THE APPLICATION OF NATURAL HAZARD MAPPING BY TERRITORIAL REGULATORY AUTHORITIES

N C ELDRED
Woodward-Clyde (NZ) Ltd

SUMMARY

Natural hazard mapping is a commonly used method for defining land areas prone to processes such as slope instability and subsidence. Recent changes in New Zealand legislation require Regulatory Authorities to control the potential effects of natural hazards. Natural hazard mapping provides one method by which the Regulatory Authorities can meet their responsibilities.

This study developed a natural hazard classification system for Waitakere City, an area located to the west of Auckland City on the North Island of New Zealand. Waitakere City is characterized by a diverse topography and geology and has a history of natural hazard issues. Integral to the development of a natural hazard classification system for the Council was an assessment of how the system could be included as part of the proposed Waitakere City District Plan and assist in the control of natural hazards. A range of proposals were developed as part of the study for the inclusion of the hazard classification system in the Plan.

INTRODUCTION

Under the Resource Management Act (1991) [1] District Councils in New Zealand are required to control any potential effects of the use, development, or protection of land. Included in this is the avoidance or mitigation of natural hazards. This paper presents a case study of an investigation undertaken for Waitakere City Council, Auckland, New Zealand to assist the council in addressing these Resource Management Act requirements. This study proposed the use of hazard mapping as one available tool for regulatory control of land. The Council requested that the study consider both the development of a hazard classification system and ways of applying the system to regulate land use.

Waitakere City forms the western part of the Auckland area and has a diverse topography and geology, including both inland and coastal environments. This has frequently created a range of inland and, in particular, coastal stability issues in relation to the development of land. Continued expansion of the City is also resulting in the development of generally more geotechnically challenging areas.

In the past natural hazard issues have had an uneven treatment in the City with an ad hoc approach to the definition of areas potentially prone to hazards. In addition, the enforcement of these issues has lead to what has been perceived to be unreasonable demands on developers and builders with no apparent sound justification for requirements, such as detailed geotechnical investigations. Therefore, technically robust and cost effective District Plan provisions, using suitable implementation techniques, were required. The study addressed these issues by providing a technically sound classification system for identifying natural hazards within Waitakere City. The developed classification system was then applied to produce a series of hazard maps to assist the Council in performing its regulatory responsibilities.

STATUTORY RESPONSIBILITIES

The Council has a number of responsibilities under the Resource Management Act 1991 [1], the Building Act 1991 [2]and other legislation for avoiding or mitigating natural hazards. Hazards include erosion, slippage, subsidence and coastal flooding.

Under the Resource Management Act (the Act), the Council has as one of its functions the requirement to control 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. Furthermore, under the Act, the Council cannot grant a subdivision consent if it considers that any land in respect of which the consent is sought is likely to be subject to damage by natural hazards or, if any subsequent use that is likely to be made of the land is likely to accelerate, worsen or result in material damage to the land or other land by natural hazards.

Under the Building Act, the Council shall refuse to grant a building consent if the land upon which the building is to be located is subject to, or likely to be subject to, natural hazards as defined above. In addition, the Council shall also refuse to grant a consent if the building work is likely to accelerate, worsen or result in natural hazard impacts.

For both the Resource Management Act and the Building Act the onus is on the applicant to satisfy the Council that the effects of natural hazards can be avoided, remedied or mitigated.

It can be seen that the maintenance of a suitable database of information on natural hazards is critical to the implementation of the Councils functions under these various legislative requirements. In addition, any database must be technically robust and the Council must be able to demonstrate that the information was collected using sound, technically defensible methods. Waitakere City Council proposed an approach where a natural hazard database would not form part of the District Plan but will be referred to in the Plan. This will allow the database to be updated and refined as additional data becomes available.

NATURAL HAZARDS AND THEIR CONTROLLING FACTORS IN THE WAITAKERE CITY AREA

Topography and Geology

Waitakere City is characterized by its diverse topography. The study area is shown on Figure 1. The east, north east and south east sections of the city border the upper reaches of the Waitemata Harbour and the Manukau Harbour and typically consist of a subdued gentle topography crossed by a series of streams. Much of the existing urban area of Waitakere City is located in these areas. Towards the west, the landscape rises to the Waitakere Ranges, a series of rugged hills which occupy much of the western part of the city. Much of the recent and proposed development is along the foothills of these ranges. The main body of the Waitakere ranges predominantly fall within the Auckland Centennial Park and were not considered in this study as they are not available for development.

