent expressions of opinion by members within the profession that the issues of Geotechnical involvement in development are not unique to the North Shore.

The profession as a whole must realise that these aspects require addressing in order to more adequately protect the public, assist territorial authority vetting of Geotechnical aspects and protect and improve the image of the Geotechnical profession.

Many engineers, local body personnel and of course architects involved in land development, find the field of Geotechnical or Soils engineering somewhat mysterious. This is likely to be due to the significant subjective component involved in Geotechnical work and also possibly results from a perception that we are often the providers of information that adds costs to projects.

As a result the Geotechnical practitioner and his/her work is often given a low priority and not involved on projects until planning and design is significantly advanced. Early involvement is essential if costs are to be controlled.

The difficulties encountered by territorial Authorities regarding Geotechnical aspects of development will continue to occur as market pressures result in ongoing marginal land development. Ways in which these could be addressed as discussed earlier could range from a sharing of information held by the profession with local authorities to the provision of approved practitioner lists and minimum guidelines for geotechnical investigations and reporting. These and other options should be considered by the profession.

Establishment of such procedures and relationships with territorial authorities will ensure that;

* Geotechnical hazards are recognised at early stage in development planning.

* A team approach is adopted with the authorities to solving these problems.

* Development plans minimise the impact of geotechnical hazards and thus avoid risks and cost shocks in the future.

6. REFERENCES

Building Act 1991.
Resource Management Act 1991.
New Zealand Standard Code of Practice for Urban Land Subdivision, NZS 4404:1981.

Preloading of a Building Foundation for Waikato Polytechnic

Clive Anderson
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Colin Jacobson
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SYNOPSIS : This case history describes the evaluation of foundation options for a six storey building on a site with variable and compressible ground. Site preloading was selected, demonstrating that it can be an effective means of controlling potentially damaging settlements when existing site constraints preclude detailed foundation assessment and ground conditions are complex.

1. INTRODUCTION

In 1994 Waikato Polytechnic Institute commissioned Worley Consultants Ltd to prepare tender documents for construction of a new Hospitality and Tourism Training Centre Building to be built in Hamilton.

The six storey building is to be built on the edge of the Hamilton CBD where variable soil conditions are often encountered. This case history paper describes the development of a foundation solution capable of controlling potentially damaging building settlements on variable soil conditions while meeting the client's budget and construction programme constraints.

2. SITE DESCRIPTION

The site, on the corner of Angelsea and Ward Streets, was occupied by a single storey building used by the Polytechnic. The gently sloping site is at the base of a hill and it had been previously excavated for construction of the former building. A single storey commercial building is close to the western boundary and city streets border the other boundaries.

3. PROPOSED STRUCTURAL LAYOUT AND COLUMN LOADINGS

The building is designed to house the Waikato Polytechnic's entire Hospitality and Tourism department "under one roof" and is a complex building in terms of the architectural requirements. The building has a central six storey tower with a surrounding three storey podium.

Preliminary design established a reinforced concrete frame structure as the preferred structural form. Column locations would be governed by architectural constraints. This resulted in an uneven spacing of columns along frame lines which produced a significant range of column reactions to be resisted by the foundations.

Column loads range from 700 kN to 2650 kN for the serviceability limit states and from 2140 kN to 7950 kN for the ultimate limit state.

The uniform bearing pressures over the tower and podium footprints are 50 kPa and 25 kPa respectively.

Preliminary geotechnical investigations had shown an upper layer of alluvial soils (to a depth of 6 m) were moderately compressible and could cause excessive total and differential settlements of the building frames.

4. GEOLOGICAL AND GEOTECHNICAL SITE ASSESSMENT

4.1 Geological Setting

The complexity of ground conditions reflects local geology. The site straddles a geological boundary between old, unweathered sediments underlying the low hills and much younger alluvial sediments of the adjacent plain. The latter sediments are part of the late Quaternary (about 15,000 years) Hinuera Formation, a collection of volcaniclastic sediments that underlie much of Hamilton City and surrounding Waikato lowlands. The Hinuera Formation was deposited against the flanks of the low hills commonly resulting in small lakes and ponds in which were deposited fine sediments and peat.

The hills represent the eroded remnant of a much older (mid to early Quaternary age) plain underlain by volcaniclastic sediments, pyroclastic flow deposits (ignimbrite) and peat. The materials are mapped as Karapiro Formation (mainly sand and gravel) and Puketoka Formation which comprises pumiceous silts and sand, peat and ignimbrite. Drillholes for other Polytechnic buildings located on the hill suggest that Karapiro Formation is absent at the site and Puketoka Formation is dominated by unwelded ignimbrite.

The hills have a mantling of weathered airfall tephra (volcanic ash), deposited prior to deposition of the Hinuera Formation, The tephra, collectively known as 'Hamilton Ash', are clay-rich, strongly weathered rhyolitic and andesitic tephra typically 3-5 m in thickness.

Local basement is dense pumiceous and quartzose sand, probably part of the lower Puketoka Formation.

4.2 Subsurface Investigations

Planning of the subsurface investigations began with a review of previous investigations of surrounding sites. In addition to investigations for existing and planned Polytechnic buildings, the available reports were for sites further out onto the alluvial plain east of the present site. They revealed a variable sequence of silt and sand typical of alluvial environments.

A key constraint on the extent of the site investigations was the client's need to continue using the existing building. This restricted drilling investigations to positions outside the main site area. Investigations were in two stages. Stage 1 comprised two fully cored drillholes to nearly 30 m depth and 8 Cone Penetration Tests (CPTs) as shown on Figure 1. Stage 2 consisted of an additional 6 CPTs (using a small rig) inside the existing building to gain more detail on the interface between the ignimbrite and Hinuera Formation.

4.3 Subsurface Conditions

Figure 2 is a section of the materials encountered across the site between the two drillholes. It illustrates a complex set of geological conditions consistent with a transition from the ignimbrite forming the hill down to Hinuera Formation alluvium.

Drillhole 1, at the toe of the hill, encountered materials typical of the low hills. Hamilton Ash overlies weathered ignimbrites (N = 2) which overlies more compact sediments and ignimbrites of the Puketoka Formation. Drillhole 2, furthest away from the hill, encountered 9 m of soft, compressible, fine grained Hinuera Formation overlying probable Puketoka Formation sediments.

5. FOUNDATION ASSESSMENT

5.1 Geotechnical Constraints on Foundation Design

The site is underlain by variable ground conditions. One of the key uncertainties during foundation selection was predicting the extent of compressible sediments across the site. The geological setting and unloading due to previous excavation suggested that the ignimbrite should be lightly overconsolidated. However, consolidation testing of the ignimbrite indicated variable and uncertain compression characteristics, probably due to variations in weathering. Shallow foundation design would be governed by the potential risk of large differential and total settlements between the ignimbrite and highly compressible alluvium. Consolidation testing confirmed the considerable alluvium compressibility. Consolidation testing of the ignimbrite indicated moderate compressibility.

Selection of a founding depth for end bearing piles between 10 and 20 m depth was impractical due to the large variations in the bearing strength of the Puketoka Formation materials.

Below 20 m moderately dense to dense grey quartz sand is an ideal target for end bearing piles. Groundwater levels are deep and do not significantly affect foundation design.

5.2 Foundation Options Considered

Foundation options comprised deep piles and shallow foundations such as pads and rafts. The following options were examined :

(a) Isolated Shallow Foundations without Basement Excavation

Column loads would be supported on square pads of different sizes. Weak, compressible soils below the pads would be replaced with at least 2 m depth of compacted hardfill. Preliminary design indicated unacceptable settlements.

(b) Piles

Both bored and driven end bearing, founded on the dense sands below 20 m were considered. Driven piles were not favoured because of the close proximity of brick and commercial buildings, sensitive to vibration. Bored piles, 900 - 1200 mm dia, founded at 28 - 30 m were the preferred pile solution with a preliminary cost of $1.8 m.

(c) Compensated Basement Foundations

The 2 options comprising unloading of the foundation soils by removing at least a 2.2 m depth of material were :

(i) Fully Compensated Basement with Stiff Raft. This assumes that the full building weight is spread evenly over its footprint, with a heavily reinforced basement floor.

(ii) Full Basement Excavation with Isolated Foundation Pads. This option permits use of a lightly reinforced floor. Full site excavation 2.5 - 3 m deep would be required along with replacement of compressible soils to 2 m depth below the pads.

(d) Raft Foundations on Compacted Hardfill

This option comprises a stiff raft to evenly distribute the building loads on a 2.5 m thick layer at hardfill replacing compressible materials. Preliminary settlement estimates indicated 65-70 mm for total settlements.

(e) Raft Foundation on Preloaded Site

This option is a development of (d) to remove the risk of unacceptable total settlement from construction. It involved removal of the top 3 m of organic material and ignimbrite, replacement with sand, placing a preload weight of sand (equivalent at least to the weight of the building), allowing consolidation to occur, removal of the sand to street level, and construction of a stiff raft foundation to evenly distribute the building pressures.

The raft would be founded on approximately 2 m depth of compacted sand. Preloading the site would essentially eliminate post construction settlements.

5.3 Selection of Preferred Foundation

Detailed assessment of the construction cost of each option quickly revealed that the preferred geotechnical solution. Piling was the most expensive (≈ $1.8 million) with compensated basement solutions being about $1.3 m. The other shallow foundation options, (a) and (d), carried a higher residual risk of long term damaging settlements.

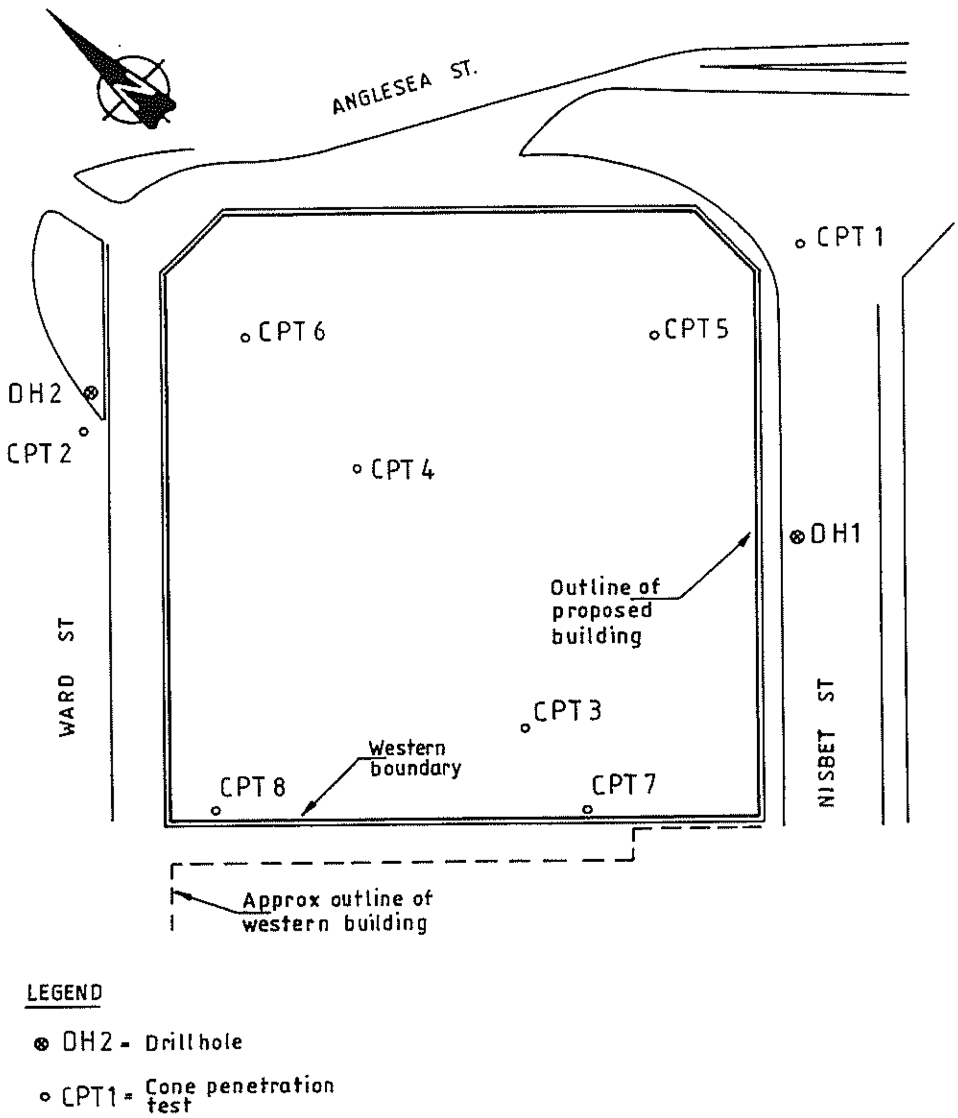

Figure 1 Location of Subsurface Investigations (NTS)

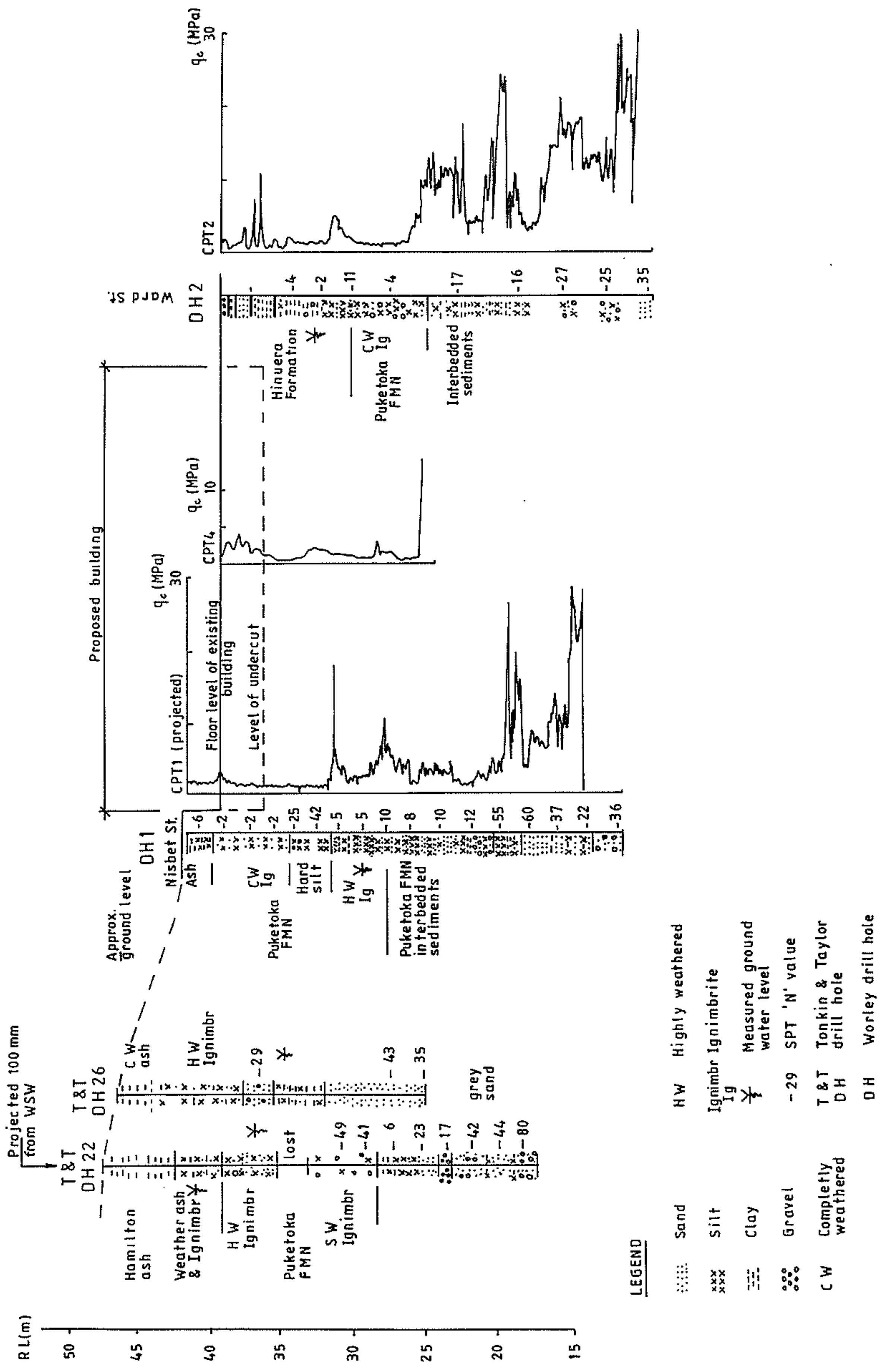

Figure 2 Engineering Geological Section (NTS)

Option (e) was therefore preferred and offered the key benefits of :

- lowest construction cost ($850,000).
- a full scale site loading which provided a very low risk of damaging post construction settlements.
- preserved the required building layout.
- could be quickly built.

