SEI.FOR.0001.SUB.1

~~~~SUBMISSION TO THE ROYAL COMMISSION; SEISMIC HEARING 2011~~~~

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Introduction briefly outlining the matters we will address re Quake*

This submission alleges that a lack of due diligence significantly increased the final death toll in. Hazard priorities were based on the idea prior seismicity related to the Alpine fault, and building codes were progressively loosened to make development of high rises cheaper due to a relative period of quiet in the last 40 years. We question the Tonkin Taylor reports assertion of a 700 year return period for major local activity, given the likelihood of a blind fault in the CBD (arguably not part of Greendale system), and the Cathedral spire hitting the pavement 3 x in a 120 year period.

This is quite likely related to a local blind fault not to the Alpine one, and the return period could as well be 150 years. Indeed many such factors may alter the perceived consequence and severity of the hazard. Government's failure to fund long sought critical studies in time and to institute safeguards raised the toll. Even models of wave amplification in sedimentary basins Taipei, Rome and "poor" Mexico City near volcanic rock exist (reference 2). A dangerous **fault lying under downtown CHCH, probably passing under Woolston/Sydenham** per the Geologist grapevine, is concerning. Is the red zone big enough?

- Inadequate quake risk assessment by Environment Canterbury post 2004 and post September 2010 thwarted local authorities abilities to meet legal responsibilities; to "identify, assess and to mitigate the effects of natural hazards". (Resource Management Act 1991 and the Civil Defense Emergency Management Act 2002).

- There was a consequential failure to offer Emergency Response Workers, Councils, and the Public sufficiently detailed hazard info and probabilistic risk forecasts, resulting in a lack of preparedness for the February Quake. Proper risk assessment would have shown potential for high Peak Ground Accelerations and shaking on the Mercalli scale in the red zone taking more buildings past tolerances. During a 40 second shake in Sept, the 12 seconds in Feb & the June EQ there was a high PGA (Peak Ground Acceleration).

- Avoidance by CERA and Central Government of critical studies to protect public safety eg by a failure to provide blind fault mapping when essential funding was applied for post September 2010, and even to fund this after Boxing Day's swarm of 32 shallow excessively harmful aftershocks, many centered directly under the city.

  In contrast, there is extensive support of studies important to property investment confidence (ie liquefaction), just not one's securing public safety per se.
  For example, the Tonkin Taylor report on ground conditions after Sept. 22nd was under-informed re blind faults, wrongly focused, and bunkum eg it said that the MM8 shaking after the Darfield Quake was a once in 700 yr event & faded to insignificance against geological risks faced elsewhere eg due to landslides affecting hill dwellings from rain in Northland under short return periods.

  Neglecting appropriate geo studies in time may keep cities attractive for investment, but it surely results in under warning, relative to science based OECD countries.

- Recommendations on building codes and land use in the City are premature until more detailed ground class maps are made citywide, which cannot occur until the natural hazards research platform, reports back on the possibility of a fault running under Christchurch Central.

  A study re this was funded belatedly by the Ministry of Science after February although it was requested after September 2010, and although such studies should have been part of a National research program already.

If the CBD is confirmed over or near a fault (a crossing one is suspected) a fault avoidance zone must be mapped, prior to any development recommendations being made. The Commission should also seek info about the strong possibility of seismic lensing intensifying City Quakes in light of the basalt in the Port Hills. ECan denies having such info or that it is accessible, however our Geologist says it is via a study. It matters for the future and ? to help explain CTV deaths.

ECan should of course be required to incorporate all new info into the "trialed but unused" Riskscape Model to produce risk assessments for possible quake/fire scenarios.

- In summary, inappropriate use of some buildings and streets post September 2010 was a result of poor hazard assessment by ECan, because important studies they had sought timely funding for (that experts had stressed a need for since 2004) weren't consented in time by a blasé Government (refer prior points 3 and 4). If done they would have had major implications re precautions taken eg more lockouts or shop frontage securing (San Fran style). For preparedness potential for ground motion in area micro-zones needs modeling.

- Under stronger legislation like the American framework combined with local Acts like the EQ Fault zoning act 1972 in California, Governments show interest in geology risk & developers and citizens receive more realistic probabilities and harm scenarios eg San Francisco has a 62% odds for quakes of 6.7 or more by 2032. Honesty drives good prep. Inappropriate development everywhere (Tonkin/Taylor) should not continue to be let slide.

- We should re-legislate to require seismic risk micro-zone mapping in population centres, said zoning to be recorded on the Land Information Report + building consents. And for accurate probability forecasts, not data deficient ones that produce a rose tinted view… LIKE ECAN'S advice of 16th Feb 11 to Regional Emergency Mngt Office (? Derived from GNS) that science showed a small, albeit decreasing, chance of a significant aftershock in the aftershock region between Rakaia gorge and Pigeon Bay, and the exact location can't be forecast. The assumptions of the model are wrong unless "small chance" has a new meaning.

*Dr Gluckmans claim Feb 22nd was an aftershock is refuted. We agree with Geoscience Australia in considering that a quake arising from a different fault to that underlying Septembers quake, indeed arising from one about 40 km removed IS NOT an aftershock. It was a new quake, that a Government which had explored blind faults (as per repeated ignored advice), would more likely have **foreseen the potential for great harm from**, and mitigated and reduced the deaths. Cheerleading failed.

To address the R.C. reports re seismicity and conclusions therein in detail

The reports omit many important considerations, and do not provide the direction for a safer future yet. Study recommendations are weak and building standards have already been prematurely arrived at without proper hazard data e.g. already they say 7 storey buildings will be allowed when some areas may lie proximal to faults.