Waitakere City is bordered to the west by the Tasman Sea, the Manukau Harbour to the south and the upper reaches of the Waitemata Harbour to the east and north east. The coastal environment varies from steep, high rugged cliffs with low angle beaches along the west cost and a mixture of steep cliffs, low angle estuaries, faceted lowlands and low angle beaches along the harbour coastlines.

Much of the low lying eastern and north eastern parts of the city, adjacent to the Waitemata Harbour, are underlain by sediments of the Tauranga Group consisting of interbedded muds, sands and gravels with some beds of peats and lignites. Rock of the Waitemata Group underlie the low lying eastern and north eastern parts of the city and also much of the foothills of the Waitakere Ranges. These rocks are mantled in part by the Tauranga Group sediments in low lying areas. The Waitemata Group rocks consist of alternating sandstones, muddy sandstones and mudstones with occasional grit beds. The upland Waitakere Ranges are predominantly underlain by volcanoclastic sandstones of the Waitakere Group. Within the City, a number of areas of unsupervised fill are also known to exist consisting of either a mixture of reworked materials or refuse.

Controlling Factors

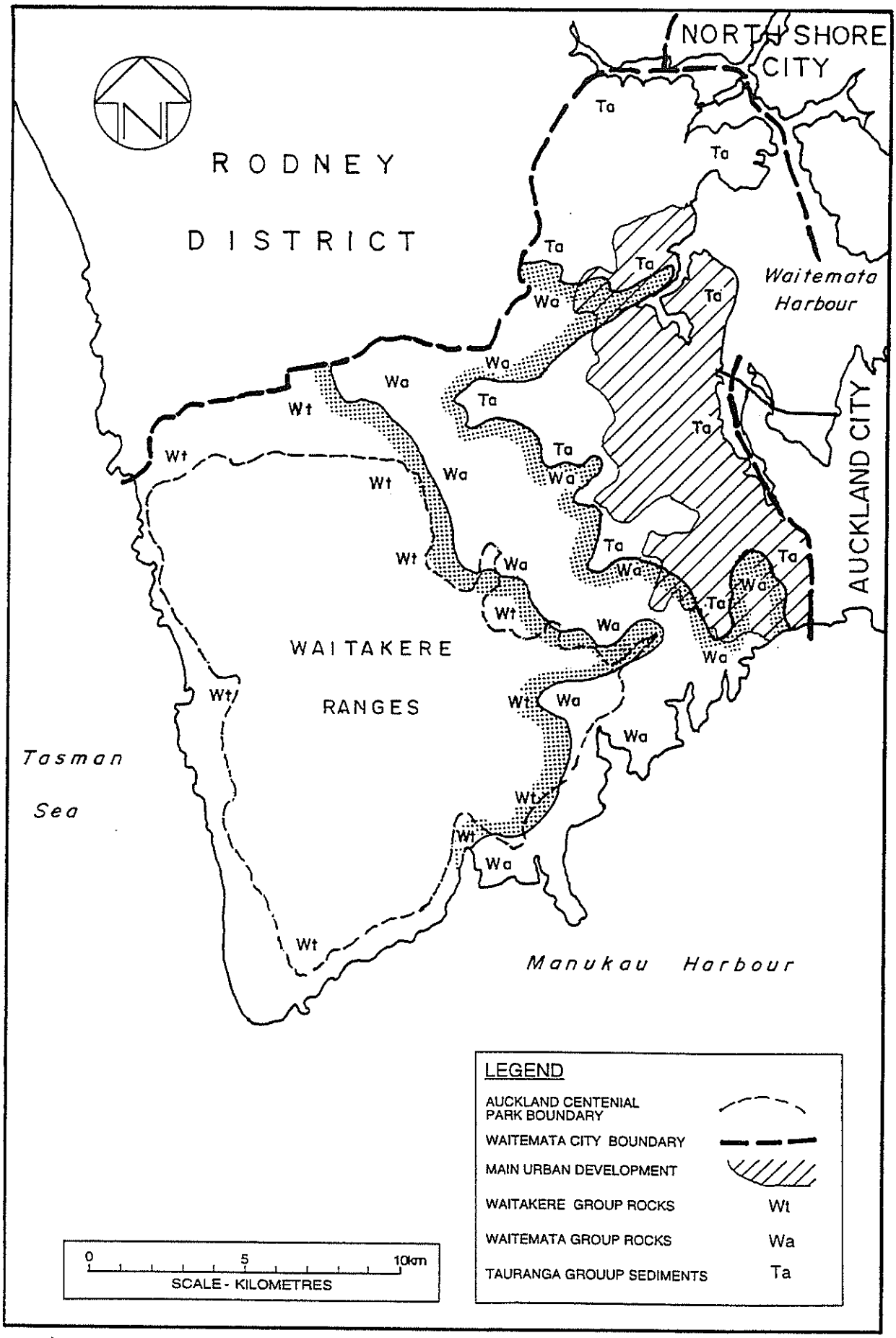
In developing a classification system for natural hazards within the City, the first step was the identification of the nature and significance of hazards along with their controlling factors. Natural hazards were considered under two headings:

Inland Hazards

Areas susceptible to **erosion, slope instability** or **subsidence**

Coastal Hazards

Areas susceptible to **erosion, slope instability** and **inundation**



Physical and Geological Plan of Waitakere City Figure 1

Inland areas susceptible to flooding were specifically excluded at the request of the Council. Seismic hazards were also not considered as part of this study.

For each of these hazards, the factors which predispose the susceptibility of a given area were defined. For example, the susceptibility of land to **slope instability** is dependent on a number of factors. These include, but are not limited to:

Slope angle; geology; groundwater; landform; and process (both natural and human).

The characteristics of the geological materials within the Waitakere City area are a key factor in the predisposition of natural hazards. Weathering of the Waitemata and Waitakere Group rocks results in a loss of structural integrity and a significant drop in strength. Slope failures associated with weathered materials are well documented throughout the Auckland region. These are typically characterized by a shallow failure plane along the boundary between highly and moderately weathered material, although deep seated failure can and do occur. The Tauranga Group sediments are often indistinguishable from completely weathered Waitemata and Waitakere Group rocks and display similar failure forms, although their generally greater thickness can result in deeper seated failures. The Tauranga Group may also be susceptible to **subsidence** where organic clays and peat units occur. Other areas susceptible to **subsidence** include zones of unsupervised fill.

Another significant attribute of the Waitemata group rocks is their behavior at the coastal margin. The Waitemata rocks appear from beneath a mantle of Tauranga Group rocks along much of the Waitemata Harbour and Manukau Harbour coastlines. While these rocks are typically competent in the unweathered state, exposure and weathering at the coastal margin results in a significant loss of strength and integrity, particularly within the more clay rich units. Relatively low energy wave and current action may result in **erosion** of material. Coastal **erosion** is of particular concern around the densely populated Waitemata and Manukau Harbours where land **erosion** rates can be as high as 1 m / 5 years.

ESTABLISHMENT OF A CLASSIFICATION SYSTEM

Based on the natural hazards identified for the Waitakere City area, the following Classification System was developed for the City. The system follows a similar methodology to classification schemes developed for other areas of New Zealand and abroad.

Four categories (Categories 1 to 3 and I) have been defined for classifying both inland and coastal hazards.

Category 1 : Potential Hazards

Areas where factors indicate a susceptibility to **instability, erosion** or **subsidence** but do not show evidence of relic or active hazards.

Category 2 : Active Hazards

Areas which either:

- display evidence of **instability, subsidence** or **erosion** events, either recent or historic, and have been identified either during development or on an "undisturbed site"; or
- existing detailed engineering reports for sites within the area have identified stability issues which have required, or will require, special measures for their development such as bulk earthworks, retaining structures and drainage

Category 3 : Continuously Active Hazards

Areas which display on-going **instability, subsidence** or **erosion** problems and require a proactive approach to development or on going mitigation of hazards.

Category I : Potential Inundation

Areas where factors provide a susceptibility to coastal **inundation** or where coastal **inundation** events are known to have occurred.

Within each category the type of hazard has been broadly defined as either slope failure (inland), **subsidence** hazard (inland), cliff failure/**erosion** hazard (coastal), beach or coastal margin **erosion** hazard or sand dune migration/**erosion** hazard. Coastal **inundation** was considered under a separate category (Category I) as it represents a somewhat different form of hazard.

It should be noted that areas of Waitakere City which do not fall within one of the above categories are not necessarily stable or free from the potential for hazards. They may simply represent zones where the methodology used in this study to apply the Classification system has not identified either existing hazards or factors which predispose potential hazards.