6. PRELOAD DESIGN AND CONSTRUCTION

Design of the preload was simple using the following criteria :

- uniform excavation to 3m depth across the site to remove weak compressible sediments. Large scale movement of the excavation slopes was not expected.
- replacement with compacted quartz sand.
- placement of a quartz sand preload with a minimum compacted density of 15 kN/m^3.
- the height of preload across the site was arranged to produce net bearing pressures equivalent to those of a stiff raft supporting the tower (50 kPa) and podium (25 kPa).
- the preload was covered and surrounded with a wooden fence to minimise sand being blown off the site.

A plan of the excavation base is shown on Figure 3. A section through the preload is shown in Figure 3.

The preload was placed and removed by Brian Perry Ltd in early 1995. During placement of the preload a simple monitoring system was installed. It comprised steel plates placed beneath the preload which were monitored for level, from the preload surface, via rods (within tubes). The positions of typical monitoring points are shown on Figure 3.

Mapping of the excavated surface prior to placement of sand revealed that approximately 20% of the site was underlain by compressible alluvium, while the remainder was underlain by ignimbrite, completely weathered to a soft compressible soil. The approximate outline of compressible materials is shown on Figure 4.

7. SETTLEMENT RESULTS

Figure 5 illustrates key settlement results during and after placement of the preload. The following observations are apparent :

- the maximum total settlement is 40mm, about two thirds of that predicted using consolidation test data.
- settlements increase across the site from the southwest corner to the northeast corner. This pattern reflects the transition from stiffer, lightly overconsolidated ignimbrite to compressible, normally consolidated alluvial sediments.
- settlement reached completion very quickly.

8. CONCLUSION

The principal conclusion drawn from this project is that when existing site constraints preclude detailed investigations, preloading of sites with complex ground conditions, is an effective means of controlling potentially damaging settlements at an economic cost. In this instance preloading proved the lowest cost foundation treatment option and was constructed with little or no time penalty compared to alternative foundation systems.

ACKNOWLEDGEMENTS

The permission of Waikato Polytechnic Institute to publish this paper is gratefully acknowledged

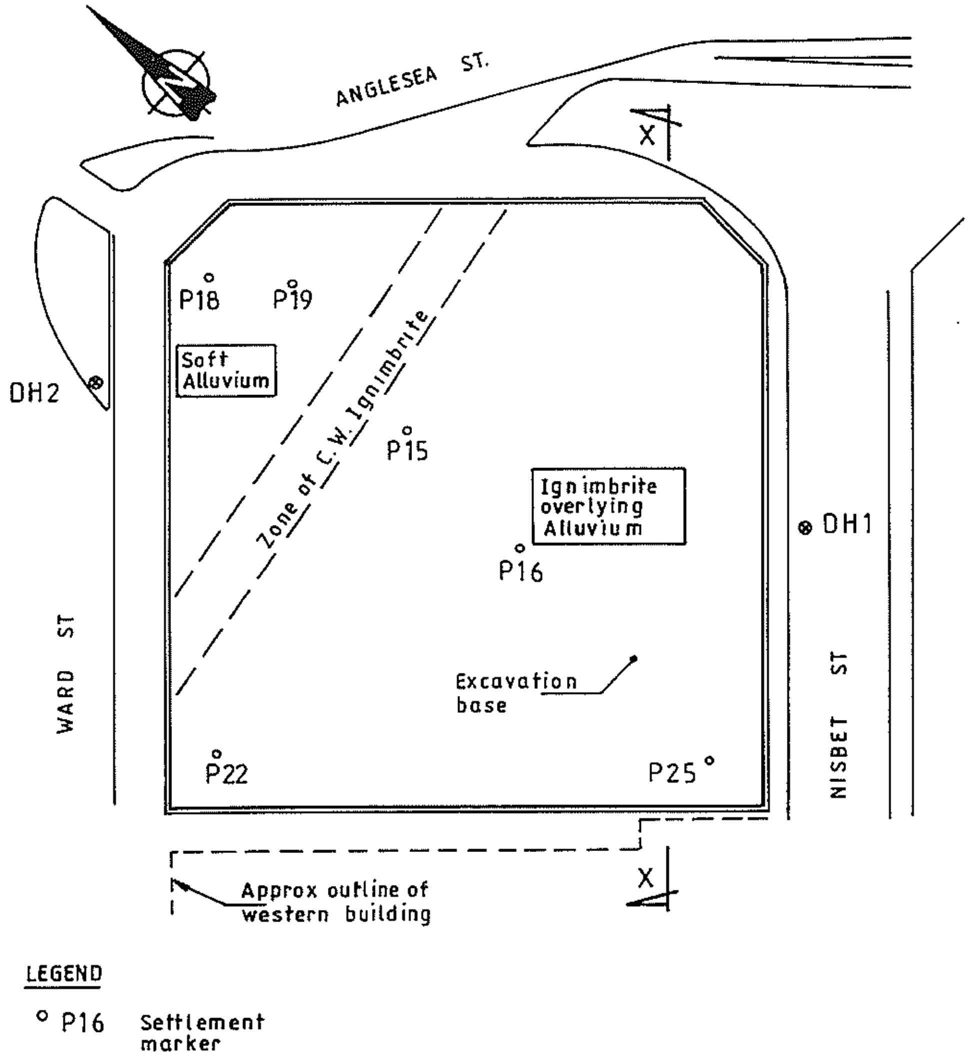

Figure 3 Location of Selected Settlement Markers (NTS)

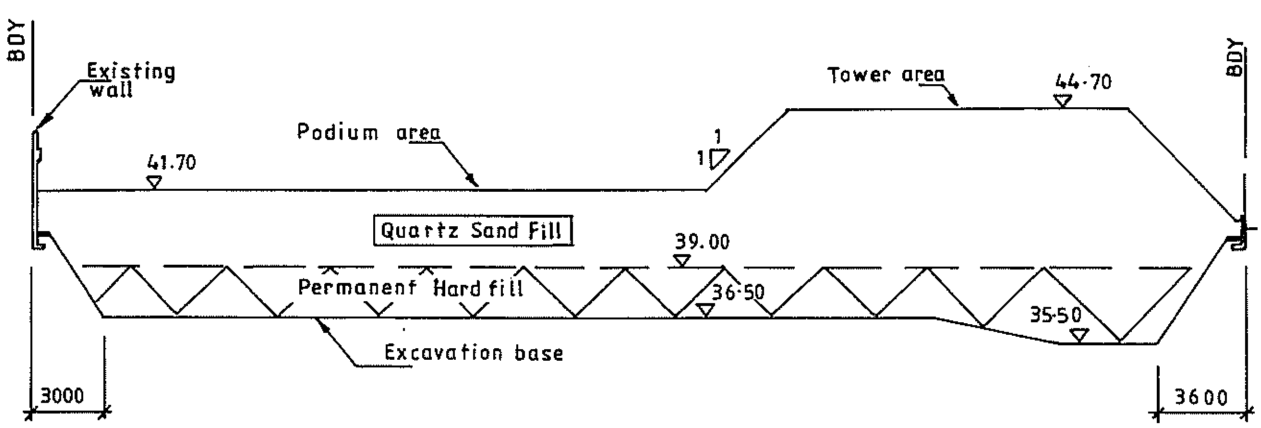

Figure 4 Section XX, Excavation and Preload Fill

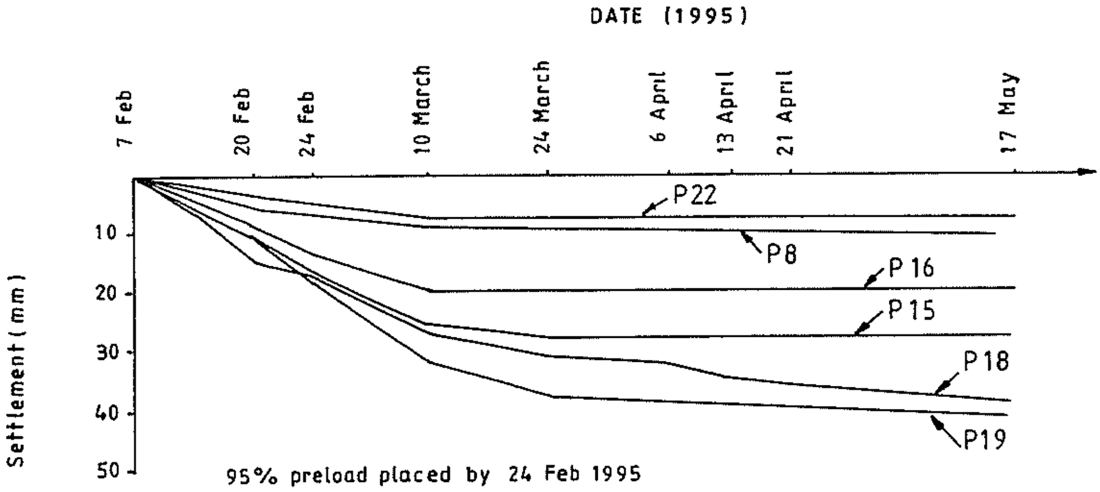

Figure 6 Settlement Versus Time

Housing Development on a Large, Active Landslide: The *Tahunanui Slump* Story, Nelson, New Zealand

Paul C Denton
Mike R Johnston
Soils & Foundations Ltd, Nelson

SYNOPSIS:

Nelson has a wide range of slope instability which largely reflects the varied geology of this city. One area of significant instability involves about 26 ha of hillside overlooking popular Tahunanui Beach. This area, the active *Tahunanui Slump*, is part of a complex rotational landslide. The active slump, some 700 metres wide, extends from sea level to the crest of the Port Hills and contains about 120 houses.

Significant, extensive movements and related damage are documented within the *Tahunanui Slump* in the 1890s, 1929 and 1962 and involve roads and houses. Ongoing resurveys of the area confirm that less damaging movements are continuing, albeit at different rates in different areas.

Residential development, which commenced in the 1920s, has been restricted since 1985 by the Nelson City Council who assumed responsibility for the Tahunanui area in 1950. The Building Act of 1991, and more specifically Section 36(2) has changed the basis by which land development can by regulated. The Resource Management Act 1991 specifies legal requirements to identify, inform and protect the public from landsliding hazards. The *Tahunanui Slump* poses a hazard to development including the possibility that developments on parts of it could be a danger to life. We present the results of our investigations to date.

1.0 INTRODUCTION

The picturesque hills above Tahunanui Beach in Nelson have been regarded by many as a desirable residential area for almost as long as slope instability has been recognised. Since the late 1800s, significant ground movements have been recorded in an area known as the *Tahunanui Slump* and comprise both dramatic failure events and less spectacular ongoing ground deformation (Bruce, 1962; Falconer, 1962; Falconer, 1963; Fyfe, 1963; Northey, 1962). Recorded major events include movement and damage in

- 1893 during road construction across its toe
- 1929 in the lower northern portion following heavy rain and earthquake ground shaking
- 1935 near the centre
- 1957 towards the upper eastern edge
- 1962 the lower northern portion following heavy rain and earthquake ground shaking

Ongoing periodic ground resurveys initiated in 1953 have confirmed movement is continuing. The latest 10 yearly resurvey indicates horizontal movements of on the order of 100mm and vertical movements of on the order of 50mm for the period 1985-1994 (West, 1994).

The Nelson City Council (NCC) assumed responsibility for the Tahunanui area in 1950 as a result of local government reorganisation and later initiated a stormwater drainage scheme which had been previously lacking (Dickinson, 1990 and others). In recognition of the instability of the area the NCC has, since October 1985, imposed property development restrictions. With passage of the Building Act 1991, which came into effect from July 1992, the NCC has embraced a redefinition of its statutory obligations in several ways.

Since 1991 Soils & Foundations has investigated more than 20 individual residential properties within the boundaries of the *Tahunanui Slump*. As part of a recent review of the slump we defined these boundaries in preparation for their inclusion in a Nelson City Council Geographic Information System (Soils & Foundations, 1995). These boundaries, to an accuracy no greater than ± 20 metres, are approximately shown on the Site Plan, Figure 1. Additional investigations are currently underway and we have documented a variety of features relating to the slump including

- disturbed foundations (some removed following failure)
- localised ground settlement
- deep, offset ground cracking (some preserved beneath houses and other structures)
- localised elevated groundwater
- damaged service utilities

One of the principle findings of our review of the *Tahunanui Slump* is that it is a complex feature within a much larger landslide and that it contains a number of subsidiary failures of varying orders of magnitude (Soils & Foundations, 1995). Another is that insufficient data collection and interpretation has been completed to date. This latter finding has implications to both the knowledge and understanding of the geotechnical setting of the *Tahunanui Slump* as well as the selection of the most appropriate planning and regulation option(s).

2.0 BACKGROUND

The hillside area containing the *Tahunanui Slump* has long been recognised by developers and property owners as a desirable residential area (see photo 1) owing to a number of unique features including its

- sunny northwesterly aspect
- proximity to the accessible, sheltered Tahunanui beach
- spectacular views over Tasman Bay
- varied topography including gently sloping and reverse slopes on what would otherwise have been a moderately steep hillside

Ironically this topography, which makes the hillside appealing and in part encouraged residential development, is the result of large scale rotational slumping over a period of thousands of years. Also instability was recognised before residential development and certainly prior to the turn of the century and probably even from the time of European settlement in 1840. A summary of milestones is listed below and the affected areas, where records exist, are indicated on the Site Plan, Figure 1.

1893 In 1893 construction of Rocks Road across the toe of the slump was well advanced when significant stability problems were encountered. Movement resulted in bulges in the sea wall at the edge of the road which, although the sea wall has since been reconstructed, are still visible (Photo 2). No correlation between road damage and the instability of the hillside above was apparently made at that time. Surveys, for the subdivision of the hillside into residential allotments, were begun in the 1920's and subsequent resurveys were to later provide the first hard measurements of movement.

1929 On the morning of 17 June 1929 a major earthquake centred near Murchison (RM 7.8*) was felt in Nelson with local shaking intensity of MM VIII*. Heavy rains and numerous aftershocks affected the area in the weeks that followed. Approximately one month latter, during the night of 13 - 14 July 1929 two houses were wrenched off their foundations by landsliding adjacent to major road cracking. Local newspaper accounts reported an area of 2 ha was involved and that the hillside moved 5 metres down and across Rocks Road at the toe. Surface bulging of the road, involving some 3 metres of carriage width, was reported.

1939 Professor Patrick Marshall of Otago University reported on the hillside and identified it as an active landslide in an unpublished report to the Loans Board in November, 1939 (Marshall, 1939). The Loans Board subsequently refused permission to raise a loan for water reticulation only and insisted on adequate stormwater drainage and sewerage simultaneously. Several months later the NCC gave permission to tap a recently completed City Council high pressure water main in the area without the requirement for sewerage or stormwater drainage.

1944 Some survey plans, including plan #3310 dated July 1944, recorded up to 1.6 metres of movement on the lower part of the slump presumably since the first subdivisional surveys were completed 20 years earlier.

1957 A 375 mm diameter high pressure water main failed by tension indicating 200mm of movement since its installation in 1940. Ground cracking developed on several lawns in the vicinity in the upper eastern portion of the *Tahunanui Slump*. At least one 50mm crack developed beneath the foundation at the centre of a nearby house.

1962 On 10 and 17 May 1962, moderate earthquakes centred near Westport (RM 5.9) shook the area with a felt intensity of MM IV. 1962 had also been the wettest year since reliable records were began in 1862 and approximately two weeks following these earthquakes, there was further heavy rain in the area. On 1 June 1962 damaging movement occurred within the slump and of nine houses that were directly affected, four suffered serious damage with at least one being condemned and torn down. An area of 1 ha immediately above Rocks Road and south of the 1929 movement was affected. Minor movement and damage was recorded elsewhere, being widely distributed throughout the body of the slump.- Further movement occurred following wet weather later that year and may have been related to the removal of toe support during the 1 June failures.

Acting on the recommendations of the investigators of the 1962 event, the NCC initiated the installation of a new stormwater system on the hillside which, while construction is largely complete, is continuing.

1994 The most recent survey data compiled by DOSLI confirms continuing movements of apparently similar magnitudes recorded for previous 10 year periods in some localities (West, 1994).

3.0 GEOLOGIC SETTING

3.1 Bedrock Units

The western side of the Port Hills consists of a sequence of consolidated well bedded sandstone-mudstone of the Magazine Point Formation which is overlain by the clay bound Port Hills Gravel formation (Johnston 1979,

*The ***Richter Magnitude (RM scale)*** is a measure of the energy released by an earthquake at its source and it is calculated from seismographic records. It is a logartithmic scale used to measure the magnitude of earthquake waves. For every unit increase in magnitude there is a 31 fold increase in energy.