Without provision of ample seismic data some parts of Christchurch (? The CBD) should not be rebuilt, and reinsurers should take flight. We now critique your preliminary reports and raise some overlooked areas.

1) We say raising the new Z factor in building standards to 0.3 is expedient & inadequate (Sei.gns.0002A10); the risk should be assessed equal to Wellington given an active fault system lies under Christchurch. **The Z factor should equal Wellingtons**, as in places shaking exceeded 2500yr design levels in some frequencies (?SH waves) IN 3 QUAKE EVENTS (?) due to **ongoing** risk of a seismic lens structure/fault in the land (see Appendix 1).

2) **We strongly agree that the National Seismic Hazards Model (NSHM) should account for hidden faults near cities** (and not in the current way of only assuming a magnitude 7 potential from them) – blind fault risk analysis based on more complex factors to do with site characteristics than just magnitude is a standard practice in other countries.

   Our Info request exposed ECANs deficiency in blind thrust fault information, and found even Council which grants building consents only has access to liquefaction maps not to any practically usable fault maps.

3) It is a misplaced for your report to only say that quakes on the planes appear to come thousands of years apart (8000 for Greendale), so the next update to the Nat. Seismic Hazard Model including a theorized long recurrence period, won't much alter the long term hazard for CHCH. Small change comes of small inquiry;
   trace blind faults 50km's out; not just in the CBD and then risk may alter.

   Isn't it far too early in the years of research required to know and properly analyse the correct inputs to the model, given that the evidence (*see neighbouring quote*) suggests a more relevant comment would note the raised short term risk?

> *Faults of known historic activity during the last 200 years, as a class, have a greater probability for future activity than faults classified as Holocene age (last 11,000 years)…*
> *and a much greater probability than faults classified as Quaternary age (last 1.6 million years)*
> *- **Cal. Dept of Conservation** Special Publication 42 Interim Revision 2007 Fault Rupture Hazard Zones in California.*

We do not believe focusing "directivity" is as significant a factor in the quake damages in the CBD from September *Darfield* and Feb *Lyttelton* (but not on Boxing Day *Opawa* or in June *Sumner*) as your reports theorise (Sei.gns.0002A.9).

- Your report says current thinking is that unusually high shaking relates to a "low deformation rate where faults seldom rupture", but we assert that the phenomenon known as seismic lensing should be investigated. If it is a factor magnifying effects then it ought to be accounted for NSHM risk models that are generated for Christchurch in the future. Local effects of quakes may be intense in river basins near volcanic rock (see Appendix 2 - Lens).

4) Vague **"glossed up" forecasts included in your reports are inappropriately space wasting** in the consultation documents. Your reports state that there will likely be 40 odd years of ongoing but reducing seismic activity with another major quake still a possibility. This sort of non specific info can lead to complacency.
The Public has a right to more accurate forecasts such as those offered to San Francisco natives – who have full info based on duly diligent hazard investigation that their risk is 62% for quakes of 6.7 or more by 2032.

5) **We reject the seismic design requirements for building engineering in NZS1170** because they only address estimated level of seismicity and directivity where building is in 20 km of 11 major known faults (wrongfully excluding populous places like CHCH with under-investigated blind faults). This is unsophisticated, upgrade is needed. Overseas with blind fault mapping done, caution extends 50km

6) We are dissatisfied with Authorities studiously neglected state of seismic knowledge; a sorry state of info starvation is well described in your reports, which note that the main Quakes contributing to the estimated peak ground acceleration hazard in CHCH don't occur on known faults, which means that risk modeling cannot be precise.

This is "duck shoving" – risk modeling can output localized risk levels. Global experts advise that "for the purpose of strong ground motion prediction, using scenario earthquakes with high resolution geographical and geologic information is necessary in any seismic hazard analysis".

• Refer appendix 1 – California case study re blind fault identification program and risk zoning, and also note for example the modeling of "lensing" of seismic waves in the Taipei Basin, which resembles CHCH (*Sims of Strong Ground Motion and 3D Amplification Effect in Taipei Basin by Using a Composite Grid Finite-Difference Method, Shiann-Jong Lee et al 2008.*

• New Zealand scientists well knew of Canterburys vulnerability and told Government long ago – for years critical modeling tasks the region required for proper preparation fell through the cracks of multiple agencies with ill defined responsibilities and a general "do nothing" focus in regards to legal obligations to manage natural hazards.

7) An Opus report ECAN in 2004 (**Earthquake Risk Assessment Study Part 1** - *Review of Risk Assessment Methodologies and Development of a Draft Risk Assessment Methodology for Christchurch Report No. U04 / 108 : Final*) was one of many sources insisting on the need for studies of blind faults around Christchurch.

Recommendation 7.6.3 of Opus would have enabled more life savings

Opus 2004, recommended retaining experts to identify potential EQ sources and to model occurrences with regard to site effects of soil amplification, liquefaction, surface rupture etc, and to model damage including fire spread (relevant to CTV), with life loss projections.

Opus recommended hazard modeling be conducted for four scenarios, including (rec 7.6.3) for a large EQ within 10-20km of CHCH; "perhaps an extension of North Canterbury faults into Canterbury Plains with an MM intensity of 9+".

Opus also recommended mesh block analysis of residential areas, and a mesh block analysis of the CBD with aggregated building risks in each quadrant, and stated that "the MM intensities would need to be modified to account for the presence of soft and deep soils in CHCH".

THE WORK WASN'T DONE – ECAN depended on fault maps that were uninformed by blind fault studies and on a highly dated map for shaking (the EQ hazard in CHCH, Elder et al 1991 EQC).

This risk map has only 3 huge zones;