APPLICATION OF THE CLASSIFICATION SYSTEM

A section of the Waitakere hazard map prepared during this study is shown in Figure 2. The Council had a restricted budget available for the production of these maps. Therefore, this necessitated a desk top approach to application of the classification system with limited resources available for field visits. It was recognized by the council that these plans represent an initial classification of the City. It is envisaged that as further data is collected over time, these plans will be added to and amended as appropriate. The methodology used to develop these maps is presented below:

Category 1

Different methods were used to define the range of natural hazards for Category 1.

Inland **Instability**

Of the range of controlling factors for inland **instability**, slope angle is considered to be critical and a parameter that can be readily defined from a desk top investigation. **Instability** features are generally associated with weaker materials within the Waitakere City area, either residual weathered material or more recent deposits, that cover nearly all the land surface area. All these materials display a generally similar range of characteristics with regard to **slope instability**. Variations that do occur would generally result from changes in critical slope angle with respect to **instability** of one or two degrees. It was not considered practical to vary the selected critical slope angle given the subtle changes in geology and geotechnical characteristics and the scale of topographic maps available for the area. Therefore, a conservative slope angle of 7 degrees was selected as an angle below which **instability** features have not generally been identified in any of the materials present within the Waitakere City area.

Category 1 zones were defined based on the topographic plans available for the City, namely the 1:50,000 and 1:25,000 topographical plots produced by Department Of Survey and Land Information (DOSLI). It was recognized that the scale of these plans is such that small areas with slope angles in excess of 7 degrees may occur outside categorized zones but may not be shown due to the map scale.

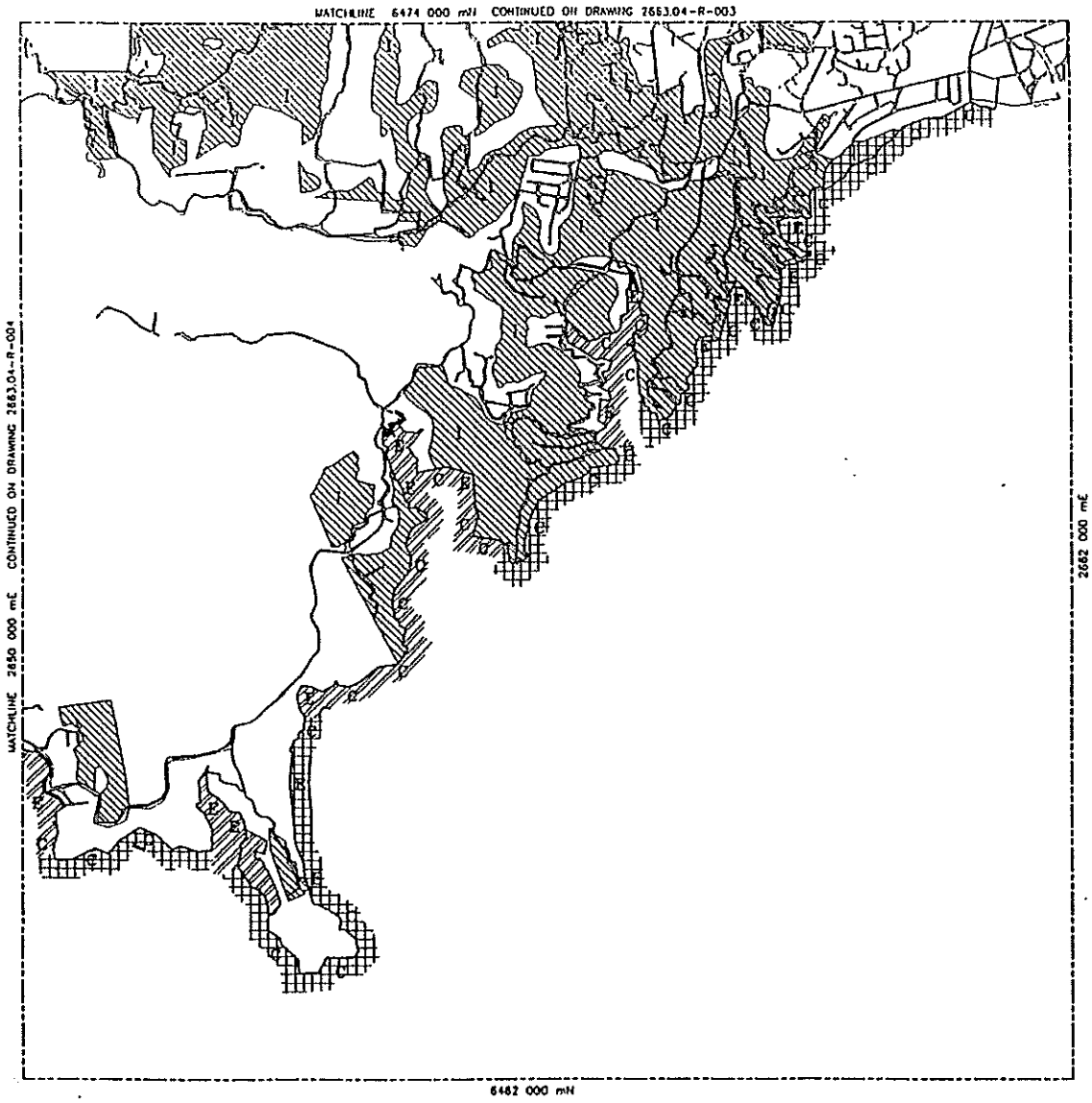
An example of this is small water courses that cross otherwise relatively level sites. The combination of steep slopes immediately adjacent to water courses and the **erosion** activity of the water course could present potential problems for development immediately adjacent to channels. It was recognized that such features are of special consideration and should be classified as either Category 1 or 2 zones. Conversely, small areas of level ground may also fall within zones categorized as potentially unstable. These issues are addressed later in this paper.

