EARTHQUAKE FAULT MOVEMENT AND TOWN PLANNING

by

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SYNOPSIS

This paper is an edited version of a submission made to the Lower Hutt City Council Town Planning Hearings Committee in August 1986. The submission was made in support of an objection by the Lower Hutt City Council to a proposed ordinance which prohibited building adjacent to the section of the Wellington fault in Lower Hutt City.

The inadequacies of the proposed ordinance are examined and the issues analysed with particular reference to the protection of life and property, and the risks involved.

Earthquake risks are further analysed and the risk of damage due to shaking compared with those due to fault movement. Comparisons of earthquake risk with other risks accepted by the community are made.

The conclusion drawn is that the additional risk of earthquake damage in a potential fault zone is sufficient to warrant constraints to development, but not so large, in the context of overall risks, to justify prohibition of all development in a fault zone.

Comment and recommendation is made as to appropriate constraints to building development in such zones.

INTRODUCTION

From time to time Local Authorities, Town Planning Committees and judicial courts are put in a position of having to resolve particular issues related to the risk of proceeding with building development adjacent to a known active earthquake fault.

It is hoped that the publication of this successful submission will assist these bodies in their task, or at least provide their expert advisors a basis for dealing with future instances of this kind. Perhaps it will motivate the publication of other submissions, or better still, the publication of a more general and widely researched paper on the subject.

BACKGROUND

The Clause prohibiting building adjacent to the Wellington fault was first introduced into the District Scheme in July 1984. The fault position is shown on the District Scheme maps and passes through a number of existing residential and commercial properties. Many objections to the proposed clause were from owners of existing developments who were concerned at the seemingly unnecessary restrictions it placed on them and the reduction in property values which would result from its enforcement.

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In fact, a number of developers had successfully applied for a specified departure, effectively by-passing the requirements of the Clause.

The Town Planning Hearings Committee upheld the objection on 1 August 1986 and a revised Clause (proposed by Lower Hutt City Council) was confirmed by Council on 25 August 1986.

The revised Clause imposed constraints on development, leaving the onus on Council and its officers to develop procedures and regulations to give practical effect to the constraints.

The following is the edited text of the Lower Hutt City Council's Submission prepared on their behalf by the author.

PROPOSED ORDINANCE CLAUSE

Ordinance II Section 3 Clause (f) by the Lower Hutt District Scheme Review No. 2 reads as follows:

> "Buildings on or adjacent to fault line:
>
> No building may be erected within 20m of each side of the fault line the location of which is shown in Appendix I to these Ordinance and also on District Planning Maps Nos.

5 and 6. Where sufficient data is available to determine the exact location of the fault line, a report will be required from a person qualified in Engineering Geology, before any approval will be considered."

This clause as it stands:

- is proper insofar as it discourages development in the immediate proximity of the earthquake fault.
- is unnecessarily restrictive in prohibiting development of any kind adjacent to a known earthquake fault.
- appears to be unrealistic in view of existing developments in the prohibited zone including major arterial roads.
- has been bypassed by successful specified departure applications. These have proved time-consuming and costly to deal with.

ANALYSIS OF ISSUES

1. Fault Movement

It is apparent from geological investigations and research that the movement of the faults in the Lower Hutt region is not expected to be at a constant rate, but rather in a series of singular events involving large relative displacements both horizontally and vertically. It has been estimated that the zone of disruption of the ground would extend 20 metres either side of the fault. It has further been estimated that such singular events would occur on average once every 400 - 800 years. This represents the risk of movement at some place(s) along one fault, but not necessarily along its whole length.

2. Building Development in Fault Zone

The land in the immediate vicinity of a known earthquake fault would not normally be the first choice for a site for building development since this involved an additional earthquake risk when compared with other sites. However, as a result of the general growth of urban areas, pressures to develop such land do exist. If the amount of additional risk is not great in relation to others accepted by the community it would appear appropriate to accept development of the land provided that suitable constraints as to its type and nature are prescribed.

3. Constraints on Development

(a) Protection of Property

It would be difficult to design a building to remain functional when subject to relative movements of the order of 2 to 3 metres. It would be reasonable to assume that any part of a building within that zone would be a write-off functionally following such an event at that location.

To the extent that damage to property is an owner's risk, he or she should be allowed to assess such risks and decide accordingly on the basis of available advice. An owner may wish to balance the risks of building in an earthquake fault zone with the costs of moving elsewhere or of safeguarding his/her investment by appropriate (additional) design measures.

When damage to that owner's property will add to the risk of damage to the property of others, some constraints on the size and nature of developments in these zones can be expected in the interests of owners of adjoining land.

(b) Protection of Life

The risk to life involved in a building development in an earthquake fault zone, implies a wide responsibility to those in the community. Not all people who live and work in such a building development can be expected to be aware of the additional risks they face. Again it would not be unreasonable to impose constraints and require an owner to take appropriate steps to safeguard lives of those likely to be in and around the building.

