A project to understand earthquake risk in the Wellington region

Russ Van Dissen (on behalf of the It's Our Fault Team)

GeoPRISMS Planning Workshop for New Zealand, April 2013

www.gns.cri.nz/ItsOurFault

It's Our Fault – The Goal

To see Wellington positioned to become a more resilient region through a comprehensive study of the likelihood of large Wellington earthquakes, the effects of these earthquakes, and their impacts on humans and the built environment

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NHRP

NIWA Taihoro Nukurangi

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Victoria University of Wellington, New Zealand

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It's Our Fault – Major Sponsors

A multi-year applied research project funded by New Zealand's

- Earthquake Commission
- Accident Compensation Corporation
- Wellington City Council
- Greater Wellington Regional Council
- Wellington Region Emergency Management Office
- Natural Hazards Research Platform

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WREMO Wellington Region Emergency Management Office

greater WELLINGTON REGIONAL COUNCIL Te Pane Matua Taiao

Some

Accomplishments

and

Highlights

over the last eight years

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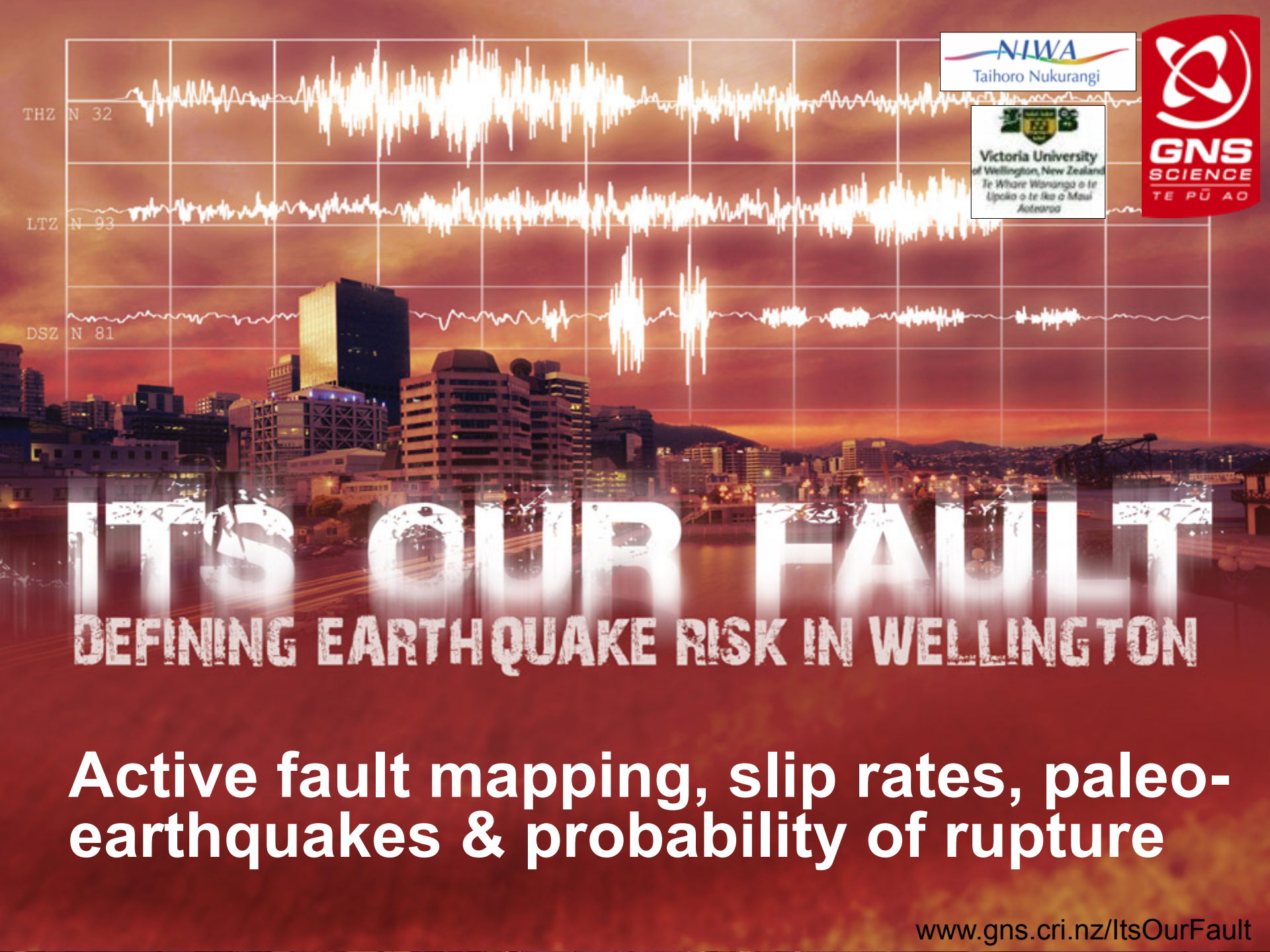