The ***Modified Mercalli Intensity Scale (MM scale)*** categorises non-instrumental observations of the effects of an earthquake on people, fittings (furniture, crockery etc), structures and the environment. Although there are twelve levels in the scale, only the first ten (ie up to MM X) have been reliably observed in New Zealand. The Modified Mercallis scale for New Zealand has recently been revised.

1981). The Magazine Point Formation, of early Tertiary age, dips southeast into the Port Hills at about 65 - 70 ° (below horizontal). The contact between the Magazine Point Formation and the Port Hills Gravel is an erosional unconformity dipping about 40° southeast which very approximately coincides with the 50 metre contour. The gravel dips parallel to the contact.

The hillside from Magazine Point extending approximately 1.4 km to the south has been involved in a very large, complex and deep seated slope failure referred to at the Tahunanui Landslide. The southern half of this landslide is now regarded as inactive, although there are relatively minor failures at periodic intervals. This southern inactive area is not believed to have moved since the cutting of the sea cliffs during the post-glacial sea level maximum (about 6,000 years ago). The northern area, which is the subject of this paper, has however continued to move. This area, measuring approximately 700 metres in width and extending from sea level to the crest of the Port Hills makes up the *Tahunanui Slump*. The landslide and slump are composed of Port Hills Gravel. The relationship between the various geologic units is shown schematically on Cross-Section A - A', Figure 2.

The rocks of the Magazine Point Formation are well exposed on the shore platform in front of the slump at low tide and in the cliffs above Rocks Road to the immediate northeast. The *in situ* Port Hills Gravel formation is exposed in the headscarp of the slump. Higher than normal rainfall in Nelson coupled with several intense rain events in 1995 has though surficial failures provided several fresh exposures in the headscarp.

3.2 Geological History

Rocks of the Magazine Point Formation accumulated during a marine transgression that moved north over the South Island during the early Tertiary (Eocene-Oligocene). The formation, whose total thickness probably exceeds 1500 metres, was deposited by turbidity currents and submarine debris flows in a relatively shallow sea environment. Following deposition the formation was uplifed, tilted gently southeast and eroded prior to the accumulation of the Port Hills Gravel.

The Ports Hills Gravel formation was deposited terrestrially during massive outpourings of debris from rising mountains that mark the onset of the Kaikoura Orogeny in the late Miocene. The formation is at least 500 metres thick and locally contains several metre thick siltstone beds. The Port Hills Gravel and the underlying Magazine Point Formation were subsequently folded and faulted during the mid Pliocene. *In situ* bedding exposed in the area adjacent to the slump defines the northwestern limb of the Port Hills Syncline which extends northeast through the Port Hills.

Deep seated, rotational slumping of these units developed during the late Quaternary and is described more fully in the section on Development of the *Tahunanui Slump*.

3.3 Faulting and Seismicity

Nelson City lies within the main seismic zone of New Zealand, the zone with the highest rates of earthquake occurrence during the last 150 years of record. It has experienced moderate to strong ground shaking (≥ MM VIII), from earthquakes originating on faults beyond its boundaries at least five times since European settlement in 1840. A similar level of seismicity can be expected in future, with ground shaking of the order of MM VIII on average every 25 years (Johnston *et al.* 1993).

A trace of the Flaxmore Fault, a component of the northeast trending Waimea-Flaxmore Fault System, is located approximately 2 km to the east of the *Tahunanui Slump*. The fault system is regarded as active (parts of it have moved within the last 125,000 years) and is therefore the source of past and future earthquakes of

RM ≥ 7.5 that will produce intensities of MM X throughout Nelson City (Johnston *et al.* 1993).

Although the ESE trending Grampian Fault is inferred to be concealed beneath the southern part of the *Tahunanui Slump,* it is mapped as inactive (Johnston 1979, 1981).

4.0 SLOPE STABILITY ISSUES

4.1 Nature of the Failure

The *Tahunanui Slump* is a complex feature with a number of subsidiary failures of varying orders of magnitude which are summarised in Table 1 below.

The approximate boundaries of the *Tahunanui Slump* as well as the major subsidiary failures within it are indicated in plan (Figure 1) and in schematic cross-section (Figure 2). The rates and nature of movements within these subsidiary blocks differ substantially as generally indicated by both the periodic resurvey records and the distribution and character of historic failures.

4.2 Development of the *Tahunanui Slump*

The Tahunanui Landslide has occurred along a surface or sole plane extending from sea level to the top of the Port Hills. This plane intersects at approximately right angles the contact between the Magazine Point and Port Hills Gravel formations. Movement of the material above the sole plane has displaced both formations downslope and westward. Erosion by the sea has removed all of the displaced Magazine Point Formation so that within the boundaries of the landslide only Port Hills Gravel remains. The southern part of the landslide has apparently stabilised allowing coastal erosion to cut a seacliff at its toe. The age of the seacliff is not precisely known but is between 2000 years and 6000 years old. Therefore, the southern part of the landslide has been stable for several thousand years.

In contrast the northern part of the landslide, the *Tahunanui Slump*, has remained active and the sea has been unable to cut a cliff at its toe. Erosion of the toe of the slump, which continued up to the construction of Rocks Road in the 1890s, further destabilised the slump.

TABLE 1 : Order of Magnitude Failures, Tahunanui Hillside

Order of Magnitude	Description	Comment
1°	Tahunanui Landslide	Southern part is stable
2°	*Tahunanui Slump*	The active northern part of the Tahunanui Landslide. The *Tahunanui Slump*, of 26 ha, extends from sea level to a 75m high headscarp at the crest of the Port Hills.
3°	Subsidiary Slumps	Within the *Tahunanui Slump* there are up to 6 subsidiary slumps each with well defined headscarps and reverse topography.
4°	Less well defined movements within the subsidiary slumps	Areas of 1-2 ha, particularly on the lower part of the hillside. Not as deep seated as the subsidiary slumps.
5°	Superficial failures	Minor failures up to several metres in depth and typical of what may occur on any hillside.

The material removed from the slump was carried by longshore drift southwest where it was deposited, as a series of gravel beach ridges, at the foot of the now inactive southern part of the Tahunanui Landslide.

Although coastal erosion has played a major role in the continued movement of the *Tahunanui Slump* it appears unlikely that it was the cause of the wider Tahunanui Landslide. Both the Magazine Point Formation and Port Hills Gravel have a high natural stability. Slopes underlain by these units have been extensively eroded during the development of the seacliffs adjacent to Nelson Haven and the Waimea Inlet and, with the exception of the Tahunanui area, have not failed. In addition at Tahunanui, both formations dip into the hillside so that there are no obvious planes on which a slope failure of this size could occur.

The Grampian Fault close to the southern edge of the *Tahunanui Slump* may be associated with the slump either by movement of the fault itself or by the creation of a zone of weakness allowing water to penetrate into the hillside (Johnston, 1979).

A probable cause of the failure is severe ground shaking resulting from an earthquake centred in the Nelson area many thousands of years ago. The earthquake may have originated on one of the active faults of the adjacent Waimea-Flaxmore Fault System in Nelson City.

4.2.1 Seismicity

Clearly seismicity has been a contributing factor in recent historic failures as both the 1929 and 1962 movements were closely associated with moderate ground shaking at the site. Earthquake ground shaking may have the effect of "reshuffling the deck" and allowing rapid water ingress resulting in movement.

A review of records of felt intensity earthquakes which began about 1912, by Northey (1962), indicated earthquakes of MM IV are relatively frequent in Nelson, occurring on average at least twice a year with MM > IV occurring at least every other year. This suggests that ground shaking alone may not be enough to initiate major movements. It is however possible that this frequency of ground shaking coupled with high rainfall may be responsible for, by minor episodic movements, the total 10 yearly resurvey measurements of ground deformation.

4.2.2 Groundwater

A primary cause of the major movements has been attributed to periods of heavy and sustained rainfall (Northey, 1962; and others). It is, however, the influence of groundwater which is directly linked with such movements and not strictly rainfall. Records indicate numerous springs and permanent ponds existed prior to subdivision of the hillside. While some springs have been intercepted by the stormwater system, their distribution is widespread and not all have been controlled.

During upwards of 35 site specific investigations in the Port Hills since 1991, we have encountered elevated levels of groundwater for sites

- near the top of the ridge
- midslope and lower
- on both the eastern and western sides of the Port Hills at most elevations.

These high groundwater levels have been recorded at virtually all times of the year and near the top of a ridge with virtually no capacity for rainfall catchment.

4.2.3 Earthworks

What has also become clear during our review of historic instability is the effect earthworks and other developments related to human activities have had on ground movements. Construction of Rocks Road at the toe is one of the earliest documented links. Our initial review of historic photos suggests that in the centre of the slump there are localised areas of fill and spoils placement related to early road development for subdivision. Some photos clearly show housing fill pad construction of several metres in thickness surcharging the head of steep slopes further oversteepened by undercutting for road construction and/or widening.

Quarrying of road materials was undertaken in some areas (Dickinson, 1990) although their relation, if any, to subsequent damaging movements is not yet known. We believe the association between housing damage and historic ground movement may well, in some cases, be a direct, although difficult to establish, link. A scarcity of documentation and the passage of time, in some cases 50 or more years, complicates the ability to clearly establish any such links.

5.0 LANDUSE CONSIDERATIONS

At present the *Tahunanui Slump* is extensively built on and is regarded by many, despite its past history of movements, as a desirable residential area. It is also clear that is still active and has yet to reach stability.

Although no dramatic movement has occurred since 1962, surveys and other evidence confirm that all of the slump is active, albeit at different rates in different areas. While no damage similar to that of the 1890s, 1929 or 1962 has occurred over the past 33 years such movements cannot be precluded in the future. Indeed, the historical evidence, admittedly over a relatively short time span, indicates that major movement could be expected approximately every 30 years. However, the 1929 and 1962 events may have been partly initiated by ground shaking of water saturated ground.

Since 1962 the amount of water infiltrating into the slump has been reduced although it cannot be completely eliminated. Also the effectiveness of the stormwater system in dewatering the slump has not been determined. It is possible that the amount of water diverted into the stormwater system may not be particularly large in relation to the total volume of groundwater affecting the slump. However, there is probably little doubt that the stormwater system has been effective in drying out the surface of the slump and reducing the incidence of relatively shallow failures.

The NCC has undertaken to fulfil its statutory obligations under the Resource Management Act 1991 to assess the hazards and associated risks from, among other things, landsliding, protect the public from known hazards, and to make the public aware of the hazards and the steps which need to be taken to mitigate the effects. Since early 1994 the NCC has begun implementation of a city wide geographic information system (GIS) in order to manage these requirements. The need for a geotechnical component of this GIS has been suggested (Denton, 1994). Delineation of the boundaries of the *Tahunanui Slump* in the GIS and the development of planning criteria for it is included in the Nelson City District Plan released as a first draft for public comment in October 1995.

While geohazards in Nelson City, including the *Tahunanui Slump,* have been recognised for many years it was not until the damaging movements in 1962 and a severe rainstorm event in 1970 that comprehensive efforts were undertaken by the NCC to manage geohazards. This included establishment of an "Engineering Conditions Registry" for properties associated with recognised geohazards and other engineering constraints. Included were all properties within the recognised boundaries of the *Tahunanui Slump.*

Since October 1985 further subdivision and building development has been severely restricted within the *Tahunanui Slump* by Condition #414. With passage of the Building Act 1991, implemented in July of 1992, Section 36(2) "Building on land subject to erosion etc" has served to guide NCC policy. This section states that the territorial authority (NCC is a Unitary authority) shall grant a building consent provided that "The building work itself will not accelerate, worsen or result in erosion, avulsion, alluvion, falling debris, subsidence, inundation, or slippage of that land or any other property".

Since March of 1995 it has been NCC policy that provided a geotechnical engineering report stating that "Section 36(2) of the Building Act will be satisfied" is submitted by a 'suitably qualified person' the Council may issue a building consent. The NCC has attempted to establish a formal register of "suitably qualified persons" but has met substantial resistance from professional engineering organisations and others as late as December 1995. We are aware of

1. Council approval of limited developments within the *Tahunanui Slump* where building consents have been accompanied by positive geotechnical engineering reports and
2. Council denial in the case of a negative geotechnical engineering report

It is clear that the *Tahunanui Slump* is an active feature that has yet to reach stability and therefore poses a hazard to development including the possibility that development on parts of it could be a danger to life. We have recommended that the area be designated a "Geotechnical Special Studies Zone", subject to specific land development criteria.

Options for landuse and development within the *Tahunanui Slump* identified by Soils & Foundations in 1995 included:

- return the area to a state approximately that prior to residential development,
- allow development to continue with urban infilling by section subdivision and possibly the construction of high occupancy apartment blocks and hotels, or
- maintain the area approximately as it is.

One of our major recommendations to assist the NCC in selecting the most appropriate option(s) was implementation of a programme of further work set out in a prioritised list of 12 specific tasks. Clearly development of a more complete picture of the geotechnical character of the *Tahunanui Slump* is crucial if the best landuse management option(s) are to be selected.

6.0 CONCLUSIONS

6.1 The *Tahunanui Slump* is an active, complex rotational failure that has yet to reach stability. The approximate limits of the slump have been identified as_ well as the major subsidary block failures within this boundary.

6.2 Significant, extensive movements and related damage are documented within the body of the *Tahunanui Slump* in the 1890s, 1929 and 1962 and involve damage to roads and houses. Ongoing re-surveys confirm that less damaging movement are continuing, albeit at differest rates in different areas.

6.3 The *Tahunanui Slump* poses a hazard to development, including the possibility that development on parts of it could be a danger to life. It has been recommended that the slump be designated a "Geotechnical Special Studies Zone" subject to specific land development criteria.

6.4 Insufficient data collection and interpretations have been completed to date which at present basically limits planning and regulation options to maintaining the slump as a low density residential area. The most appropriate future option is unlikely to become known without completion of the further work recommended.

7.0 ACKNOWLEDGEMENTS

We gratefully acknowledge information provided by various personnel at the Nelson City Council, particularly Ms Sue Twigg, Principal Policy Planner and Mr Peter

Thornton, Technical Services Engineer. Resources to present this paper are the courtesy of Royds Consulting Ltd, Nelson.