~~~~~~~~ ***the Port Hills marked as Zone 1 (Bedrock at shallow depth MM6)*** ~~~~~~

Zone 2 at the base of the Port Hills (sediments <50m MM7) ~~~~~~~Zone 3 everywhere else (Sediments 50-800m, MM8-9)
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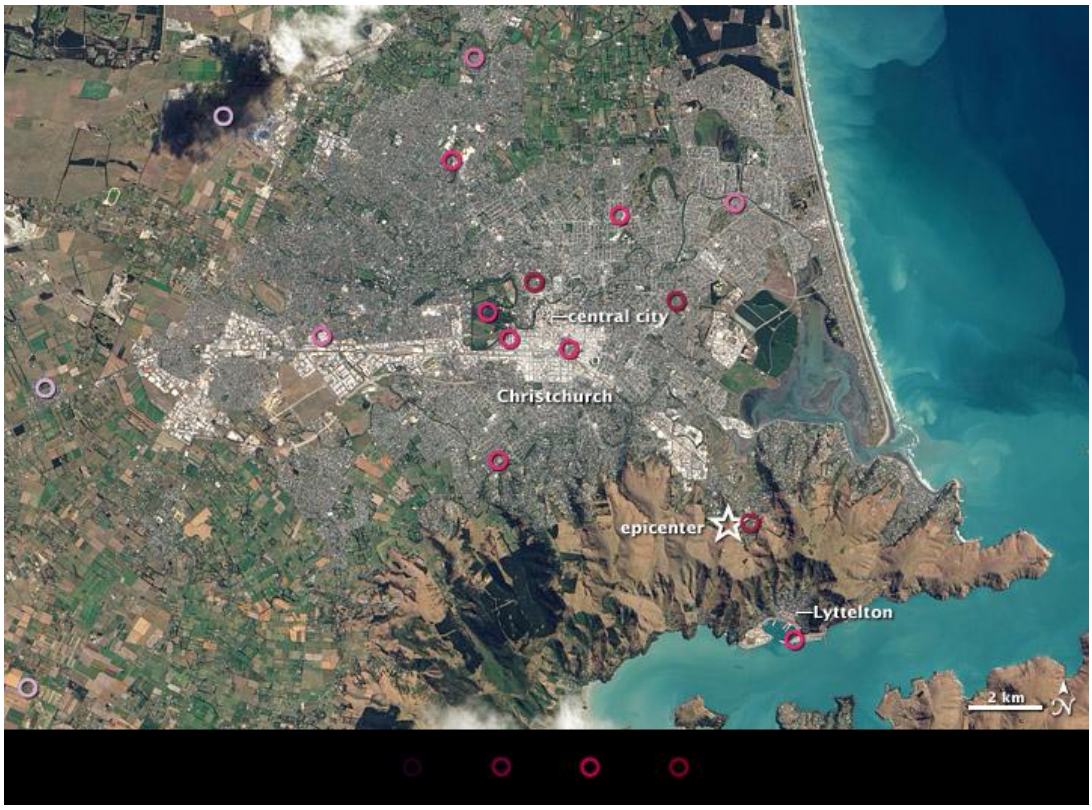
8) On 30/3/11 ECAN advised media how hazard risk studies fell through gaping cracks;

> *"The (2004) report from our website was a scoping report to develop a risk assessment methodology for earthquakes in CHCH. About the same time as the work was being done a national initiative was begun, called the Risk Scape project.*
>
> *This was established nationally (with GNS and NIWA as the leads) and CHCH was a pilot for the project and so the work which was kicked off in the Opus work was not continued, as it was taken up at a national level."*

Except that it was not "taken up" in any sense, work just ceased. Contents of the response to an Official Info Act request that we made to ECAN and dated 15/7/11 further clarified that;

"ECAN has tested the Risk Scape model, but has not used it to run risk assessments. No other specific risk assessments had been (entered into) by ECAN during the time 1/1/04 – 1/4/11".

So ECAN have only trialed it and NEVER used it to produce one real risk assessment!
Apparently they just waited for the real event to see what might happen….



ACTUAL SHAKING HOTSPOTS MODELLED IN REAL TIME INSTEAD OF IN RECOMMENDED MODELLING

So **where was the geological research budget** actually funneled following clear advice from Opus to look after the populations public safety interests?

Answer; Big money has for one thing been spent on an oil / gas seismic survey in Canterbury (*Canty EQ's scientific answers to critical questions - Office of PM's scientific advisory committee*).

9) **ECAN made one final heroic effort to obtain the most critical info it required, after the Sept EQ.** It supported an application by the Natural Hazards Research Platform to the Ministry of Science and Innovation through Canterbury EQ Recovery Commission, for funding to investigate the possibility of a blind fault running under the CBD.

But this funding was only provided to commence the study (then only a partial one of CBD faults not citywide) AFTER THE FEBRUARY 2011 Quake. (OIA 15/7/11). Instead, the priority was liquefaction studies (funded to the tune of $480 G per ECAN when that is not fatal).

ECANS preexisting budget for quake hazard investigations in 2011 was only $43,000 (an amount not even revised after the Boxing Day quake). In contrast to the slim pickings sought for needed public safety research re blind faults and withheld, NZPA reported (5/1/11) that 65 scientists are funded by several million dollars to study the Alpine fault.


lpine - ***A distant active fault that would by all accounts be less damaging to life and property than the recent seismicity in CHCH. (Scientists to probe Alpine fault).***

> One of the key lessons of the 2008 Wenchuan EQ in China (70,000 dead and $122B in real estate lost) is the importance of EQ mapping and zoning for adequate building codes"
> - Peter Yanev, World Bank.

10) **ECAN has written to us that it "cannot comment on whether seismic risk zone maps are being created** or sought by CHCH city council to assist in new building consenting within the four avenues" and the Councils data clerk has told us they hold nothing related to localized faultlines.

This isn't good enough; does ECAN not have legal obligations to help identify and mitigate the effects of natural disasters, which includes providing the Council with better maps than the feeble 1991 map mentioned in point 7.

11) Your reports just fleetingly mention that **there have been few micro-zonation studies** identifying local site specific risks here, but if we are to emulate best practice our Government will conduct the above studies (in 8 and 9), and **support the future plan mooted to model the stress changes** created by the Canterbury quakes in the light of rate and state friction laws.

12) It will then **ensure that findings are belatedly used (per best practice)to produce seismic risk microzone maps** for Christchurchs' main urban areas, which can dictate building exclusion zones and varying building standards in a meshwork pattern of city blocks. As per advice given in 2004.

13) Your reports say that research to improve knowledge of active faults near cities would need to be targeted "due to resources", so studies should only be done when GPS surveys of ground displacement identify areas of strain that suggest blind faults.
We say **GPS surveys should be required in populous areas and geological research to map blind faults in them should be made mandatory** by law with regional councils to hold maps they commission or that Developers of new settlements submit.

14) Studies mentioned above (in points 8/10) and their proper end products of seismic risk microzone maps should have been commenced at the very latest straight away after the September Quake, and must be undertaken now, so likely areas of future activity (and so heightened risk) can be identified.

- Such knowledge allows radically different preparation and event responses to that incompetent one steered by Bob Parker and Co following the September 2010 quake.
- A response that resulted in buildings being wrongfully occupied like CTV/PNG etc, wrongful ongoing use of city thoroughfares by pedestrians at what should by February have been highly foreseeable risk beneath negligently unsecured Central City masonry.