(c) Techniques of Structural Design

While it may not be possible to prevent functional write-off of the building, design and construction techniques currently available do permit realistic special measures to safeguard lives and property. Such measures can be directed at improving the integrity of the building structure under the action of large ground movements. The extent of the measures will vary with building type, size, occupancy and usage.

(d) Balance of Risks

Any constraints imposed on owners whether in relation to protection of property or the safeguarding of lives need to be in balance with other risks of a similar nature.

EARTHQUAKE AND OTHER RISKS

For the purposes of this submission the earthquake risks can be divided into those due to ground shaking and those due to fault movement.

The risk of earthquake ground shaking is present in any locality in the region whether adjacent to the fault line or not. Provisions to deal with this risk are implicit in current building codes. It is important to realise that such code provisions are not a guarantee that no damage to property (or to life) will occur in the event of a major earthquake. Thus there is a risk involved and attempts have been made to quantify the risks to property from ground shaking in the Wellington region. A more detailed analysis of this risk is described in Appendix 1 of this submission.

The risk of damage through major fault movement is to a large degree additional to the risk of ground shaking and applies only to those building developments in the immediate vicinity of a fault displacement. If it is assumed that the building will be functionally a write-off in the event of such displacement and that such events occur once in every 400 - 800 years, then the average annual risk would be 0.25% to .13% of the value of the property per annum.

This compares with a computed average annual risk for buildings subject to ground shaking (refer Appendix 1) of 0.4% for modern reinforced concrete buildings, and 0.6% for timber dwellings. It can be seen that the additional risk represented by fault displacement is significant but not of a different order to that represented by ground shaking.

Property risks can be computed as a percentage of the value of the development per annum. Life risks are more difficult to assess, but some insight into earthquake risks to life is available from statistical records. Assessments have been made of the likely risk to life represented by buildings designed to our current codes,(1) although these have been very approximate with a wide range of possible answers. In order to put the earthquake risk in context it is helpful to refer to Table 1.

TABLE 1 : COMPARISON OF ACCIDENT STATISTICS

STATISTICS - ACCIDENTS EXTERNAL CAUSES - "INVOLUNTARY"

Activity	Deaths/yr for 3 million population
Earthquake (NZ) (average for period 1843 - 1983)	4 to 5
Earthquake (NZ) estimated for modern buildings	2 to 10
Earthquake (California)	6
Lightning (UK)	3
Aircraft Accident (USA)	0.3
Tornadoes (USA)	6

NEW ZEALAND STATISTICS - ACCIDENTS EXTERNAL CAUSES - "VOLUNTARY"

Category	Deaths/yr for 3 million population
Motor vehicle and transport	750
Poisoning	30
Falls	345
Machinery	18
Homicide	48
Drowning	126
Firearms	18
Fire	45

This table separates risks into "Involunary" and "Voluntary". Involuntary risks are those to which people are subject without having any reasonable control over them. Volunary risks are those over which people have some control. The Table has been presented to compare the deaths per annum on the basis of a three million population. This affords comparison with published statistics of deaths by accidents such as car accidents, drowning and fire in New Zealand. It can be seen that there is a wide difference between the numbers for voluntary and involuntary risks. Of relevance to this submission, however, is the level of earthquake risk compared with those of other involunary risks. It may be seen that the earthquake risk to life is not negligible in relation to other risks, nor is it disproportionately high.

The level of additional risk from fault movement has been shown to be within the same order as that due to shaking. It is reasonable to conclude that such an increase would not take the assessed risks beyond acceptable limits, particularly if constraints on the type of development were to be imposed.

CONCLUSION

Certain types of development in the immediate vicinity of earthquake faults of the type at Lower Hutt should not be encouraged but development need not be totally prohibited.

It would be reasonable to prescribe limits within which development can take place, and this is the basis of the City Council's Objection to the present Clause 3(f), and is the main thrust of their proposed amendment.* Restrictions are proposed on the types of developments in a way which, allows Council to withhold approval if it is not satisfied with the proposed measured to deal with the additional risk.

The Council plans to implement procedural steps as to a pre-requisite to granting a building permit. These procedures will call for special measures to be taken in the design of the building to improve integrity in resisting severe ground movement, with the objective of reducing the risk to life, and if applicable, third party property. The procedures will also prohibit the construction of buildings of high value or risk to the community.

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* The revised Clause 3(f) accepted by the Town Planning Hearings Committee read as follows:

Building on or adjacent to fault line:

Notwithstanding any other provision of these Ordinances, where any building or structure (other than minor additions or alterations to buildings or structures not intended to be used for living accommodation or commercial or industrial purposes) is proposed in the vicinity of the fault line, Council may require that any proposed use in the vicinity of the fault line shall take cognizance of its presence and Council may withold approval if it is not satisfied that reasonable provisions are made for the added risk.