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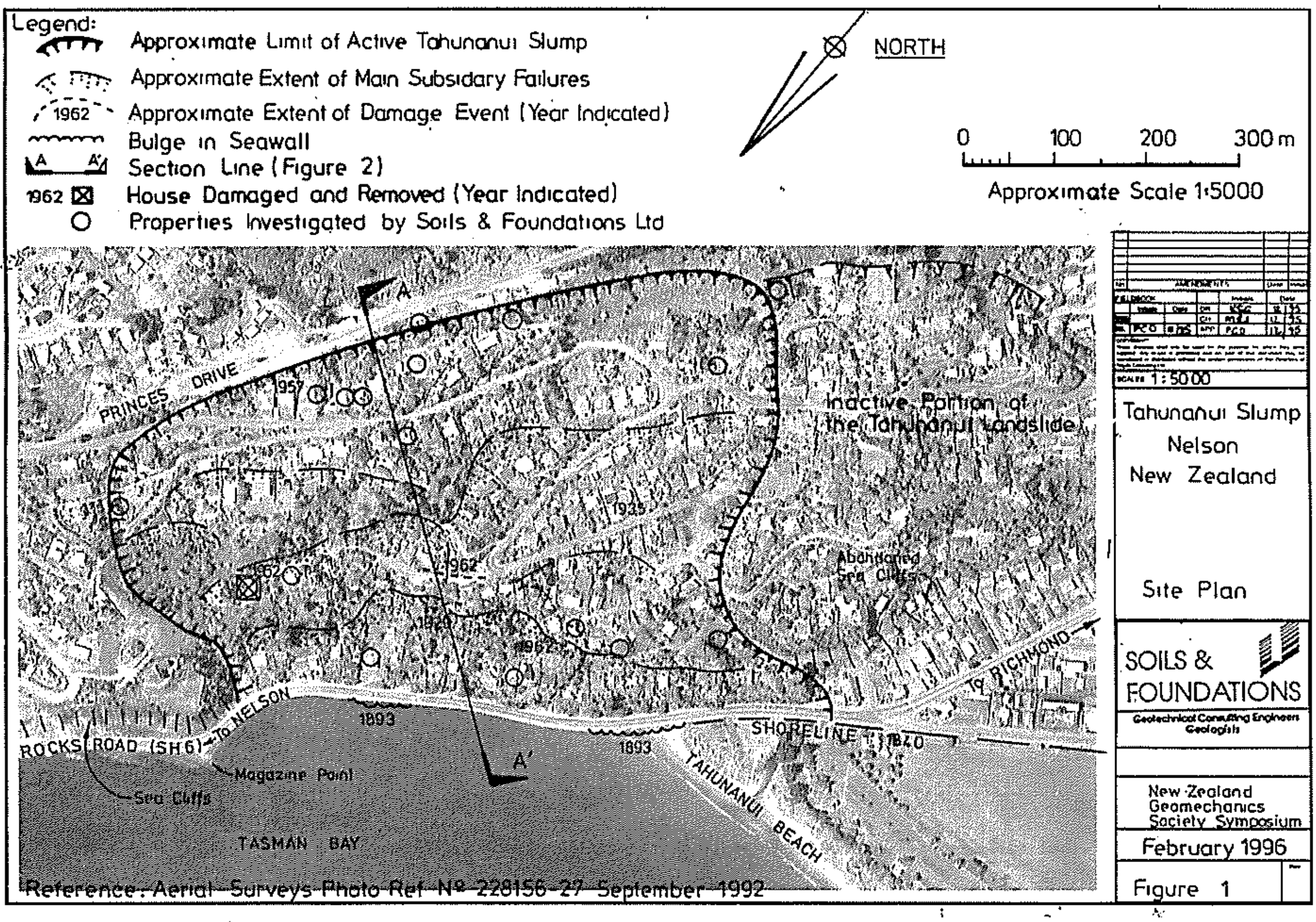
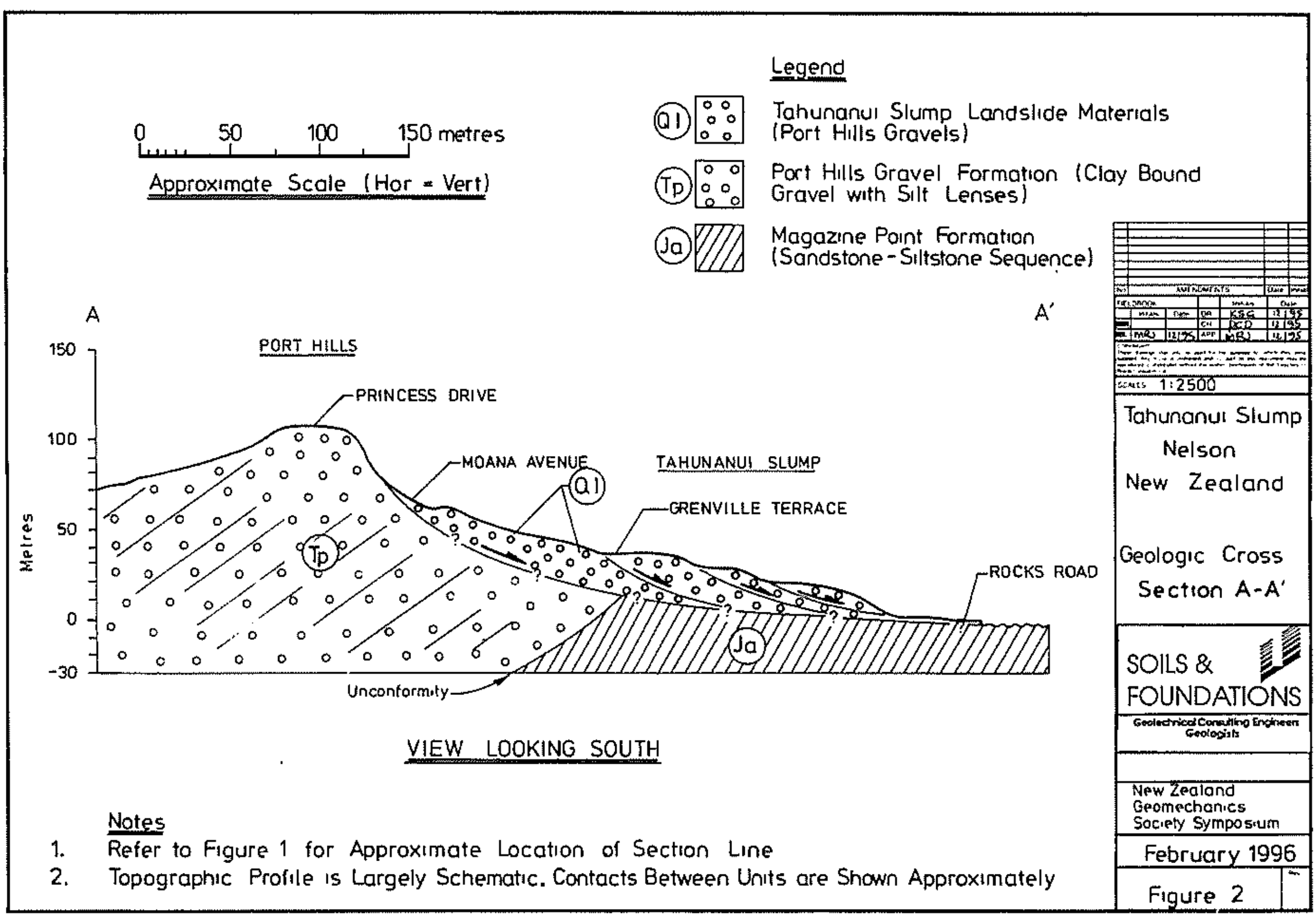

Legend:
Approximate Limit of Active Tahunanui Slump
Approximate Extent of Main Subsidary Failures
1962 Approximate Extent of Damage Event (Year Indicated)
Bulge in Seawall
A A' Section Line (Figure 2)
1962 House Damaged and Removed (Year Indicated)
Properties Investigated by Soils & Foundations Ltd
NORTH
0 100 200 300 m
Approximate Scale 1:5000
PRINCES DRIVE
Inactive Portion of the Tahunanui Landslide
Abandoned Sea Cliffs
To RICHMOND
ROCKS ROAD (SH6) To NELSON
Magazine Point
Sea Cliffs
TASMAN BAY
SHORELINE 1840
TAHUNANUI BEACH
Reference: Aerial Surveys Photo Ref Nº 228156 27 September 1992
SCALE 1:5000
Tahunanui Slump
Nelson
New Zealand
Site Plan
SOILS & FOUNDATIONS
Geotechnical Consulting Engineers Geologists
New Zealand Geomechanics Society Symposium
February 1996
Figure 1


0 50 100 150 metres
Approximate Scale (Hor = Vert)
Legend
(Q1) Tahunanui Slump Landslide Materials (Port Hills Gravels)
(Tp) Port Hills Gravel Formation (Clay Bound Gravel with Silt Lenses)
(Ja) Magazine Point Formation (Sandstone - Siltstone Sequence)
A
A'
150
100
50
0
-30
Metres
PORT HILLS
PRINCESS DRIVE
MOANA AVENUE
TAHUNANUI SLUMP
GRENVILLE TERRACE
ROCKS ROAD
Unconformity
VIEW LOOKING SOUTH
Notes
1. Refer to Figure 1 for Approximate Location of Section Line
2. Topographic Profile is Largely Schematic. Contacts Between Units are Shown Approximately
SCALE 1:2500
Tahunanui Slump
Nelson
New Zealand
Geologic Cross Section A-A'
SOILS & FOUNDATIONS
Geotechnical Consulting Engineers Geologists
New Zealand Geomechanics Society Symposium
February 1996
Figure 2

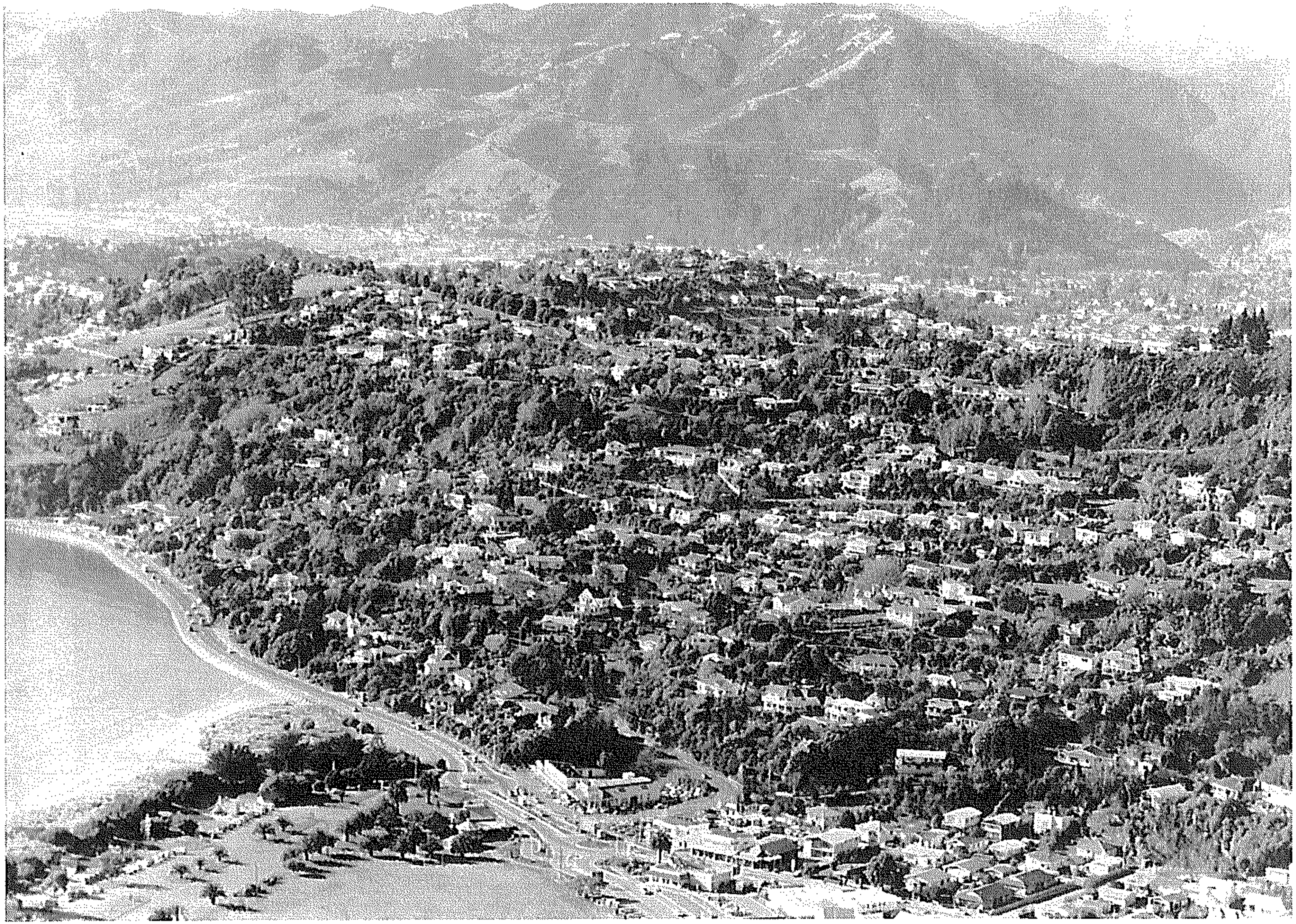


PHOTO 1: Tahunanui Hillside looking northeast showing the extent of residential development on the active *Tahunanui Slump*. **PHOTO CREDIT: Nelson Mail, 1994**

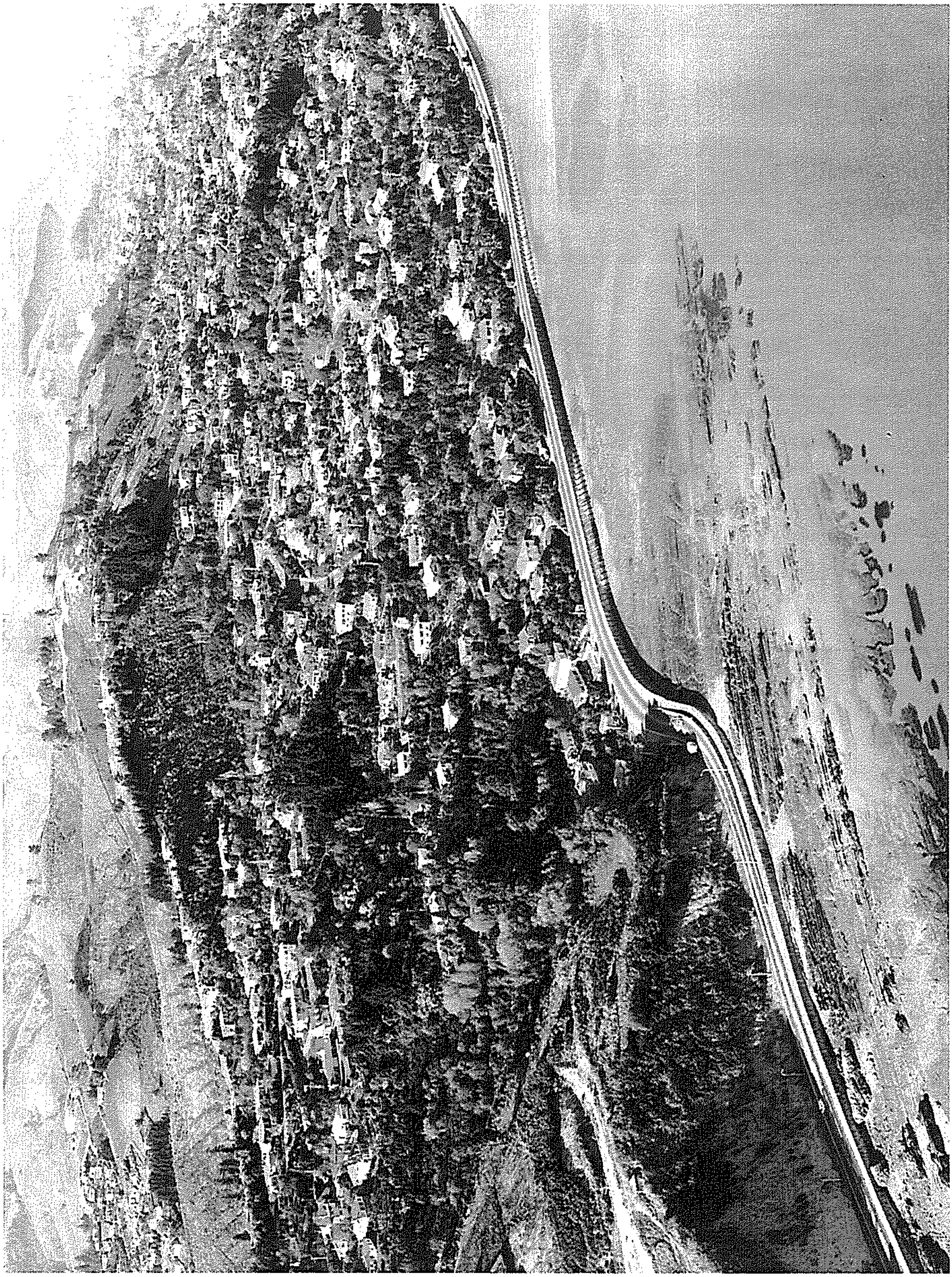


PHOTO 2: Tahunanui Hillside looking south showing the active *Tahunanui Slump*. Visible are a 75m high headscarp, the absence of seacliffs at its toe (between Magazine Point in foreground and the shops opposite Tahunanui Beach) and bulges in the seawall. **PHOTO CREDIT: D L Homer, Institute of Geological & Nuclear Sciences Ltd, 1978**

Hazard Assessment and Site Selection For a Hut in Fiordland

Jeff Bryant

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SYNOPSIS: The Arthur Valley, Fiordland National Park, is a young, dynamic landscape situated in one of the highest rainfall areas of New Zealand. Numerous examples of natural hazards (e.g. snow avalanches, rockfalls, flooding) abound; some recur annually while others may only have occurred once since the end of the last Ice Age. The possibility of a catastrophic event occurring during the life time of a hut on the Milford Track is quite high but with judicious siting the likelihood of total loss can be minimised.

The existing hazards are examined and a methodology for rating potential hut sites and comparing them to the existing site developed. Two sites, within proximity of the existing site, were identified for further evaluation.

Because of the cost involved in developing a new hut complex, remedial works to the side stream that is currently affecting Dumpling Hut were recommended as the preferred option. The proposed works involve diverting the stream flow via a section of new channel into an older disused channel that will carry flood flows some distance up valley of the huts.

1. INTRODUCTION

The Milford Track is New Zealand's premier walking track with 10,000 people a year undertaking the 54 km trek through the spectacular glaciated scenery of Fiordland National Park. The track traverses two valleys and the steep sided Mackinnon Pass (1073 m) before finishing at sea level. Although not particularly high, the terrain is extremely rugged and the environment harsh such that the track is only open for the six month summer season. Out of season snow falls and an attendant avalanche risk may limit the season.