Inland **Subsidence**

Areas potentially susceptible to **subsidence** were defined based on: geological maps and records of unsupervised fill; anecdotal records from senior engineering office's for Waitakere City and other experience in the area. By its very nature, materials susceptible to **subsidence** are often difficult to identify without detailed investigation and a relatively conservative approach was adopted to define these areas.

Coastal **Instability** and **Erosion**

All areas of the coast which fall outside Category 2 and 3 zones were considered to be inherently within Category 1 . Based on the processes operating at the coast and the geological materials present, it was established that **erosion** and **instability** could potentially occur, or be induced to occur, anywhere along the coast.



NOTES:

1 TO BE READ IN CONJUNCTION WITH DRAWINGS 2663.04-R-001, 002, 003, 004

KEY:

CATEGORY: 1	- POTENTIAL HAZARDS
CATEGORY: 2	- ACTIVE HAZARDS
CATEGORY: 3	- CONTINUOUSLY ACTIVE HAZARDS
CATEGORY: I	- POTENTIAL INUNDATION
I	- SLOPE INSTABILITY
SF	- SUBSIDENCE (FILL)
SP	- SUBSIDENCE (PEAT)
D	- DUNE MIGRATION/EROSION
C	- CLIFF INSTABILITY/EROSION
E	- BEACH/COASTAL MARGIN EROSION

MAP ACCURACY ± 100m

Example of Natural Hazards Classification

Figure 2

Category 2 and 3 - All Hazards

Category 2 and 3 were defined on the basis of the following data for both coastal and inland hazards: 1:25,000 stereo aerial photographs and 1:10,000 vertical aerial photographs; 1:250,000 and 1:50,000 geological maps; anecdotal information from Council offices; experience within the area; Geotechnical Reports for the area; and limited field visits to selected sites.

Category I - Potential For **Inundation**

Category I was defined on the basis of the following data: coastal elevation; slope angle of coastal margin; and likely maximum storm surge events; and tsunami events.

APPLICATION OF THE HAZARD CATEGORIZATION SCHEME

Hazard mapping has been used extensively throughout New Zealand and abroad for categorizing land for a wide range of purposes. However, the practical application of these schemes under various regulatory methods has been sporadic and somewhat ad hoc. The second part of the brief from Waitakere City Council was the development of methodologies which enable the City Council to regulate land use activities in relation to natural hazards. With respect to the natural hazard classification system developed for Waitakere City Council as part of this study, the following is one possible method for controlling the effects of development in relation to hazards.

With regard to the subdivision consent process, District Pan rules could require differing levels of geotechnical investigation (e.g. to establish safe and stable building platforms) and engineering design. The methods would depend upon the zoning of land being subdivided and its categorization under the hazard system outlined above.

With regard to building consent applications, the subdivision consent process may already have identified suitable building sites during subdivision. However, in previously developed areas, circumstances may arise where land is redeveloped in such a way that could contribute to and/or be affected by a particular hazard. In these circumstances, use should be made of the classification system and associated geotechnical investigation and design measures outlined below if no site specific geotechnical report is available for the original subdivision.