China has successfully evacuated large cities hours before major earthquakes avoiding loss of life

15) **It's astounding that you reveal ECAN has proceeded to lodge Environment Court evidence re the suitability for future development of Greenfield areas** proposed in the Greater Christchurch Urban Development strategy given the dearth of incomplete blind fault info – and that it is defining a fault avoidance zone just for the Greenfield fault presently when CHCH city needs similar attention.

We do understand that prominent city land holders are lobbying to have their land "forgiven"

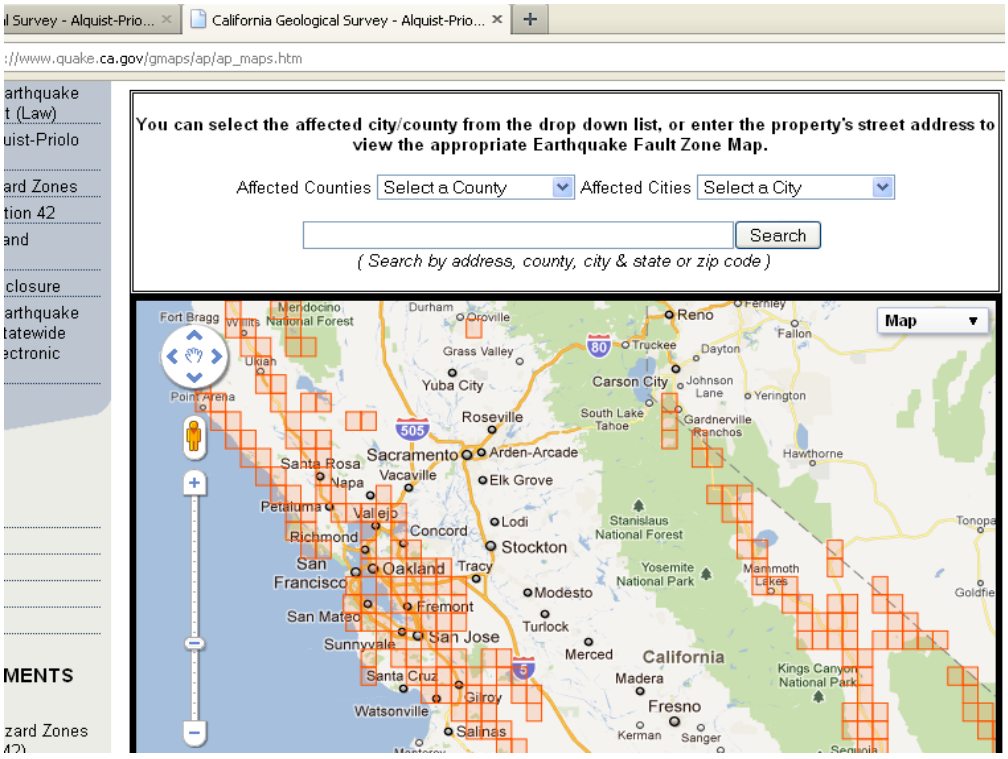
16) There is an urgent need to tighten the law, given the long history of authorities failure to collate and use the required standard of risk info about quake hazards proved massively fatal. Funding denials from Cabinet seem to fuel the negligence as well as poorly delineated areas of responsibility eg the Opus, ECAN, GNS, NIWA, Council building permits "duck shoving" over who should have done blind fault risk assessments/maps (see points 7-10).

Just how local authorities and central Government funders are interpreting the legal responsibility to "identify, assess and to mitigate the effects of natural hazards" is obviously loose and dangerous, and perhaps more than doubled the reasonable earthquake toll and economic damages for Feb 22nd. Reinsurers need competency.

We submit that NZ needs to change the Resource Management Act to place much more specific requirements on authorities as regards collection and use of seismic risk info to ensure proper land use and building standards, **or that NZ alternatively requires a new Earthquake Zoning Act** – perhaps that's the best choice given our position on the Pacific Rim.

At the least local authorities of major cities must be required to base urban zoning / development rules on seismic hazard maps that include active surface and blind faults and identifies titles within 50 km and their risks.

Appendices contrasting our state of risk info systems and best practice examples now follow.



Appendix 1 – California case study re blind fault identification and risk zoning

An exemplary case study is seen in California. California's Alquist-Priolo Earthquake Fault Zoning Act required mapping of fault zones from 1972 and Nat standards for a methodology of fault reports are established. The law regulates development and prohibits human habitations within at least 50m of faults ones unless geological studies show the fault poses a minimal hazard.

Concord
H *Hayward
HA Hat Creek
HC *Hilton Creek & related
HE Helendale
HL Honey Lake
HU Hunting Creek
I *Imperial
J *Johnson Valley & related
KF *Kern Front & related
L Lenwood
LA Los Alamos
LL *Little Lake
LO Los Osos
LS Little Salmon
M *Manix
MA *Maacama
MB Malibu
MC McArthur
ME Mesquite Lake
MR Mad River
N *Nunez
ND Northern Death Valley
NF North Frontal
NI *Newport-Inglewood
O Ortigalita
OV *Owens Valley
P Pleito & Wheeler Ridge
PI *Pisgah-Bullion
PM Pinto Mountain
PV Panamint Valley
R Raymond Hill