Dumpling Huts, in the Arthur Valley, are where independent walkers spend their third and final night and can accommodate up to 40 people. The hut complex is currently threatened by aggradation and degradation in two channels of a side stream which flow either side of the huts. Although the huts are of basic construction, they have a relatively high replacement cost as the only access is by foot or by helicopter. It was thus considered necessary to evaluate the risk to the existing hut site and do a hazard assessment for an alternative hut site in the near vicinity.

2. PHYSIOGRAPHY

The Arthur Valley comprises narrow, deeply dissected valleys separated by steep valley sides, sharp ridges and aretes. Overall slope angles in the U-shaped valleys exceed 40° with near vertical or overhanging bluffs common on most slopes. Although relief is high, the Arthur River does not rise much above 200 m and the summit elevation of the surrounding ridges is around 1600m. Figure 1 shows an aerial view of the middle part of the valley.

The floor of the lower Arthur Valley is occupied by a broad flood plain through which the river meanders or, as in just below Dumpling Hut, splits into several braided channels. Just above the hut, the valley narrows and the gradient steepens such that flat areas are small and localised.

The main feature of the local climate is the heavy, orographically accentuated precipitation. The adjacent mountains form a barrier to the moist westerly airflow that circulates across the Tasman Sea. Mean annual rainfall at Dumpling Hut is around 7.5 m with a recorded maximum of over 10 m. The summer months are generally considered to be the wettest season although heavy rainfall can occur in any month. Twenty-four hour rainfalls of around 300 mm are not uncommon and over 500 mm has been recorded. In winter months, much of this precipitation falls as snow, at least as far down as the bush line (ca 1000 m). Small, permanent snow fields and cirque glaciers remain throughout the year at altitudes above 1700 m.

Vegetation has been found to be a key indicator in the distribution of natural hazards. Two distinct associations are present in the valley floor and lower side slopes with the boundary between the two either abrupt or gradational (see figure 1).

Figure 1: View of Arthur River valley immediately downstream of Dumpling Huts. Recent avalanches have stripped vegetation down to bedrock in places, whilst older runout zones (far right) are covered by regenerating scrub.

Mature beech forest can be found in the lowermost parts of the valley and on slopes unaffected by all forms of mass movement. On slopes laid bare by impact, burial or stripping off of original cover, a shrubland association of varying complexity has colonised the ground. Most of the larger trees are vulnerable to impact by either debris or air blast and burial of their root systems. Much damage is sustained to established forest particularly at the margins of avalanche run-out zones. Beech saplings, sub-canopy softwoods or trees with tough springy branches are often found at such margins as they are more resilient to damage.

3. GEOMORPHOLOGY

The Arthur Valley is a young, dynamic landscape typical of this part of Fiordland. Late Quaternary glaciation filled the valleys to about 1600m leaving only occasional aretes elevated above the ice. Major tributaries now enter the Arthur Valley as hanging valleys.

The fluvial system has yet to make much of an imprint on the pre-defined glacial landscape despite the very high rainfall. The competent nature of the bedrock seems to resist frost shattering at high altitudes, deep seated slope failures and abrasion by river erosion. Some erosion and deposition of materials have taken place since the last Ice Age finished (ca 14,000 years b.p.) but the quantities transported are insignificant compared to that moved by the glaciers. The main impact of fluvial processes has been to infill the valley floor. Small flood plains have formed upstream of the huts and are more frequent and broader with distance down valley where the prehistoric damming of the valley by a landslide to form Lake Ada has flattened the river gradient upstream. River terraces are conspicuously absent.

Of secondary importance is the creation of debris fans and cones where the valley floor meets the hillside. In many areas, these fans have merged to form a more or less continuous marginal strip of intermediate slope between the flat floor and the steep wall of the hillside. A feature of fans developed principally from avalanche deposits is a crater like depression at the apex of the cone. Their formation is attributed to the explosive effects of trapped air masses at the foot of avalanche run-out zones decompressing and flinging material outwards (Owens and Fitzharris, 1985). Another characteristic is a flatter angle (5° to 15°) and smaller volume compared to the steeper (5° to 35°) and larger fans derived from landslide deposits.

4. GEOLOGY

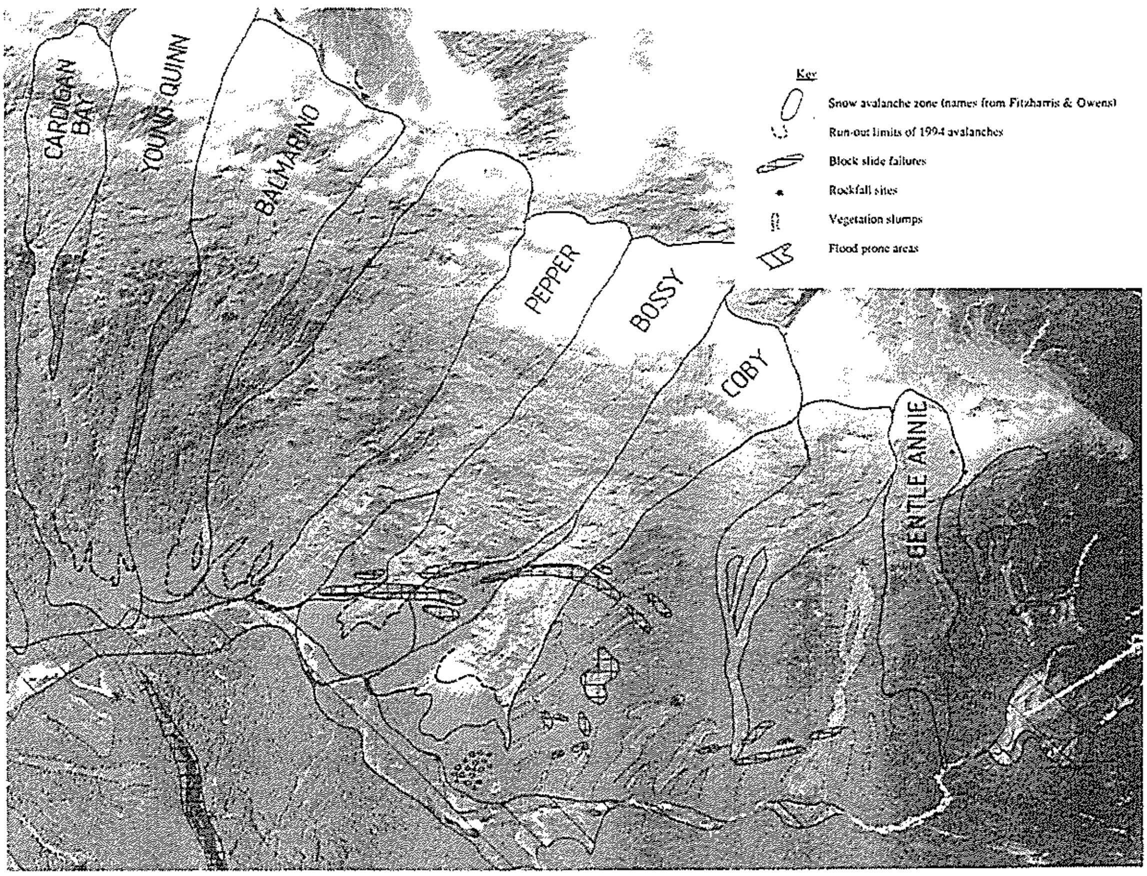
The metamorphic bedrock forms conspicuous outcrops from valley floor to ridge crest. A coarse grained gneiss is the dominant rock with diorite and orthogneiss also present. Although visible differences occur, all rocks are hard, very strong, competent masses with a pervasive, weakly foliated structure. The fabric is tight and only rarely seen to be defect forming. True defects were found to be scattered and widely spaced such that few well defined joint sets were apparent. The most prominent are steep to subvertical and subparallel to the overall valley trend with a less prominent set also subvertical and striking normal to the other set. Very few low angle defects were seen. Other major discontinuities are suggested by the alignment of adjacent valley systems.

Alluvium forms flood plain deposits where the valley is broad enough to accommodate them. The alluvium is comprised of rounded gravels, cobbles and boulders (up to several metres diameter) with interstitial sand.

The youngest deposits are those found in debris fans at the side of the valley. The nature of the materials reflects their mode of placement, however, more than one mechanism may have been operating at the time of failure or alternately with time such that clear distinctions are not always apparent.

Fans containing predominantly rock debris (taluvium) result from block slides or rockfalls and consist of a broadly graded mixture ranging from fine gravels through to very large (up to 10m) boulders. A degree of sorting is apparent with the coarser material often traveling to the toe of the fan where it forms a chaotic jumble of huge boulders. Some reworking of rockfall debris by the side streams results in a concave profile with gradients up to 35° at the cone apex down to less than 5° where it merges into the flood plain. Despite this reworking, most particles are angular in contrast to the rounded alluvial

Figure 2: NATURAL HAZARDS IN THE MID ARTHUR VALLEY



gravels. Debris fans formed by snow avalanches are characterised by a minor detrital rock content and a high organic content from the trees and shrubs swept down by the mass movement.

Colluvium and weathered soil horizons occur in small, restricted localities protected from erosion or slope failures but are more frequently absent altogether.

5. NATURAL HAZARD IDENTIFICATION

Natural hazards are those resulting from naturally occurring processes on natural slopes and exclude atmospheric hazards (e.g. wind, rain, snow) as they are not sufficiently site specific in terms of hut site selection criteria. Table 1 categorises and describes the various hazards considered applicable to this study and Figure 2 shows the readily identifiable hazards in the mid Arthur Valley.

Snow avalanches have long been recognised as the commonest hazard affecting the Milford Track. The winter of 1994 was a particularly heavy snow season which saw the extension and merging of known run-out zones and the development of new avalanche paths. The increased activity left the bush surrounding the distal margins of the run-out zones badly damaged at both canopy level, where branches were trimmed off by the air blast, and at ground level, where stream bed mobilisation of debris buried root systems.

The forms of mass movement involving rock debris are mostly rock falls, most of which are less than 50 m^3 (Figure 2). The two largest failures are sufficiently deep seated to be classified as block slides and probably occurred shortly after the retreat of the valley glaciers. Their position coincides with the lower tracks and run-out zones of two large avalanche paths and their debris fans project

TABLE 1
NATURAL HAZARDS IN THE MID ARTHUR VALLEY

TYPE	CONDITIONS FAVOURABLE TO DEVELOPMENT	LOCATION	CONSEQUENCES
DYNAMIC			
Mass Movements:			
Snow avalanches	Snow slopes of 30°- 45°, certain atmospheric conditions.	Initiation zones start above 1300m but tracks and runout zones extend down to valley floor.	Direct impact by debris, burial by transported debris, air blast over broader zone.
Rock falls, topples	Subvertical slopes (bluffs); defects subparallel to bluff, high groundwater pressures.	Steep sided valley walls where conditions favour their development.	Direct impact and partial burial by debris. May lead to initiation of vegetation slumps.
Rock slides	Oversteepened slopes or bluffs; unfavourably oriented defects; high groundwater levels.	Steep sided valley walls where conditions favour their development.	Direct impact and burial by debris.
Vegetation slumps	Steep to very steep slopes; glacially polished surfaces; very heavy rainfall.	Valley walls below the bush line	Direct impact and burial by debris.
Fluvial processes:			
Alluvion (aggradation)	Rivers or side streams transporting material; heavy rainfall.	Proximity to any stream, particularly where gradient flattens	Partial burial by sand and gravel; disruption of water supply and sewage disposal.
Avulsion (degradation)	Rivers or side streams transporting material, heavy rainfall.	Proximity to any stream, particularly where gradient steepens	Loss of foundations and amenity areas.
STATIC			
Flooding	Heavy rainfall, low lying ground, impervious ground	Valley floor adjacent to river, swampy ground.	Flooding inside buildings, loss of access, septic tanks affected
Differential settlement	Recently deposited materials with high water and organic content.	Valley floor in avalanche run-out zones.	Distortion of structure, jamming of doors, cracking of windows.
Poor bearing capacity	Organic peaty soils; very loose or cavernous ground.	Valley floor in avalanche run-out zones.	Sinking of piles into ground; distortion of structure.

material further outwards towards the river. Heavy rainfall in 1988 saw reactivation of the scar and the development of fresh overhangs (see Figures 2 and 3).

Vegetation slumps are peculiar to the steep, valley walls of Fiordland. The glacially polished walls give little purchase to the rain forest which can be completely stripped off when the weight of the saturated mass becomes too much for the slope to bear. Failure may be triggered by a small rock fall, wind-thrown trees or avalanches. Several recent scars are visible but it is apparent from the lack of mature stands of beech on the valley walls that few slopes have not failed in this manner.

Other hazards associated with rivers, such as flooding or erosion, are restricted to the low lying ground of the valley floor.

Figure 3: View of Dumpling Huts, debris fan and avalanche path behind (top left corner). Note mature rain forest around huts and scrub in impact zone beneath bluffs. Side stream splits into two channels just above huts.

6. THE PROBLEM AT DUMPLING HUT

A side stream arises in the large rockfall/ avalanche zone behind the hut complex (see Figure 3) and splits into two channels that flow either side of the huts. On the right hand side, a small water course flows intermittently and can encroach on to the hut's foundations during heavy rain. The water course on the other side passes about 15 m away from the uphill corner of the new accommodation block. This branch appears to be the dominant of the two judging by the width of the flood plain and the amount of gravel aggradation. There was no well defined channel as a consequence of the aggradation and gravel was spread through the forest on either side

A detailed inspection of the stream above the huts showed the flow and bed load behaviour changed constantly along its concave profile. In the vicinity of the huts, the gradient (about 5°) is too flat for the left hand channel to sustain normal flows. During heavy rainfall, flood flows mobilise the loose gravels which are then readily replenished via a continuous connection with the main channel upslope.

The smaller channel on the right hand side of the hut could be traced back upslope for about 40m where the entire flow was seen to emerge from a spring a few metres to one side. A further 40m upslope, a branch of the main stream discharges into a soak pool from which no outflow occurs and it seems reasonable to infer that this is the source of the spring. Because the smaller side channel is not connected with the main channel, no gravel is transported in this direction. However, the low relief of the stream bed upslope suggests that a damaging flood flow could readily scour a new channel or redirect the passage of gravel towards the right hand side of the huts.

7. RISK AND CONSEQUENCE

Risk involves both probability and impact of the hazard. It may be defined as a combination of the likelihood of a given event or event magnitude, such as a landslide of a certain size, occurring within a given time, and the impact or damage potential that the hazard will have on the facility (Hearn and Fulton, 1987).

The probability of a certain event occurring during the design life time of a hut on the Milford Track (say 50 years) could be determined from the magnitude - frequency rating of the controlling factors if such data were available. Precipitation would appear to be the main controlling factor for all hazards identified in this study. Unfortunately, there is insufficient knowledge on what precursory conditions are necessary and what amount of precipitation constitutes a limiting threshold value for a damaging failure to occur in the Arthur Valley. Clearly, it would not be possible to develop a quantitative risk analysis.

For snow avalanches, Owens and Fitzharris (1985) have calculated the probability of a moving encounter between an avalanche and a walker. A *hazard index* for the entire track is then calculated by summing the probabilities for all paths and multiplying by the number of users for both winter and summer seasons. For a static encounter with a hut that remains throughout the year, an approach similar to that used to assess the risk to parked cars on the Milford Road (Fitzharris and Owens, 1980) could be adopted. The risk then becomes the frequency of a particular hazard occurring times a weighting factor. Although frequencies for the known avalanches have been estimated (Owens and Fitzharris,1985) no information exists for the other hazards and there is no known methodology for assessing the impact on damage potential.

An alternate approach would be to adopt a qualitative analysis that assumes the necessary climatic conditions for a damaging hazard capable of causing total loss will occur in the lifetime of the hut. A risk category can then be assigned depending on:

- Proximity of hut to toe of slope greater than 40° or to stream course;
- Slope and aspect of intervening ground;
- Surface "roughness" or ability to absorb and decelerate moving debris.

All methods provide a snapshot of the risk thought to be prevailing at the time based on historic data or assumptions about what has gone on in the past. No consideration is given to how risk may change with time. Examples of factors that may have a bearing over the lifetime of a structure include:

- gradual climatic changes (global warming) which result in heavier snow falls or more intense rainstorms;
- piecemeal retreat of the beech forest buffer zone which allows debris to encroach closer to the hut and track.

Table 2 gives risk categories for various values of the above criteria.