Rural Zones

In some circumstances only parts of a given land parcel may fall within one of the identified hazard category areas. If it can be demonstrated that the proposed building development is outside of the categorized area, no specific geotechnical investigation should be required under this scheme. However, if the proposed development falls within one of the hazard category zones, the proposed investigation and design criteria outlined below should be followed.

Urban Zones

Where a subdivision is proposed, a geotechnical investigation of some form will be required to determine the location of suitable building sites on each lot. Where a proposed subdivision falls wholly or partly within one or more of the identified hazard zones, the investigation and design criteria outlined below should be followed.

Category 1 Areas - Where land is identified as being prone to **Instability** (either coastal or inland) it may be possible to identify building platforms that meet the following criteria within the Category 1 areas: slope angles less than 7 degrees; the site is outside the coastal environment; and the site is not crossed by, or immediately adjacent to a stream or river channel where steep and potentially unstable banks and/or bank **erosion** occur.

In these circumstances geotechnical investigations could require, as a minimum, a walkover survey to confirm that building platforms meeting these criteria were available. However, where building sites: are proposed in **instability** areas that do not meet these criteria; are within the Coastal Margin; or are in areas that have been identified as potentially prone to **subsidence**, a more thorough geotechnical investigation would be required which specifically addresses these hazards to the satisfaction of the Council It should be noted that these are minimum requirements. Any subdivision will require some form of geotechnical investigation.

Category 2 Areas - In general, development within Category 2 areas should require a detailed geotechnical investigation that addresses the specific hazard(s) identified. It is envisaged that the design of the development would include measures to mitigate potential hazard issues.

Category 3 Areas - Category 3 areas are generally confined to the coastal margin. It is envisaged that development would be either discouraged in these areas or very carefully controlled. Furthermore, a proactive approach may be required in some areas to mitigate the effects of hazards on existing development.

Category I Areas - It is envisaged that development within areas of the coastal environment designated as potentially prone to **inundation** would be discouraged. Where development is proposed, any engineering investigation and design should incorporate measures to mitigate potential **inundation** effects.

OTHER REGULATORY METHODS

Other regulatory methods available for controlling or mitigating natural hazards based on the hazard classification system include:

- District Plan rules or bylaws could set minimum floor levels for new residential development in areas subject to flooding and a "coastal protection yard" in coastal areas in general .

- District Plan rules could require a land consent for certain activities, the effects of which have the potential to contribute to natural hazards. For example, vegetation clearance, and earthworks that exceed a specified volume. Such rules could be targeted at areas identified as being affected or potentially affected by particular natural hazards and the Council could grant consents if satisfied that adverse effects would be controlled.

- Undeveloped coastal and inland areas identified as being affected by significant natural hazards could be zoned "rural" or "open space" rather than for future urban development.

- In areas of existing urban development identified as being affected by significant natural hazards District Plan rules could limit the density of development. For example, higher density infill housing may have a greater potential to contribute to and/or be affected by hazards such as slippage or coastal flooding.

- District Plan provisions for the creation of esplanade reserves and esplanade strips can be used to mitigate natural hazards at the coastline. For example, the legal instrument creating an esplanade strip can prohibit the willful damage or removal of any plant from the strip and control public access over the strip (including the use of recreational vehicles). Such controls can be used to mitigate coastal **erosion**.

ADVANTAGES AND DISADVANTAGES

The development of hazard classification schemes and their application under appropriate regulatory methods can ensure that the adverse effects of certain activities in terms of natural hazards are adequately controlled. This may not otherwise occur if, for example, the avoidance or mitigation of natural hazards was solely reliant upon the provisions of information and public education.

However, the disadvantages of a regulatory approach is that perceived private property rights may be curtailed, with limitations placed on the ability of landowners to make their own choices about the use of their land. Categorization of property may also impact upon property values Furthermore, the cost of making a land use consent application to the Council for a particular activity can be high. In addition, the method relies upon adequate and accurate information so that controls target only areas of concern, a particularly difficult requirement when dealing with natural hazard identification without spending comparatively large sums of money.

CONCLUSIONS

This approach to the application of hazard mapping systems provides a useful tool to assist the Territorial Regulatory Authorities in meeting their requirements under various legislation. Furthermore, the location of the

hazard database outside the District Plan allows the data to be updated as and when further information becomes available.

REFERENCES

1 The Resource Management Act (1991), New Zealand

2 The Building Act (1991), New Zealand