These procedures, when coupled with the recognition by owners of the additional risks (or the additional costs of safeguards) will, in my opinion, provide an effective means of controlling the overall risk to the community while not preventing limited development of the land immediately adjacent to the fault line.

ACKNOWLEDGEMENT

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REFERENCES

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2. Smith, W.D., Berryman, K.R., "Revised Estimates of Earthquake Hazard in New Zealand" - Bulletin of the New Zealand National Society for Earthquake Engineering, Vol.16, No.4, December 1983.

3. Birss, G.R., "Methodology for Assessment of the Damage Cost Resulting from a Large Earthquake in the Vicinity of Wellington" - Bulletin of the New Zealand National Society for Earthquake Engineering, Vol.18, No.3, September 1985.

4. Brown, L.J., "Geological Comment for the Lower Hutt City District Scheme Review" - NZ Geological Survey, September 1982.

APPENDIX 1

COMPARISON OF EARTHQUAKE RISKS DUE TO SHAKING AND FAULT MOVEMENT

On the basis of recent studies, (Refs. 2 and 3) it is possible to gain an appreciation of the risks to property represented by earthquakes.

The purpose of this Appendix is to compare the risks due to earthquake ground shaking (applicable to all buildings) with that due to both ground shaking and major fault movement (applicable to buildings in the fault zone).

This comparison is made by computing the annual average damage to property for each situation. The following data and assumptions are used:

- The Annual probability of ground shaking (MM levels) was taken from Reference 2.

- Damage intensity relationships for ground shaking were taken from Reference 3, reproduced as Figure 1. Only timber dwellings and modern reinforced concrete buildings are included in the comparisons.

- Two damage intensity relationships for ground shaking plus fault movement were used. These are marked A and B on Figure 1. Relationship A assumes that the property will be totally written off along the entire fault zone for earthquakes of MM IX or greater. Relationship B is based on the more realistic assumption that total write off will not occur until after MM X. Assumption A implies fault movement once every 200 to 300 years. Assumption B once every 500 to 600 years. This compares with the assessed probability from geological evidence of once every 400 to 800 years.

Computation of the Annual probable average damages are shown in Table A1.

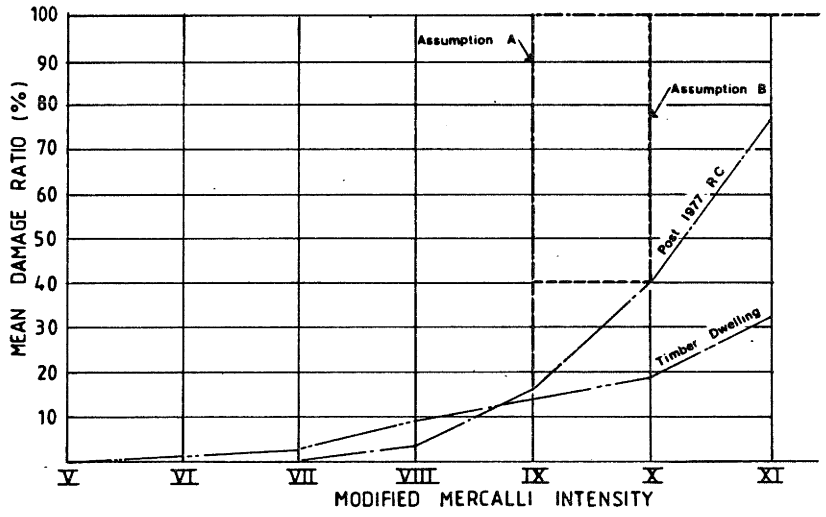

FIG. 1 - DAMAGE INTENSITY RELATIONSHIPS

TABLE A1 - COMPUTATION OF DAMAGE RISK

EQ Intensity	Annual Prob Wellington	Annual Prob of EQ in Range	Timber Buildings			Modern RC Buildings		
			Shaking Damage Ratios	Shaking plus Fault Damage Ratios		Shaking Damage Ratios	Shaking plus Fault Damage Ratios	
				Assumption A	Assumption B		Assumption A	Assumption B
V	0.80	0.60	0	0	0	0	0	0
VI	0.20	0.147	.015	.015	.015	.002	.005	.005
VII	0.053	0.038	.06	.06	.06	.025	.04	.04
VIII	0.015	0.101	.115	.115	.115	.10	.15	.15
IX	0.005	0.004	.15	1.0	.40	.40	1.0	.40
X	0.001	0.001	.24	1.0	1.0	.60	1.0	1.0
XI	0.0001							
CUMULATIVE ANNUAL RISK =			.006	.010	.008	.004	.007	.005
Increase due to Fault Damage %				66%	33%		75%	25%