TABLE 2:

RISK CATEGORIES FOR HUT SITE CRITERIA

Criteria Risk category:	very risky	risky	some risk	slight chance	unlikely
Proximity to toe of slope >40°	<25m	25-50m	50-100m	100-150m	>150m
Proximity to permanent stream	<10m	10-20m	20-40m	40-80m	80-150m
Proximity to ephemeral stream	<5m	5-10m	10-20m	20-40m	40-80m
Slope of intervening ground	40-30°	30-20°	20-10°	10-5°	<5°
Surface roughness upslope	smooth rock face	bare ground no shrubs	regen. scrub boulders	mature scrub tree fuchsia pole beech	mature beech forest
Score:	1	2	3	4	5

Susceptibility rating = Σ scores/5

8. ALTERNATIVE HUT SITES

The present hut site lies within a clearing approximately 30 m by 40 m. Part of this space is required for a helicopter landing pad whilst water tanks and septic tanks take up additional space. Other factors to consider are:

- ease of site formation including excavation for septic tanks,
- adequate founding conditions,
- access to suitable water supply,
- vista,
- aspect in relation to the sun,
- track proximity and
- plant conservation.

The last factor is concerned with avoiding cutting down mature forest in preparation for a new hut. However, the only natural clearings are those created by past hazards e.g., on frequently flooded areas or avalanche run-out zones. Although siting a hut within the forest has an adverse environmental impact, it is nevertheless necessary as it plays an important role as a buffer against damaging hazards.

Alternative hut sites were searched for within 2.5 km of the existing site in order to roughly maintain the present distances between the previous hut and the end of the track. The constraints imposed by the known natural hazards and the hut site criteria meant that very few sites were available. Four sites were eventually selected with the above considerations in mind and a susceptibility rating determined for each according to the criteria in Table 2. Rating values of 2.6, 3.3, 3.8 and 3.8 (out of a maximum of 5) were derived for the four sites and a comparative value of 3.5 obtained for the existing Dumpling Hut site.

Two sites with higher ratings emerged as possible alternatives, however, they did not rank significantly higher to the extent that developing a new site was the preferred option. Instead it was decided to consider extending the life of the existing Dumpling Hut complex by undertaking remedial works to the stream above the huts. A conceptual proposal of utilising linked gabion baskets to divert the stream channel at a level where it continues to flow was put forward. Immediate concerns were the difficulty of constructing an engineered structure on a steep, forest-clad slope, the cost and the likelihood of such a structure surviving in the hostile environment. At the time of writing it was decided to trial a low impact, non-engineered stream diversion accepting that ongoing maintenance would be necessary. In the meantime, the two alternate hut sites would undergo further evaluation and monitoring for flood damage during severe rain storm events.

ACKNOWLEDGEMENTS

The permission of the Department of Conservation to publish this paper is gratefully acknowledged.

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Land Assessment for Development Suitability

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SYNOPSIS : The suitability of land for building development is determined in a Land Assessment. An approach to Land Assessment is outlined which has as its principal philosophy the early identification of constraints so that they can be taken into account by the subdivider, at an appropriate time, to maximise site usage. The approach is based on understanding the site geology and geomorphology, which allows a good assessment of natural hazards, and a close involvement with the subdivider to avoid inappropriate subdivision proposals, thus allowing a smooth passage through the consents process.

1. INTRODUCTION

The suitability of land for building development, usually residential and commercial/industrial, requires assessment either when District Scheme Plans are reviewed or when subdivision of land is proposed.

At present Territorial Authorities have a wide range of criteria for assessing land suitability information. Some emphasize geotechnical issues based on stability models, while others emphasize geological assessment. The Worley approach is to integrate the two, but build on a sound geological base. The approach is presented in this paper by reference to an example of a subdivision of a difficult block of land in North Shore City.

2. STAGES OF LAND ASSESSMENT

2.1 Stage 1 : Land Suitability Assessment Map

2.1.1 Engineering Geological Assessment

The first stage of a Land Assessment is the preparation of a Land Suitability Assessment Map by making an engineering geological assessment of a block of land to identify natural hazards (eg slope instability, flooding, seismicity, erosion, poor ground - eg peat, mud etc).

The engineering geological assessment comprises :

- Study of aerial photographs, geological maps, existing reports, nearby ground investigation data (eg augerholes, pits, drillholes).
- Field investigations, eg mapping of geomorphology and geology, augerholes, drillholes, pits etc.
- Mapping onto a good topographical plan if possible.

Mapping is the primary tool to classify land into development suitability classes and in most cases, engineering geological assessment is used to classify features such as large areas of instability rather than attempting to apply computer based stability models which commonly cannot be adequately defined for complex ground conditions without prohibitive cost.

Often the engineering geological assessment is broken down into 2 parts, the second part examining key features in more detail. Here, computer based stability analyses may be appropriate for slopes with marginal stability and for which a stability model can be constructed at reasonable cost. This usually involves cored drillholes, laboratory testing and groundwater level monitoring.

The engineering geological assessment produces a development constraints /opportunities map termed a Land Suitability Assessment Map.

Land is generally classified into 3 classes :

(a) Few constraints to development (minor earthworks etc). Building in terms of NZS 3604 is permitted.

(b) Moderate constraints to development, by steepness of ground, marginal stability, poor ground. Considerable earthworks and remedial works for slope stability and foundations are required. Building in terms of NZS 3604 maybe permitted following earthworks and remedial works, otherwise specific investigation and design is required.

(c) Unsuitable for development.

The engineering geological assessment also provides data for design of earthworks and together with the Land Suitability Map is suitable for submission to the Territorial Authority for subdivision consent. The document submitted for subdivision consent is often called a Geotechnical Assessment.

2.1.2 Example of a Map

An example of a Land Suitability Assessment Map for a subdivision of difficult land is shown on Figure 1. In this case because the land is difficult, only 2 classes of land are used and they are shown on the engineering geological map of the subdivision. Building restriction zones (and building restriction lines) in which building development is not recommended, are delineated on the basis of field data and stability analyses. The building restriction lines are indicative only and intended to aid the scheme plan layout.

The remainder of the land outside those zones would usually be suitable for residential development in conformity with the requirements of NZS 3604, Code of Practice for Light Timber Frame Buildings not Requiring Specific Design. However in this case, due to the relative steepness of topography, it is recommended that development of all lots be subject to specific investigation and design. Following completion of earthworks, lots should be re-assessed to define those for which this recommendation may be waived or relaxed or any further restrictions (such as development constraints) defined.

2.2 Stage 2 : Subdivision Layout

In the second stage of a Land Assessment, the subdivider develops a preliminary subdivision layout using the Land Suitability Assessment Map. Further investigation work may be required at this stage to examine particular features (eg stability of cuts and fills, and the development potential of particular lots on difficult ground).

2.3. Stage 3 : Final Assessment of Development Suitability

2.3.1 Land Suitability Statement

The third and final stage of a Land Assessment is final assessment of development suitability, made after completion of earthworks etc. Building restriction zones are established directly in the field and each lot is classified according to ease of development. Building restrictions may be defined by steepness of slopes and the need to maintain stability, poor ground requiring special foundations etc. Observations of ground and groundwater conditions, made during the earthworks are used in this final assessment.

Land classifications and any restrictions are presented in a Land Suitability Statement which includes :

- Statement of Professional Opinion as to Suitability of Land for Residential Development.
- Land classification (shown on Land Transfer Plan) showing areas subject to Land Covenants, eg building exclusion zones, areas subject to specific investigation and design etc.
- Land Suitability Report which amplifies the Statement and includes earthworks quality control results, road pavement test results, previous Geotechnical or Engineering Geological Assessment of the subdivision etc.

The Territorial Authority uses the Land Suitability Statement to prepare Consent Notices to be registered on new Certificates of Title for the lots in the subdivision.

2.3.2 Example of Land Classification Plan

Figure 2 presents an adaptation of the Land Classification Plan for the subdivision shown in Figure 1. Figure 2 illustrates the final restrictions and zones for the subdivision following review of earthworks construction observations, and final assessment in the field of building line restrictions.

The preliminary development exclusion zones (and building line restriction) determined during the first stage of Land Assessment (shown on the Land Suitability Assessment Map, Figure 1) are also shown on Figure 2 for comparison. It can be seen in this example that the subdivision was laid out using the development preliminary exclusion zones as a framework, and that the final building exclusion zones were smaller than the preliminary zones.

3. CONCLUDING REMARKS

The principal philosophy of a Land Assessment is the early identification of constraints so that they can be taken into account by the subdivider, at an appropriate time, to maximise site usage. Territorial Authorities should also be consulted early so that they can be involved in setting their requirements concerning natural hazards and appropriate mitigation measures.

Worley's approach is based on :

- Understanding the site geology and geomorphology, which allows
- a good assessment of natural hazards, and
- a close involvement with the subdivider to avoid inappropriate subdivision proposals, allowing a smooth passage through the consents process.

At present Territorial Authorities have a wide range of criteria for assessing land suitability information. Some emphasize geotechnical issues based on stability models, while others emphasize geological assessment. The Worley approach is to integrate the two, but build on a sound geological base.

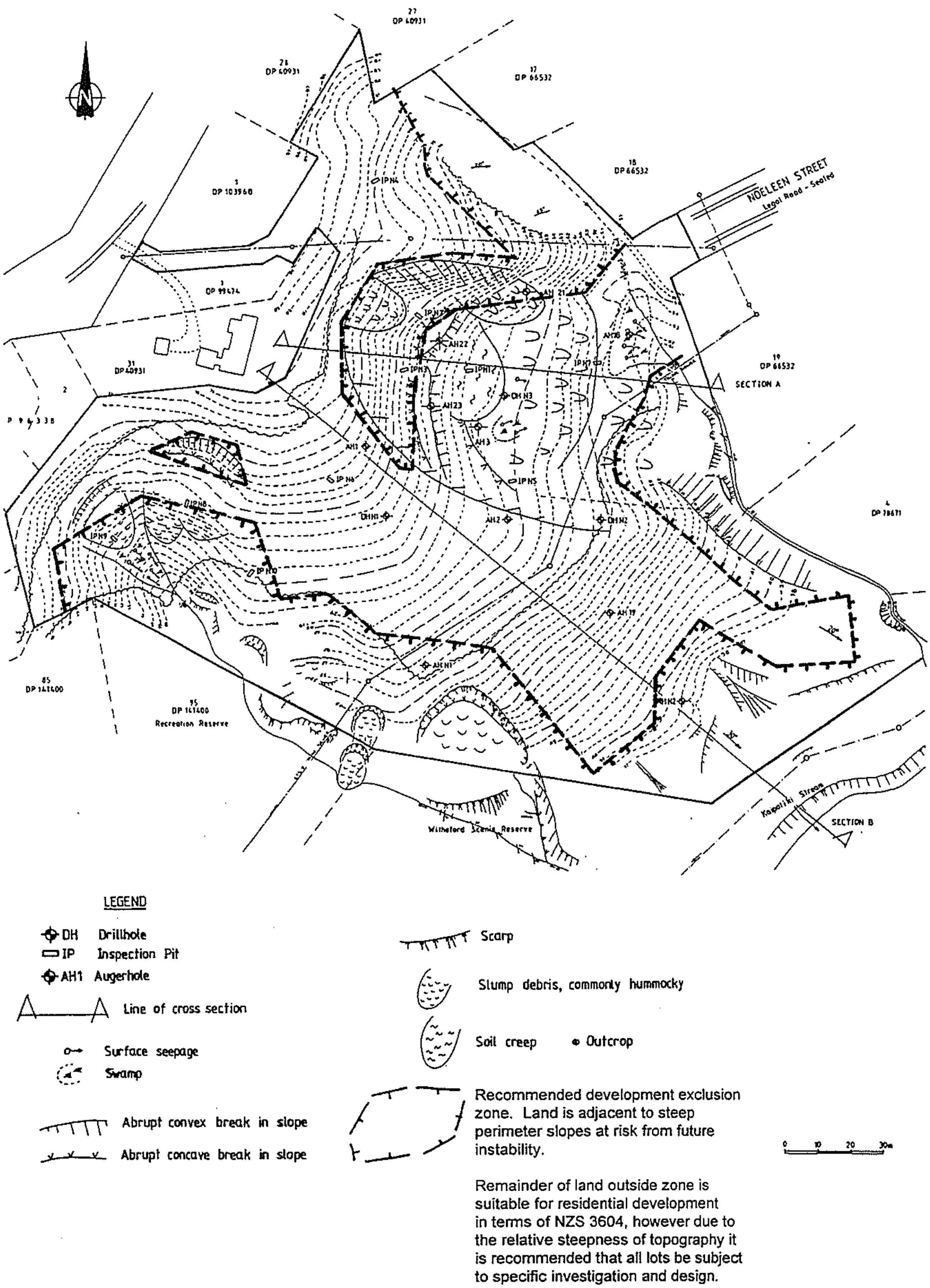
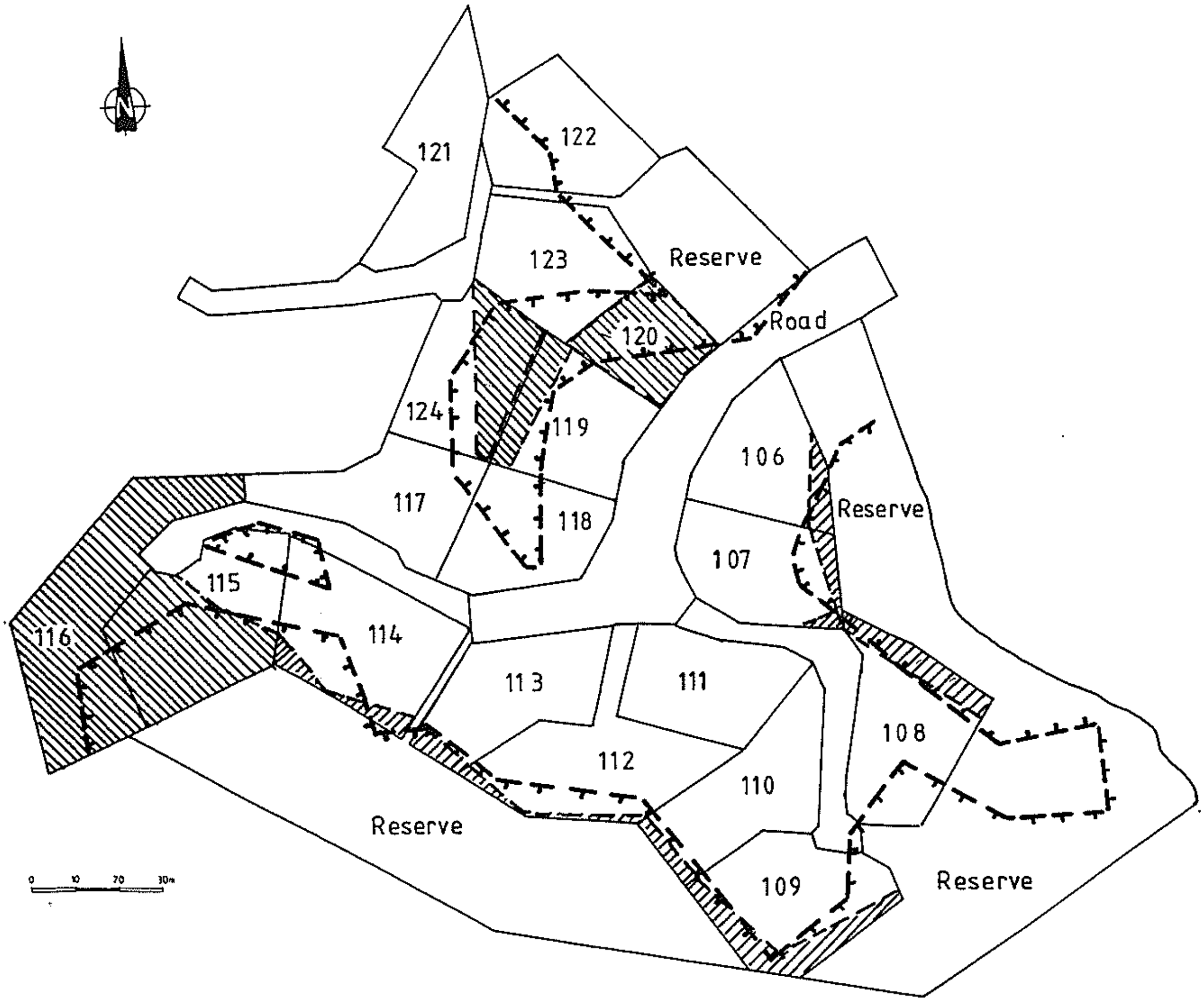


Figure 1 Land Suitability Assessment Map



LEGEND

Area considered suitable for development. All earthworks involving cuts or fills in excess of 1.0 m, retaining walls, and building foundations shall be designed and have construction supervised by a Registered Engineer, experienced in geotechnical engineering and slope stability, familiar with the requirements of Worley's Geotechnical Report.