RC Rose Canyon

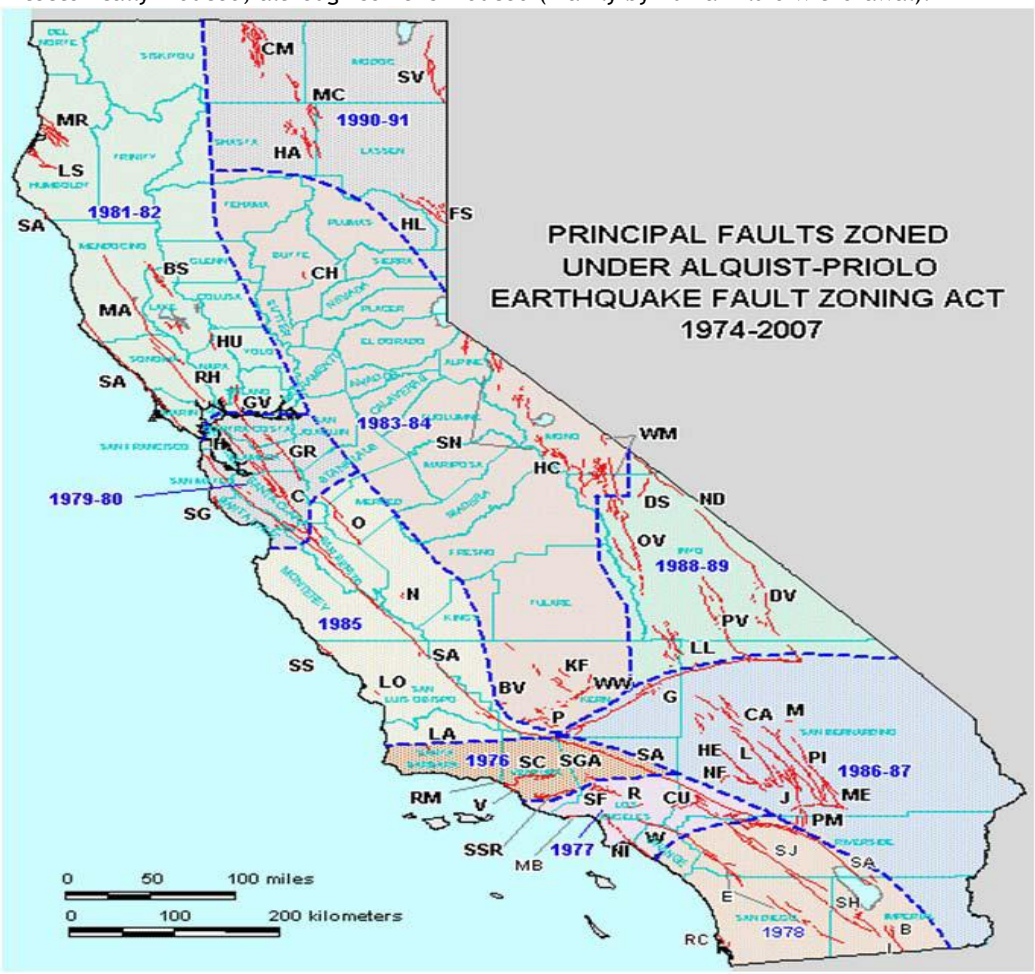
Special definitions for active faults were devised by the mining and geology board defined an active fault as one with surface displacement within the Holocene (last 11,000 yrs), while a potentially active one was considered to be any with displacement during Quaternary time (last 1.6 million years).

The 500+ National seismic hazard maps (required by law) covering 6 counties and 104 cities incorporate active including blind thrust fault models in parts of California, specifically blind ones are in the Southern Transverse ranges/ Northern Peninsula ranges boundary, Santa Barbara Channel, and along the Western margin of the Great Valley (WGCEP, 2008).

The Southern California EQ Centre exists to offer probabilistic quake forecasts and likely impacts as magnitude only forecasts such as NZ's assessment framework is built on are outdated. It helps with micro-zoning by analyzing how geology can modify shaking for better or worse.
The Act requires disclosure of EQ fault zones to the Public and A person who is acting as an agent for a transferor of real property that is located within a delineated earthquake fault zone, or the transferor, must disclose it to buyers if the property is located within a delineated earthquake fault zone.

The policy since 1977 is to position the EFZ boundary about 500 feet (150 meters) away from major active faults and about 200 to 300 feet (60 to 90 meters) away from well-defined, minor faults. Exceptions to this policy exist where faults are locally complex or where faults are not vertical.

Recent coseismic rupture occurred on faults mostly or entirely within the Earthquake Fault Zones in nine of the rupture events. A sequence of four rupture events occurred in the Lompoc diatomite quarry and presumably was triggered by quarrying. In addition, aseismic fault creep has occurred on many zoned faults in the last 30 years. Mostly creep has been tectonically induced, although some is induced (mainly by human fluid withdrawal).



APPENDIX 2 – Our Government won't talk seismic lensing and is cagey on faults – implications for areas of CBD rebuild or other secrets?

In response to initial debates where many experts chipped in about seismic lensing being explanatory of the high MM readings in some suburbs Government diverted early on (week 1) saying that the quake was stronger than Septembers because it was shallower - yet most of the aftershocks have been shallow. On 25th February the Herald reported Geologist Hamish Campbell of GNS Science discussing the prospect of seismic lensing (CHCH earthquake: Deadly tremors rebounded on city).

But media were soon advised to avoid discussing quake aetiology for reasons of National security (Source Fairfax) and sources became restricted to Government ones – which repeatedly conflict with comment of overseas experts. Three weeks later the PM's office published a "lying by omissions" Fact Sheet… it said;

“"Why was the magnitude 6.3 earthquake able to cause so much more destruction in the CBD and Christchurch suburbs than the magnitude 7.1 quake last Sept?
It was the closeness of the earthquake to the city and its shallowness that led to the increased destruction. Overall, the levels of ground shaking in the CBD during the magnitude 6.3 earthquake were consistent with ground shaking observed for other similar-sized earthquakes elsewhere in the world."

The prior quakes were all local and shallow so this is not sufficient explanation. The September 7 quake registered a 5 foot rise in Observation well 27F2 SOW 019, located in Christiansburg, Virginia but the February one of much lesser magnitude didn’t even register. Haiti which was magnitude 7 had only Peak Ground Acceleration 0.5 - the ground accelerations were up to 4x those reported in Japans recent magnitude 9 EQ.
On Close Up mid March GNS scientists talked about what seem to be seismic lensing impacts by another name – they claim the effects were a newly discovered phenomenon called “trampolining”, although a recent letter from ECAN indicated to us they hold no info on this or seismic lensing.

The Government ignores Occam’s razor with all the sidestepping. We deduce from many clues that the possible reason Dr Gluckmans draft report on the earthquake science was recently withheld from us under the Official Info Act was that it contained some mention of seismic lensing. Perhaps because Government should have been better prepared for lensing?