Building Exclusion Zone. Land unsuitable for development.

Stability sensitive zones within the 2 new amalgamated titles comprising lots 115, 116 & 117 and lots 119, 120 & 124. Prior to any building or re-subdivision of the amalgamated title comprising lots 115,116 & 117 a satisfactory Geotechnical report incorporating specific engineering design is to be prepared by Worley and submitted to Council. Prior to any building or re-subdivision of the amalgamated title comprising lots 119,120 & 124 a satisfactory Geotechnical report incorporating specific engineering design for building sites ad with particular emphasis on stability of adjacent land is to be prepared to the satisfaction of Council.

Preliminary Development Exclusion Zone (refer Figure 1)

Figure 2 Land Classification Plan

ACCREDITATION OF GEOTECHNICAL ENGINEERS AND ENGINEERING GEOLOGISTS

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SYNOPSIS
Tauranga District Council has established an accreditation process to access the academic training and practical experience applicants hold in respect of geotechnical engineering and engineering geology. This accreditation process has provided a basis on which geotechnical reports would be accepted from applicants in respect of geotechnical matters without Council having to have reports referred to independent checking.

Reliance on an annual practising certificate under the Engineers' Registration Act and/or the IPENZ Code of Ethics has proved to be an inadequate assurance of practitioners' compliance in the specialist area of geotechnical engineering..

In the past, Council officers have made their own judgements as to who are the specialists and who are not, and the accreditation procedure merely seeks to formalise that judgement and no other changes are proposed or implied The only areas where specialist input is routinely required would be on slope stability problems of some magnitude and difficult settlement problems such as when it is proposed to build on uncontrolled fill.

1. INTRODUCTION

The Tauranga District Council under legislation such as the Building and Resource Management Acts has a responsibility to ensure that land development and subdivision and building construction is planned and undertaken to particular standards. The standards are generally of a nature to ensure that Council is protected in such matters if development and construction problems arise.

Up until May 1993 there was no formal mechanism in place regarding the acceptance of geotechnical reports from consultants. Staff made a decision from whom to accept geotechnical reports which were submitted as part of the subdivisional development process. However, such decisions could be viewed as being arbitrary and tended to be based on experience to date. There had been requests from consultants that reports prepared by them on geotechnical matters, be accepted by Council. To achieve this in a fair and reasonable way and to ensure that Council was not being exposed as to liability issues a process to scrutinise and evaluate the academic training and experience in geotechnical matters was proposed. The proposal was to ensure that reports from such individuals were of a certain standard and quality on which assessment could be made as to whether a particular subdivisional development was to be given approval.

2. ACCREDITATION PROCESS

An established process has allowed the Council to assess the academic training and practical experience applicants held in respect of geotechnical engineering and engineering geology. The assessment has provided a basis on which geotechnical reports would be accepted from applicants in respect of the above mentioned matters without Council having to have the reports referred to another person for assessment. In addition, there were associated amendments to Council's Code of Practice for development. These amendments defined the nature of information to be provided in geotechnical reports and other information. The suggested amendment to the Code was publicly notified and opened for submissions for one month and also was circulated directly to consultants in the Bay of Plenty and Waikato areas.

The result of submissions to Council was that Council policy was confirmed to implement an approval process in respect of geotechnical engineers and engineering geologists to evaluate academic training and experience and such policy was to be implemented in general accord with Attachment A. The Director of Planning and Environment was also given delegated authority to confirm recommendation from the geotechnical panel regarding whether applications for acceptance of qualifications were successful or unsuccessful.

Presently, at the time of subdivision application, the development engineer or his assistant visits the site and makes a decision as to the levels of soils reporting appropriate. On very small subdivisions less than five lots where no particular soils problems seem apparent, no soils reports are required from the developer.

On small subdivision where there are particular soils issues to be addressed and on all major subdivisions a report is required as to the suitability of the site for subdivision and building development. At that time the development engineer or his assistant makes a judgement as to whether reporting from a registered engineer or specialist geotechnical engineer is appropriate. The situations where specialist input is required are almost always limited to where there is a major slope stability issue to be addressed, (for example building on or near seacliffs or relic slips) or where there is a particularly difficult settlement problem to be addressed. For example, where uncontrolled filling has been placed across soft, underlying material. For those situations where we deem that specialist input is required, we are currently imposing a condition of subdivision that a specialist geotechnical engineer provides soils reports that demonstrate the suitability of the site for building development.

3. BACKGROUND

The Council's role is one of ensuring that the people submitting reports are competent and the Tauranga District Council can accept with a high degree of confidence. The fact that it is no longer appropriate for all registered Civil Engineers to undertake all soils problems has now become established and is reflected in such documents as:

(a) **NZS 4404: "Code of Practice for Urban Land Subdivision"** which defines the Soils Engineer as a person who is currently entitled to practise as a Registered Engineer and has experience in soils engineering acceptable to the Council; and

(b) **The Branz Study Report SR4 (1987): "Assessment of Slope Stability at Building Sites"** which refers to Civil Engineers who have *specialised as "Geotechnical Engineers"* and says 'that not all Civil Engineers will necessarily have the required skills and experience for carrying out slope stability".

The purpose of the Geotechnical procedure is to establish and formalise in an impartial, professional and fair way, some minimums in terms of geotechnical knowledge and experience that is acceptable to Council. Its implementation will hopefully leave a high degree of responsibility etc with Engineer. To my mind, we can have all the procedures in the world but the concept is to ensure that those involved in geotechnical matters have a sufficient degree of technical competency in geotechnical matters to allow reliance to be placed on their work. The option of engaging consultants to review a design is there, but this places the Council in the position of passing on additional costs to an applicant and the resultant delays. The customer invariably perceives the delay as being caused by "Council bureaucracy" rather than any shortcomings on the part of his design professional. Council staff are also very reluctant to criticise the designer in front of his client. Furthermore, should a designer get out of his depth on a geotechnical matter, the reviewer inevitably becomes a defacto designer as he continually points out the shortcomings of the design until at last by a process of elimination, the designer comes up with something that the reviewer will accept. More often than not this is a bare minimum solution. Why should Council, through its agent who is reviewing the design, assume this defacto designer role? It is obviously much better from a customer point of view for them to go to those who have their qualifications approved and obtain the right advice from the start.

The issue of Code of Ethics and the creation of a privileged group within the Tauranga area is not really our concern. Our concern is ensuring there is competent advice in reports being submitted to Council, that recognise local geotechnical issues and minimise Council's liability.

The role of Council is not to review and assess the adequacy of information for each project. Given the changing role, Council is endeavouring not to be a checker of a checker but endeavouring to provide a mechanism where those who meet certain requirements lay their knowledge, experience and liability on the line to a greater degree. This approach is consistent with certification and the Building Act; that is, certifiers are listed "based on competency". The greater the Council involvement, the greater the liability we buy into.

In response to the Territorial Authorities of the Auckland Region's request for comment on the use and acceptance criteria for Producer statements, the New Zealand Geomechanics Society in November 1992, made the following comments:

"The Geotechnical Services that many members of the Geomechanics Society provide address the stability of land, slopes, compressible soils, erodeable soils, filled ground and investigation and design of foundations, earthworks and earth retaining structures. Producers include designers, specifiers and construction contractors, all of whom should provide assurance that Geotechnical matters have been assessed and taken into account in the design and construction.

Reports by providers of Geotechnical Services should be prepared by persons who have academic and practical experience at a standard recognised in the profession and acceptable to the Territorial Authority. Reports should comply with the Territorial Authority's guidelines as to procedure of investigation and supervision and content of report. They should also comply with statutory requirements and relevant standards and they should recognise the two essential aspects of Geomechanics which are *geology* and *engineering*. Specialist services such as Geotechnical should only be provided by appropriately qualified and experienced persons and do not recognise the important input of Engineering Geologists to many geotechnical problems.

Geotechnical professionals would have involvement in design and design review but perhaps the most important is construction review. Due to the inherent uncertainties associated with many aspects of geotechnical engineering, it is essential that inspections are undertaken during construction to verify design assumptions and to recommend modifications if necessary. The importance of such inspections has long been recognised by design professionals who have recommended to their clients that such inspections are necessary and why many Local Authorities who have required inspections during construction by appropriately qualified professionals.

Producer statements in the field of geotechnical engineering should be provided only by professionals with specialist training and practical experience in the field of geotechnical engineering. The qualifications and training depend on the nature of services being provided. If a geotechnical report provides engineering recommendations then the reporter should be an experienced registered engineer. They should also be involved in observation of construction to ensure that the intent of the recommendations are adhered to and to make modifications if necessary. However, there are also situations where investigation procedures for specific sites can be defined better if they are preceded by geomorphological examination which can best be undertaken by engineering geologists. Engineers issuing producer statements should also have mandatory membership of a professional association. This could be either active membership of ACENZ or corporate membership of IPENZ.

It must be remembered that geotechnical engineering is a specialist field and it is important that only those with the necessary specialist training and practical experience should be permitted to issue producer statements."

3. WHY HAVE ACCREDITATION?

Whilst there is quite a bit of hazard information located in various places in Council, this has not been developed into a comprehensive hazard map of the kind envisaged by different professional bodies. One of the concerns in formalising hazard information is trying to deal fairly with land owners whose properties may be devalued (perhaps unjustifiably) by a broadbrush hazard information. I am of the view that we should only develop and formalise hazard maps for those areas where the benefit of doing so outweighs the negative aspects associated with them. We must not lose sight of the fact that we are here to look after the interests of our ratepayers and not consulting engineers.

Tauranga's soils are not any more difficult to deal with than those in many other areas of New Zealand. The development engineer has personally found them to be much more predictable than the complete jumble that is found in Auckland. The basis of a listing of accredited geotechnical engineers as I see it, is that in all areas of New Zealand there are some soils problems more appropriately addressed by a specialist geotechnical engineer than the non-specialist registered Civil Engineer (just as there are some medical problems more appropriately dealt with by a brain surgeon than a GP). It is believed that by and large the profession realises this. The purpose of the listing is to formalise the decision making as to who is the specialist and who is not. Ever since about 1984 the engineers in the County, City and District have realised the need to differentiate between the two and have simply made their own somewhat arbitrary judgement on the matter. The fact of the matter is that the reports done by specialists are as different from those done by non-specialists as chalk is from cheese. Furthermore, the reports done by the non-specialists are all too frequently less conservative than those done by the specialists. This is the reality of what is happening on the ground.

As already commented upon, the listing procedure is primarily aimed at situations where the developer (not the Council) is the client. It is suggested though that the first and most important task in managing the consultant is to ensure that the persons engaged are competent for the task (reference the FIDIC Guidelines on the selection of Consulting Engineers that places prime emphasis on "selection by ability" and lists technical competence as the first of the matters to be evaluated). Unfortunately, many clients are not at all good in determining this and there is nothing but trouble for all parties when some homeowner has rather innocently spent their hard earned money on an inadequate report. This does occur and Council is not looking after its customers' interests when it allows them to repeatedly fall into the same trap. Council officers also end up coming under extreme pressure from enraged or heartbroken clients to accept a report from someone who is not up to the task he/she has taken on. It is far better to get it right in the first place and set up systems to ensure the right person is engaged from the start.

On the surface, the setting of standard tests sounds like a good idea, but in reality it is not. What is being suggested is the Council defining what tests etc must be done in the areas of various risk and thus making the preparation of soils reports relatively "idiot proof". In practice however, the determination of what level of testing is appropriate is dependent upon more factors than simply the area. For example, the cost of the structure proposed has a bearing. It is not appropriate to do the same level of testing for a gazebo as for a multi-million dollar project. Also the amount of testing done on nearby similar sites is also of relevance. If the engineer has already done extensive testing on the similar site next door he/she will not need to do the same amount of testing as if he/she is coming in cold. The decision as to what level of testing is appropriate is an expert decision which should not be taken away from the designer. We should allow the designer to use their skill in this matter. I am strongly opposed to the prescriptive, blunt instrument approach of Council specifying the level of testing required. It is well nigh impossible to draw up requirements that allow for all the relevant factors. If we call up the roles that fits the worst case scenario then we are faced with the alternative of either becoming bloody minded and enforcing it in all cases or alternatively backing off and agreeing to a lesser standard. If we do back off however, we have significantly increased our liability by breaking our own rules and also by becoming a defacto designer by specifying the level of investigations.

We, in Council, are not specialist soils engineers and are not competent to judge the appropriate level of investigation. A far better approach is to ensure that only the right people are doing the work and then let them use their expertise to determine the appropriate level of testing.

When presented with a report by someone with inadequate skill, the end result is invariably far from ideal. The Council usually gets sucked in to becoming a sort of defacto designer as it is continually asked the question: "Will you accept this?" Ultimately by a process of elimination, the consultant ends up covering most of the points that Council thinks he should have. The end result however is that most of the shots have ended up being called by Council and Council has become so thoroughly immersed in the process that it is fully liable for the outcome. It should also be noted that Council does not have on its staff, specialist geotechnical engineers capable of calling all the shots on geotechnical matters.

It is agreed that it is a shame that we cannot rely on the Code of Ethics. It would be very good if we could simply ask for a registered engineer and be sure of a satisfactory outcome. The reasons for a lack of confidence in application of the Code of Ethics could be due to:

(a) failure to realise that some geotechnical problems have now become areas best handled by specialist; or
(b) over-estimation of their competence; or
(c) financial pressure.

The fundamental issue is that the Council perceives a need for a specific listing of persons qualified and experienced to act as geotechnical engineers in the Western Bay of Plenty area. Reliance on an annual practising certificate under the Engineers Registration Act and/or the IPENZ Code of Ethics has proved to be an inadequate assurance of practitioners compliance in this specialist area.

The Tauranga District Council does not accept the producer statement arrangements promulgated by the inter-professional group because they do not provide for any transfer of liability and hence there is no benefit accruing to us. This is not an overly-cautious position as our responsibilities are to protect ratepayers at large, not accept risks on their behalf in the interests of benefiting private individuals or companies. ACENZ is correct in that the application of this system logically does lead to the accrediation this for other engineering specialisations.

It is the view of the professional staff of the Tauranga District Council that it should be a role of the professional institutions to undertake the examination and accreditation of individuals in specialised fields of engineering. Indeed we believe that IPENZ should be undertaking this role, if necessary under licence to the building industry authority. In the absence of the professional bodies grappling with and resolving the issue of accreditation of specialisations then there is no doubt that other bodies and individuals will attempt to fill the gap, not entirely satisfactorily in our opinion.

A Council's geotechnical listing procedures are a local response to a problem where the professional bodies seem unwilling or unable to effectively deal with. It is the responsibility of the professionals to regulate themselves and I believe there is a perception in the community, and certainly within territorial local government that there is considerably more that can be done in regard to the accreditation of specialisation, the enforcement of the Code of Ethics and discipline of professional engineers. The profession does not appear to deal with that effectively and until that is done the community will find ways of regulating the profession externally.

4 GENERAL COMMENTS ABOUT ACCREDITATION PROCESS

The interview panel has been concerned that no engineering geology specialists have presented for accreditation to date. It is vital that engineering geology expertise is available to specialist geotechnical engineers practising in the Tauranga area and also available to assist Council where required.

The panel has also felt that it was important that the rationale behind the accreditation process should be made widely known. It should be made quite clear that the purpose of Tauranga District Council's policy on accreditation of specialist geotechnical engineers is certainly not to require that all soils problems be addressed by those who have gained accreditation. Most foundation designs and soil problems will continue to be addressed by registered engineers. There will be no Council requirement for special accreditation to address the straight forward matters.

The purpose of accreditation is to have a list of approved geotechnical engineers or engineering geologists to address those soil problems which in the judgement of the Tauranga District Council's Development Engineer, require specialist input. In the past Council officers have made their own judgements as to who are the specialists and who are not and the accreditation procedure merely seeks to formalise that judgement and no other changes are proposed or implied. It is anticipated that the only areas where specialist input is routinely required would be on slope stability problems of some magnitude and difficult settlement problems such as when it is proposed to build on uncontrolled fill. However, this is not to say that Council may on the odd occasion seek input from a specialist geotechnical engineer on the question of some significance such as liquefaction potential for a multi-storey building site.

The applicants' information as submitted was generally poor and in some cases, quite irrelevant. The panel could also see a potential problem arising with regard to the use of peer review. Peer reviews from accredited specialists would be required if unaccredited engineers carried out relevant work. Peer reviews requested by Council of accredited specialists should also be made only by accredited specialists. With the limited number of specialists accredited so far, this could create difficulties.