Perhaps because it is undertaking secret works (such as the U.S project detailed in Study C below) to identify blind faults or seismic lens structures in the Wellington/Wairarapa region, when that's what CHCH had required per expert advice? Geologist type people have been seen blowing things up in deep boreholes in the Wairarapa. Maybe it wasn't done in CHCH because there could have been adverse impacts on gas/oil/mining resource consents in the region?
IS THE PHRASE SEISMIC LENS A BANNED PHRASE - LEST IT TRIGGER UNWANTED INQUIRIES THAT MAY PANIC US UNDER THE OFFICIAL INFORMATION ACT OR ANTI MINING ACTIVISM?

Northbridge California and Seismic Lensing

This quake in California occurred on a blind thrust thought to be an extension of the Oak Ridge fault system at a depth of 17.5km. The Modified Mercalli Intensities ranged from VIII to XI. Though Northridge would normally be considered "moderate" on the earthquake magnitude scale the magnitude-6.7 earthquake, killed 61 people and, it did tremendous physical damage with high PGA 1.7g and thousands of aftershocks occurred in the following months. It was the costliest natural disaster in U.S. history. , causing more than $40 billion in damage.

The boundary between the heavily damaged (Sherman Oaks and Santa Monica) and the slightly damaged zones is sharp; the transition takes place over a distance of less than one kilometer. There is no systematic difference in building types, building codes, or earthquake resistance between the heavily and slightly damaged zones. The strong motions caused extensive ground liquefaction. Damage to concrete and steel framed buildings showed the need for better preparedness and the Northridge quake emphasized the need for stricter criteria and guidelines in identifying the seismic risk within a region.

It was theorised that a bowl-shaped dip in the bedrock beneath the northwestern Los Angeles Basin may be responsible for the damage pattern. Using oil company geologic maps, they found traces of a 1.8-mile-

wide depression beneath the southern edge of the Santa Monica Mountains. Like a lens focusing sunlight into a burning dot, the depression might have focused passing seismic waves and caused stronger ground shaking at the surface in Santa Monica and/or contributed to the unusually strong shaking in Sherman Oaks, but part of the blame also rests with soft sediments deposited there in the past by the LA River. The sediments jiggle like a bowl of Jell-O, amplifying the ground shaking.

Study A
An early study by Justin Rubenstein. UCLA (ref 7), Identified "hot zones" where the amplitudes were much higher than the surrounding regions. Tracing rays through a moveable lens from the hypocenter of an event to the surface allows researchers to pinpoint the location of lens. Sherman Oaks produced two regions of concentrated amplification, but no systematic azimuthal pattern as seen in Santa Monica was detected. The study of Sherman Oaks did produce two regions of fairly consistent enhanced amplitude with regard to ray path. One region is found at the base of the north edge of the Santa Monica Mountains. the region of enhanced amplitudes appears to have a dependence upon source location, thus supporting the lens model for Santa Monica.

Study B

Another study (ref 6) found that after the local site factors are removed, the waveforms from the Fort Tejon shot exhibited localized amplification adjacent to and south of the fault, 2-3 times larger than that of the surrounding area. The observations further lent support to the argument for deep structural focusing from a basin.
Study C

In 1998, scientists from UCLA, the U.S. Geological Survey, and the California Institute of Technology put the theory to the test using a plan to set off 60 explosive charges underground in a line stretching from the Malibu Coast to the Mojave Desert. Vibrations from the explosions -- essentially, small artificial earthquakes -- will travel through any buried geologic structures, like blind faults or dips, which will bend and reflect the waves. The returning signals, picked up by a network of 1,000 seismometers, should contain traces of the bowl's effects on the waves -- if the bowl is there. If so, locating similar structures elsewhere could point to areas more at risk than others from nearby earthquakes. (Source for this paragraph – pbs org savage earth website).

Study D

S. Gao, H. Liu et al (reference 5) also explored why Sherman Oaks and mid-Santa Monica experienced much greater damage than neighboring regions at similar distances from the epicenter. “To understand the cause of the concentrated damage, we installed an array of 98 seismic stations to record aftershocks in the two heavily damaged areas as well as along two profiles across the San Fernando valley and the northwestern part of the Los Angeles basin.
The analysis of peak P- and S-wave amplitudes and Fourier spectral ratios for S- and S-coda-waves from 32 aftershocks indicated that the enhanced damage in Santa Monica is explained in the main by focusing due to a lens structure several km beneath the surface, and having a finite lateral extent. The diagnosis was made from the observation of late-arriving S-phases with large amplitudes, localized in the zone of large damage.

Our results suggest that a contact between high velocity material underlying the Santa Monica Mountains and low velocities of the Los Angeles Basin is warped to form a 3D lens that focuses waves arriving from the north on sites in mid-Santa Monica. ...enhanced damage in Santa Monica is explained in the main by focusing due to a lens structure at a depth of several km beneath the surface, and having a finite lateral extent.
...The reason why the difference of S-wave amplification factors between the central and northern parts of Santa Monica is significantly larger than the coda amplification factors is that S-wave energy is focused on the stations through the lens, while coda wave rays, being omni-directional, are not.

We show that the focusing, and hence the large damage in Santa Monica was highly dependent on the location of the Northridge event and that an earthquake of similar size, located as little as one source dimension away, would not be likely to repeat this pattern."

Study E

William, Frankel et al (ref 4) build on the Northridge study and several others including Kawase [1996] which demonstrated that basin-edge effects caused a high damage belt in the 1995 Kobe earthquake through constructive interference of the direct S-wave arrival and basin induced phases. There was >20% more damage in some city blocks in Seattle so William et al suggested that the observed damage pattern was caused, in part, by basin-edge effects as well as localized seismic wave trapping.

The Seattle fault zone is an upper-crustal, actively deforming region dominated by reverse faulting. Its location and extent through west Seattle is mapped from marine seismic reflection data to the west in Puget Sound [Brocher et al., 2004] and from aeromagnetics on land [Blakely et al., 2002]. The inferred frontal fault (northernmost) of this zone was most likely the source of a M7 earthquake A.D. 900 [e.g., Blakely et al., 2002]. There are no documented subsurface features that explain how the fault zone affects earthquake ground motion or the location of high-damage pockets.

Frankel et al. [2002] documented a nearly three-fold difference in observed horizontal peak ground acceleration at 1 Hz during the Nisqually earthquake between strong motion seismograph stations WEK and HOLY. These stations are within (WEK) and outside (HOLY) one of the consistently recurring pockets of high chimney damage.

In order to better define the locations of faults and geologic structures within the Seattle fault zone, and to characterize their effect on observed ground motion, we acquired a shear-wave (S-wave) seismic reflection profile between WEK and HOLY. The 200-m bedrock fold at 300-m depth is caused by deformation across an inferred fault within the Seattle fault zone.

Ground motion simulations, using the imaged geologic structure and northward-propagating north-dipping plane wave sources, predict a peak horizontal acceleration pattern that matches that observed in strong motion records of the 2001 Nisqually event. A pocket of chimney damage reported for the 1965 and 2001 EQ's coincides with a zone of simulated amplification caused by focusing. This study demonstrates the significant impact shallow (<1km) crustal structures can have on earthquake ground-motion variability.

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Ref 1 - Pure and Applied Geophysics Volume 161, Number 7, 1533-1547, DOI: 10.1007/s00024-004-2519-0 Simulation of the Seismic Response of Sedimentary Basins with Vertical Constant-Gradient Velocity for Incident SH Waves F. Luzón, L. Ramírez, F. J. Sánchez-Sesma and A. Posadas

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Ref 3 – The Canty Earthquake sequence and implications for seismic design levels. GNS and University of Canty Consultancy Report (for Royal Commission 2011/183)

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Separation of Site Effects and Structural Focusing in Santa Monica, California: A Study of High-Frequency Weak Motions from Earthquakes and Blasts Recorded during the Los Angeles Region Seismic Experiment, Shirley Baher*, Paul M. Davis and Gary Fuis

Ref 7 - Analysis of Azimuthal Variation in Amplitude Factors in Sherman Oaks During the Northridge Earthquake Aftershock Sequence by Justin Rubenstein. UCLA