5. RISK & PROFESSIONAL NEGLIGENCE

In the real world there is risk in everything. The only sure way of taking absolutely no risk is to do absolutely nothing! The real art of engineering is balancing those risks out at levels acceptable to the client and society. It is for the client, who is suggested in our case as represented by Councillors, to decide what level of risk should be taken. It is the job of Council staff to brief the client on what the risks are in a balanced way. In some cases, different District Councils are now erring on the conservative side or trying to take no risk at all. This is understandable when one considers past history of Councils taking far too much risk and being taken to the cleaners for subdivision stability failures.

There is no doubt that the nature of work performed by a professional engineer involves a blend of skill and specialisation including a recognition that there must also be a commitment to principles and ethics. However, on occasions, these two aspects can be in conflict. There has also been an increasing emphasis on specialisation within the profession of engineering. Specialisation has brought about a change in the inter-relations of the professions found to be working together on a project. For complex projects a matrix of relationships and responsibilities between professional persons can occur. Although specialisation can be considered to be a societal phenomenon in the thinking of the consumer it does not follow that he or she will distinguish between the level of reliance to be placed on advice from a civil engineer, as against a specialist geotechnical engineer on a matter normally dealt with by the latter.

To the consumer, he or she is dealing with a professional engineer. The consequences in law of not distinguishing between the two may be lost in the consumer but they should never be lost on the professional engineer.

Competency has the inherent quality of currency. Competency can be equated with knowledge. The difficulty today with the complexity of professions has not diminished the need for greater emphasis on currency of professional knowledge.

6. CONCLUSION

The purpose of the accreditation propose is to establish and formalise in an impartial, professional and fair way some minimums in terms of geotechnical knowledge and experience that is acceptable to Council. Its implementation will hopefully leave a high degree of responsibility with the engineer or engineering geologist. The fundamental issue is that the Council perceives a need for a specific listing of persons qualified and experienced to act as geotechnical engineers in the Western Bay of Plenty area.

Reliance on an annual practising certificate under the Engineers Registration Act and/or the IPENZ Code of Ethics has proved to be an inadequate assurance of practitioners compliance in this specialist area. It is the view of the professional staff of the Tauranga District Council that it should be a role of professional institutions to undertake the examination and accreditation of individuals in specialised fields of engineering.

7. REFERENCES

Smith, Damien, J (1986) *Engineers & Professional Negligence*, Currency Productions Pty Ltd

NZ 4404; *Code of Practice for Urban Land Subdivision*

The BRANZ Study Report SR4 (1987) *Assessment of Slope Stability at Building Sites*

ATTACHMENT A

TAURANGA DISTRICT COUNCIL GEOTECHNICAL PROCEDURES CRITERIA FOR APPROVAL OF QUALIFICATION OF GEOTECHNICAL ENGINEERS AND ENGINEERING GEOLOGISTS

1.0 OBJECTIVE

Council has legislative responsibility to ensure that land development and building construction are planned and executed to adequate standards.

One of the fields in which Council will need to be provided with advice is in Geotechnical Engineering which has to do with the stability of the ground in which development takes place and by which buildings and other structures are supported.

Council is concerned to take reasonable precautions to ensure that advice given to it upon Geotechnical matters, either directly or in support of development applications, or in execution of developments, is based upon sound professional training and experience.

Both formal academic training and practical experience are required in the two disciplines of Geology and Engineering but not necessarily in the same person.

Any geotechnical investigation should be oriented in the general geology and geomorphology of the area (encompassing the particular site) of which a general study demands academic training in Geology (especially geomorphology and geological mapping) and practical experience in its application to land-use planning and to engineering problems. Such regional information may be available in previous publications or reports or it may be prepared specifically for the particular development being proposed.

When it comes to designing and implementing engineering works necessary for the use of the land, then academic training and experience in Civil Engineering are necessary with particular emphasis upon soil mechanics, geotechnical engineering, engineering geology and encompassing design, specification and supervision of construction.

Geotechnical Engineering advice includes (but is not restricted to) the functions of the "Soils Engineer" as defined by Council's Code of Practice for Development.

2.0 QUALIFICATIONS AND EXPERIENCE REQUIRED

2.1 Academic Training

The usual requirement should be a first degree from an approved university with concurrent or subsequent specialised courses in relevant subjects.

For Geological and geomorphological appraisals:-

A university degree in Geology or Earth Sciences with specialist courses in Engineering Geology and optionally Geomechanics and/or Geotechnical Engineering.

For Geotechnical Engineering:

A degree in Civil Engineering from an approved university with core subject matter in Geology and Geomechanics supplemented with specialist courses in two electives from Engineering Geology, Geotechnical Engineering, Rock Mechanics or Geomechanics.

2.2 Practical Experience

For Registration under the Engineers Registration Act 1924, 4 years advanced practical training under a mentor is required.

The same concept can be applied to Geologists and Soil Scientists who offer specialist services thus:-

A minimum of four years' post-graduate experience in Geology applied to civil engineering or to land stability evaluation, under the tutelage of a Registered Engineer or experienced Geology or Soil Science

Graduate, who has countersigned reports prepared by the applicant.

3. APPLICATIONS FOR ACCEPTANCE

3.1 Applicants for acceptance as specialist advisers shall provide:

* evidence of academic qualification
* evidence of tutelage from their mentor (Registration under the Engineers Registration Act, or Corporate Membership of IPENZ shall suffice)
* A list of relevant geotechnical reports which they have prepared, stating:
    - geographic location of site
    - reference number of report
    - dates
* copies of two reports selected from the above list and be prepared to supply further samples from the list on request.

3.2 Experience in the specific geological environment of the Bay of Plenty is required.

3.3 Apart from the applicant's academic and practical training and experience the constraints and facilities of his commercial organisation will be considered with relevance to:

* Quality assurance facilities
* Autonomy of decision
* Delegation of support activities
* Professional indemnity insurance

3.4 Applicants will be required to attend an interview in Tauranga, with a panel comprising two independent senior geotechnical professionals and a senior professional from the Council's staff.

EXPLANATORY NOTES

1.0 APPLICATION FORMAT AND CONTENT

1.1 Fee

A non-refundable fee of $675.00 (GST inclusive) is to accompany each application

1.2 Legibility

Text should be typed wherever possible, and other material such as graphics should be of a quality to photocopy clearly.

1.3 Computer printouts

These may be submitted as part of sample reports but must be supported by sufficient explanatory notes and calculations to confirm understanding.

1.4 Qualifications and Experience

These are defined in the attached statement of criteria

2.0 FORM OF APPROVAL

2.1 Individual Only

Only individual applicants (and not firms) can have their qualifications approved.

2.2 Five Year Period

Each approval is valid for a period of five years only, after which qualifications and experience will be reassessed.

However a review could be undertaken at anytime within that period where circumstances warrant as a result of an engineering incident and on recommendation of the panel.

2.3 Limitations

Acceptance of an individual does NOT imply any approval for designs that such an individual may subsequently produce or certify.

3.0 DEFERRED APPLICATIONS

3.1 Further Information

The panel may defer an application when further information is required and the applicant will be requested to supply such information.

3.2 No Additional Fee

No additional fee is required when submitting this further information although it may be necessary to supply a new statutory declaration.

4.0 DECLINED APPLICATIONS

4.1 Explanation

Reasonable efforts will be made to explain in general terms why an application has been declined.

4.2 Remedial Advice

In some cases the panel may recommend that a declined applicant undertake particular further training, work under a mentor, or gain more experience before re-applying.

4.3 Re-application and Fee

Anyone may re-apply at any time and this will require payment of the full fee normally chargeable at the time of the re-application.

5.0 AUTHORISED PERSONS

The Oaths and Declarations Act 1957 provides that persons authorised to witness a statutory declaration include Members of Parliament, Justices of the Peace, Solicitors, Court Registrars or Deputy Registrars.

6.0 PROCESS

The panel will recommend to the Director of Planning and Environment whether an applicant is or is not regarded as being suitable for acceptance as a specialist adviser in geotechnical engineering and/or engineering geology and with or without restrictions or conditions, as appropriate.

The Director of Planning and Environment's decision shall be final.

7.0 LIABILITY

Accreditation by the Tauranga District Council does not provide for a transfer of liability from the accredited person to the Council or the panel.

SELECTIVE LISTINGS — IPENZ PERSPECTIVE

John P Blakeley
Deputy President IPENZ
Centre for Advanced Engineering, University of Canterbury, Christchurch, New Zealand

SYNOPSIS: Recent (1994) changes in the IPENZ rules to broaden its membership base and also to allow the establishment of Practice Colleges are reviewed. Possible future changes in the Engineers Registration Act are discussed and a proposal being developed by IPENZ for the use of Post-Nominals.

It is proposed that the New Zealand Geomechanics Society establish a Practice College for recognition of particular specialisation(s) of its members. How such a College might work in practice is then discussed.

1. INTRODUCTION

I am pleased to be able to participate in this Symposium. As Chairman of the Society, I presided over an earlier Symposium on "Tunnelling in New Zealand" held in Hamilton in 1977.

Some of the issues being discussed at the present Symposium have been around for a number of years. During my time as Chairman in the late 1970s, I recall considerable discussion on the issue of land stability certificates for subdivisional work which were being proposed by territorial local authorities and the important consideration of who should sign them. I also remember the issue being raised of the better recognition of the particular skills and experience of engineering geologists and whether this could be done by some sort of statutory recognition such as registration (similar to the Engineers Registration Act 1924).

The objective of this paper is to give an IPENZ perspective on the issue of recognition of particular qualifications and experience in geomechanics by means of some type of register.

2. RECENT CHANGES IN IPENZ RULES

Over the last few years considerable changes have been initiated within IPENZ with the objective of broadening and expanding the membership base.

These changes were canvassed in the "Pathways to the Future" document of IPENZ (1993) and reflected changes in the centre of activity of the Institution away from regionally based Branches and towards Technical Groups, within which most of the learned society activity of the Institution is now based.

The New Zealand Geomechanics Society which was founded in 1958 became the first Technical Group of the Institution in 1965. There are now 18 Technical Groups of IPENZ and discussions are ongoing with other groups wishing to join.

Until the rule changes were implemented in September 1994 following on from the "Pathways" document, many members of Technical Groups were not eligible to be members of the Institution itself. Two new grades were then introduced as follows.

Technical Membership is open to anyone with suitable experience and who holds a relevant tertiary qualification such as NZCE, or a science or technology degree not covered by other grades of membership.

Associate Membership is an interest-based type of membership which is open to anyone interested in becoming part of IPENZ but who would not qualify for other categories of membership.

It is hoped that many members of Technical Groups will take up the opportunity to join IPENZ through one of these two membership categories.

The same rule changes introduced the concept of Practice Colleges and this is discussed further under Section 5 below.

3. REGISTRATION OF ENGINEERS

Since 1924 professional engineers in New Zealand have had the privilege of statutory recognition through the Engineers Registration Act. A common professional interview procedure has enabled people with the required qualifications and experience to become Members of IPENZ or registered engineers, or both.

There has been considerable debate within IPENZ in recent years as to whether the Institution wished to continue with statutory recognition of engineers' registration or, if it was to be abandoned, IPENZ would prefer to take the initiative and set up its own register.

Although at IPENZ Council and (subsequently) Board level, views on this were rather mixed, it appeared that the membership at large quite strongly supported continuance of statutory recognition because this was seen as recognition by Government of the importance of tasks carried out by professional engineers.

Government views on this issue have also varied in recent years but it now seems clear that registration of professional engineers is to continue, especially in regard to matters concerning public health and safety and there is the opportunity of significantly upgrading the Engineers Registration Act in the near future.

At present, the Engineers Registration Act 1924 (and subsequent amendments) contains no requirements to:

- continue to practise in areas of claimed competence,
- undertake a specified amount of continuing professional development over a given period of time,
- adhere to a Code of Ethics

Also, there is no distinction as to the field of engineering the registrant is qualified in. It is possible to remain on the register without undertaking any continuing professional development or actively practising in a particular field and there are many retired people still on the register. Although the IPENZ Code of Ethics is printed on the back of the Annual Practising Certificate as a guide, there is no mandatory requirement to adhere to it.

This situation could make the engineering profession extremely vulnerable to criticism for failing to police its own standards if a major engineering incident was to occur which was attributable to professional incompetence.

4. PROPOSAL FOR THE USE OF POST-NOMINALS

At present, IPENZ is developing a proposal for an improved system of recognition of professional engineers (and technologists) in New Zealand which requires:

- continuing practice in professional engineering (or technology)
- self certification of an agreed minimum annual amount of continuing professional development
- adherence to the IPENZ Code of Ethics and (possibly)
- the maintenance of professional indemnity insurance, either directly or through one's employer.

The use of a post-nominal such as Pr.Eng. or Pr.Tech. will be the incentive to make an *annual commitment* to the above (at the time of renewal of the annual IPENZ subscription) and it is hoped that the post-nominal will also help to elevate and differentiate the image of professional engineering (and technology) in New Zealand.

The present proposal is for IPENZ to take the initiative of setting up a register of its own Members and Fellows who have given the required continuing commitment in order to use the post-nominals, but to leave the door open for a subsequent joint register to be established with the Engineers Registration Board which may have statutory recognition.

Such a joint register may also have to be open to other people who are not Members or Fellows of IPENZ but who must be able to demonstrate that they are qualified to be eligible for the equivalent membership grade in order to be on the register.

5. ESTABLISHMENT OF PRACTICE COLLEGES

As noted in Section 2 above, the IPENZ rule changes introduced in September 1994 made provision for the establishment of Practice Colleges.

Members would have to be prepared to comply with requirements established by the self-governing college such as continuing professional development, professional indemnity insurance, and possibly other practice review procedures.

The intention was that the Practice College concept was to be initially applicable to IPENZ Members and Fellows prepared to give the annual commitment described in Section 4 above. Ultimately this would be in order to maintain international recognition of IPENZ qualifications by overseas professional engineering institutions, which are themselves seeking to introduce a CPD requirement.

However this intention has now been replaced by the proposal for the use of Post-Nominals described in Section 4 above, leaving the way clear for the term Practice College to be applied to more specialist groups within IPENZ.

As noted in Section 3 above, the present Engineers Registration Act is very much for the recognition of generalists only and it is envisaged that any replacement legislation will still only be for generalists within the main broad fields of professional engineering, rather than any detailed specialist field of activity.

Two groups within the Institution who are at present indicating that they wish to have a specialisation recognised are:

(a) geotechnical engineers and engineering geologists, especially in the field of land stability certification

(b) fire engineers.

It is suggested that such groups can set up their own Practice College within the Institution and draw up their own rules for admission to that College, which may then become the requirement imposed by outside bodies (eg local government organisations), before people can undertake certain types of work. It would be up to each College to decide on its own CPD requirements.

6. OPERATION OF PRACTICE COLLEGES

If the New Zealand Geomechanics Society wishes to proceed with a system of recognising the appropriate level of specialisation to undertake specified geotechnical tasks, then I believe that establishment of a Practice College as provided for in the IPENZ rule changes of September 1994 is an appropriate method of doing this.

However there are serious legal considerations involved and it should be made very clear that any register established listing members of a Practice College is of people whose qualifications and level of appropriate experience have been closely assessed and who are also prepared to give a *regularly renewed commitment* covering continuing professional development, ethics, continuation of practice in the field and possibly professional indemnity insurance cover.

Being on the register should not be interpreted by outside bodies as certifying competence in a particular field.

My suggestions for further consideration by the Society as to how a Practice College would operate are:

(a) It should be under the overall control of the Society but at "arms length", with a management committee being either appointed or elected by the Society and accountable to both the Society and to the

IPENZ Board (since IPENZ is the parent body).

(b) It should establish its own annual fee for each person who is on the register of the members of the College.

(c) It should determine whether there should be just one overall register, or alternatively separate listings of particular specialisations.

(d) Admission to the College would be on the basis of peer review of qualifications and experience plus (possibly) an interview to clarify any uncertainties, *plus* a commitment given on annual renewal of membership covering the matters listed in the second paragraph of this Section.

(e) There may either be only one broadly representative admission panel or alternatively separate panels for particular specialisations within geomechanics (especially if the register is to list such specialisations).

(f) It should set its own admission and discipline standards but should keep both the Society and IPENZ (as the parent body) closely informed of these and being given the opportunity to comment on them.

(g) It should establish its own requirements for continuing professional development and may become involved in arranging courses for this, either on its own behalf of through the Society.

(h) All people listed on the register should be required to keep records of their continuing professional development undertaken each year, including documentary proof of attendance at courses which would be subject to audit, probably on a random basis.

7. CONCLUSION

I hope that the Society will now give serious consideration to the establishment of a Practice College. As the first Technical Group to be established within IPENZ in 1965, it would be entirely appropriate if the Society were to make this pioneering move which is now provided for under the rules of the Institution.

8. REFERENCE

IPENZ (1993). The Pathway to the Future. October 1993. 12 page brochure.