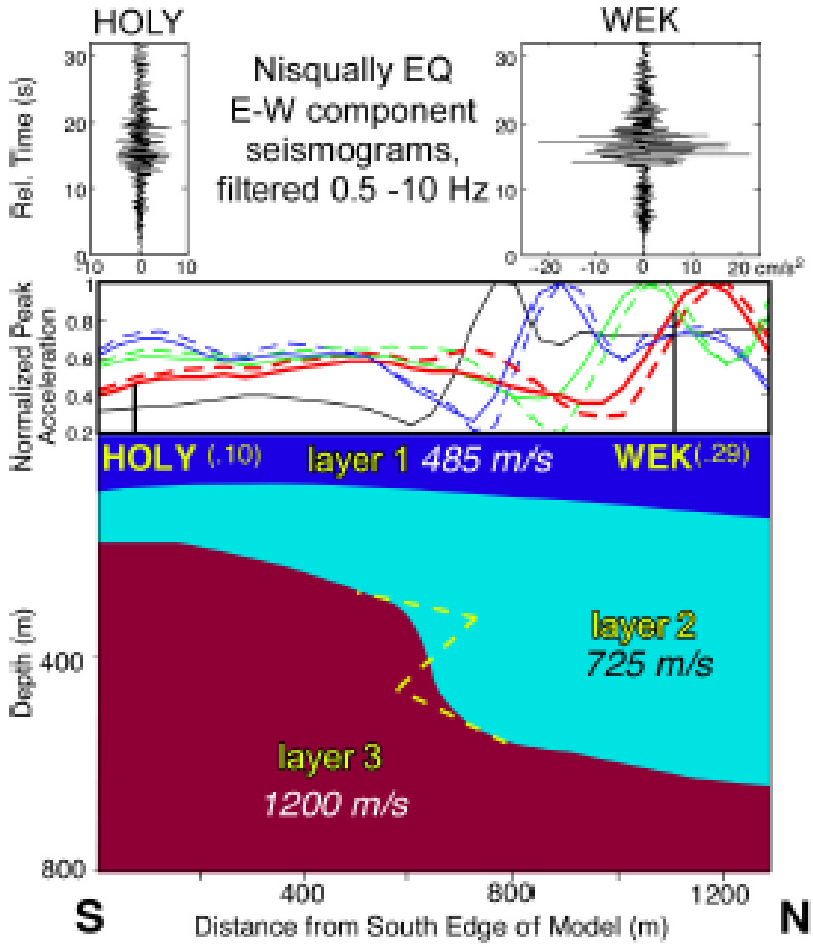
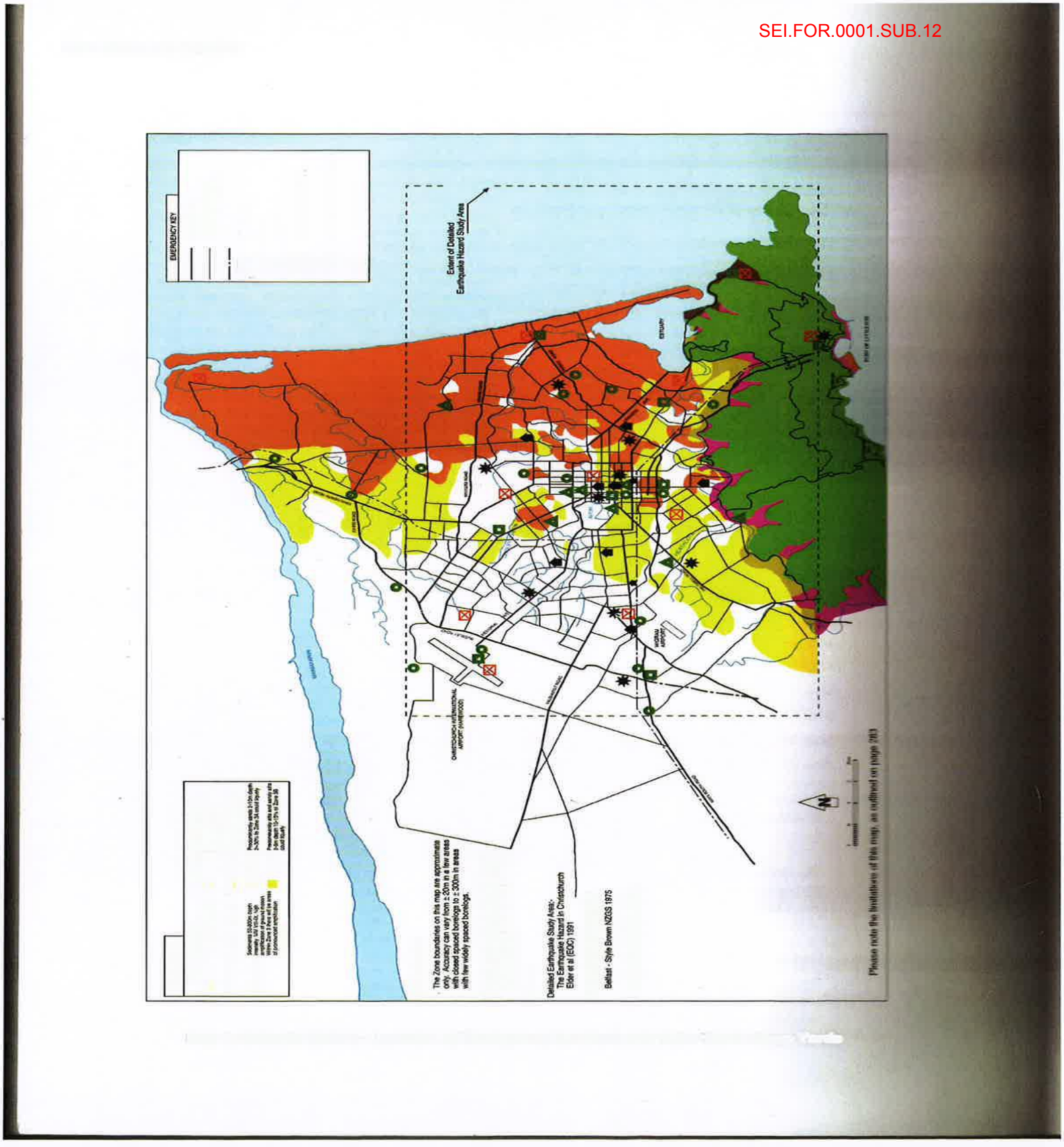
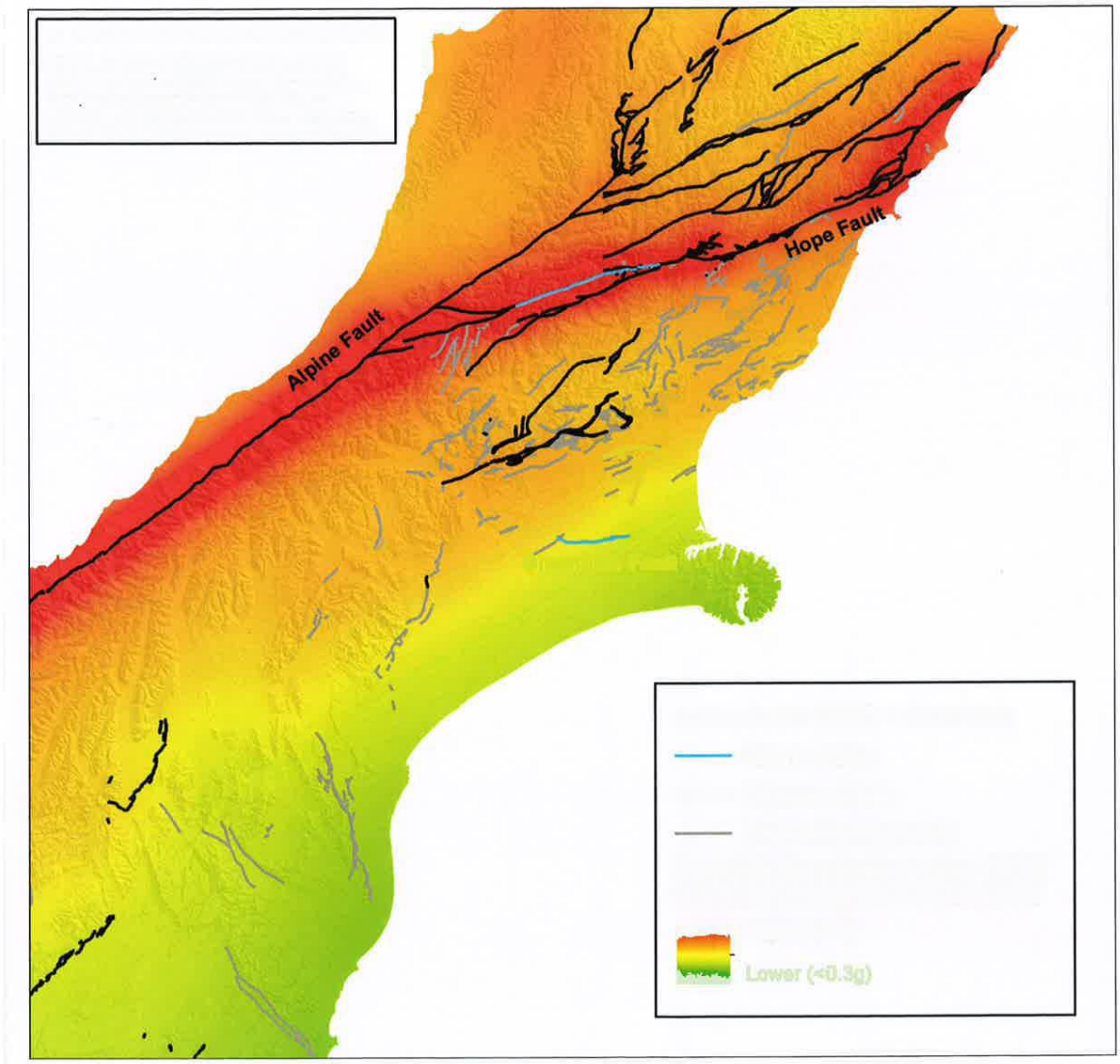


Diagram from one of cited studies demonstrates a seismic lens as it impacts on active fault activity



ECAN FAULT (BELOW) AND SHAKING POTENTIAL (ABOVE) MAPS SHOWING VERY INCOMPLETE DATA



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