Active fault mapping, slip rates, paleo-earthquakes & probability of rupture

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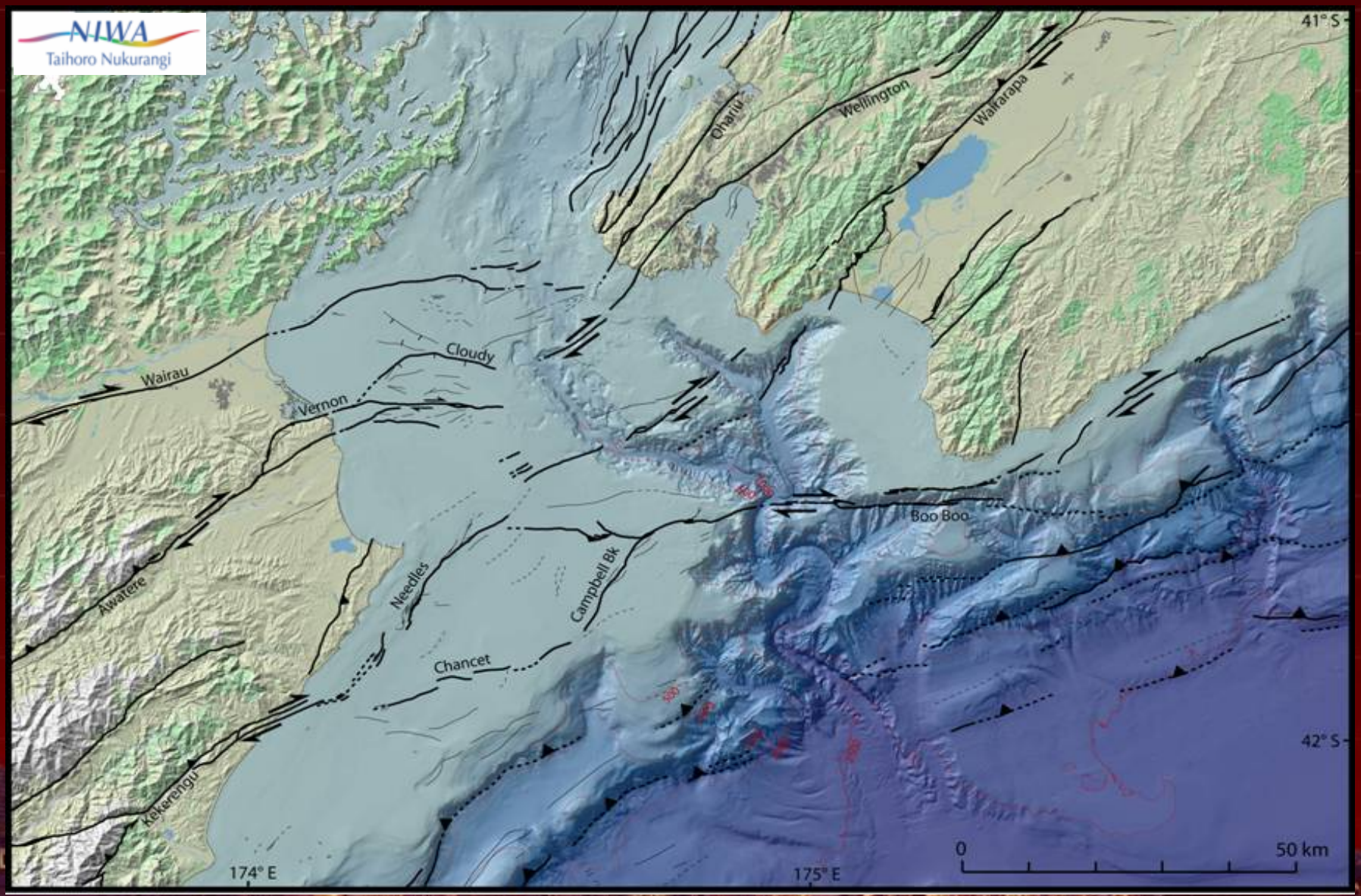
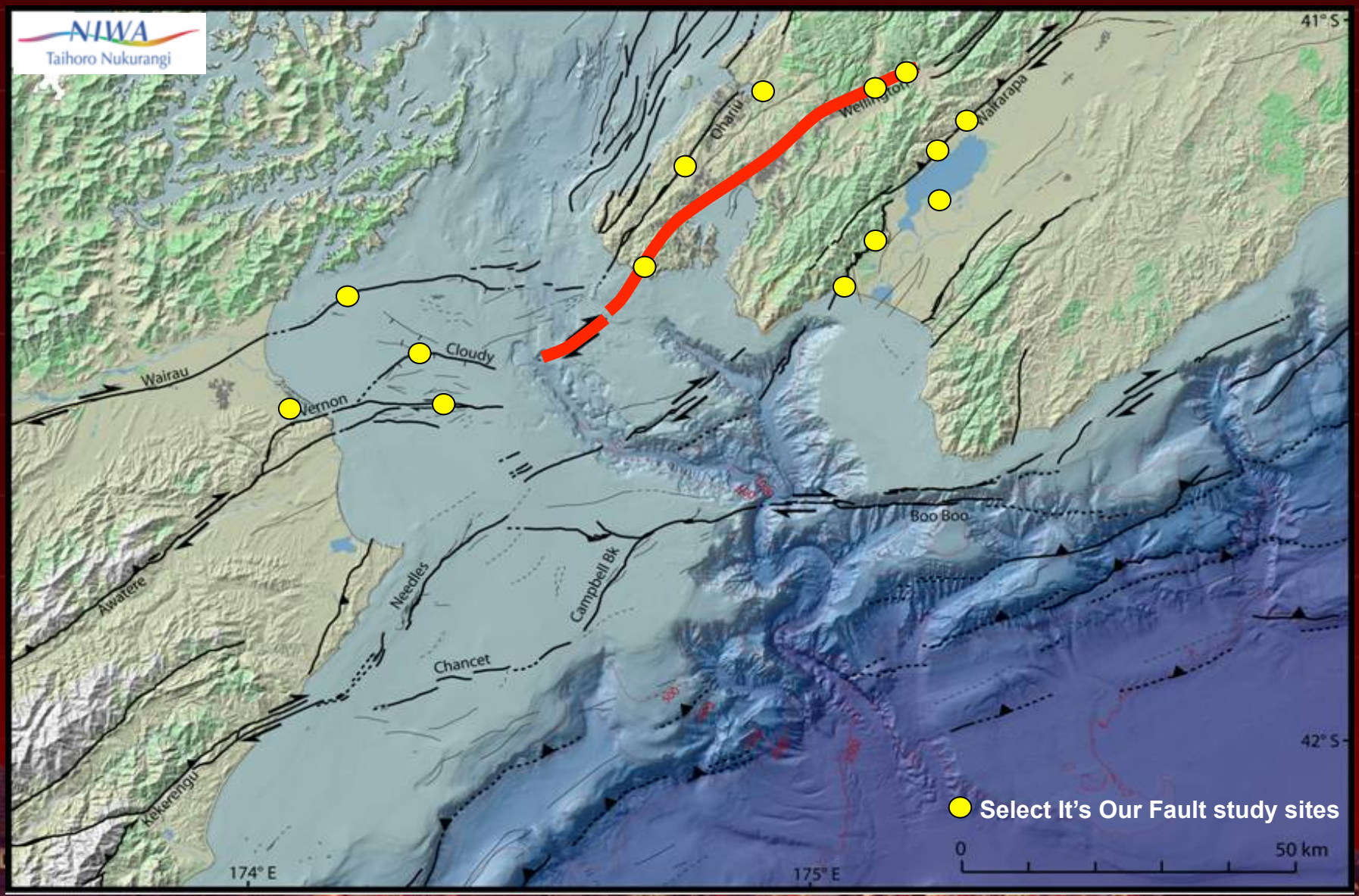
Active Fault Mapping
(defining the geometry of deformation)



(Pondard et al. JGR)

Slip rate & paleo-earthquake sites



Wellington Fault
Conditional Probability of Rupture

(accounting for)

- Elapsed time since most recent rupture
  - Slightly younger than previously thought (*~ 300 years ago*)
- Timing of older ruptures
  - Slightly less frequent than previously thought (*~ every 800-1000 years*)
- Single event displacement size
  - Slightly larger than previously thought *(~ 5 m per rupture*)
- Slip rate
  - Slightly slower than previously thought (*~ 6 mm/year*)
- Rupture statistics of the Wellington-Wairarapa fault pair in a synthetic earthquake catalogue derived from a physics-based numerical model
  - Rupture of nearby Wairarapa Fault "unloads" Wellington Fault
- Various recurrence-time models

Exponential, Lognormal, Weibull, inverse Gaussian

(Rhoades et al. BNZSEE)

Probability of rupture of **Wellington Fault** within next 100 years

Pre-It's Our Fault: ~ 30%

New: ~ 10%

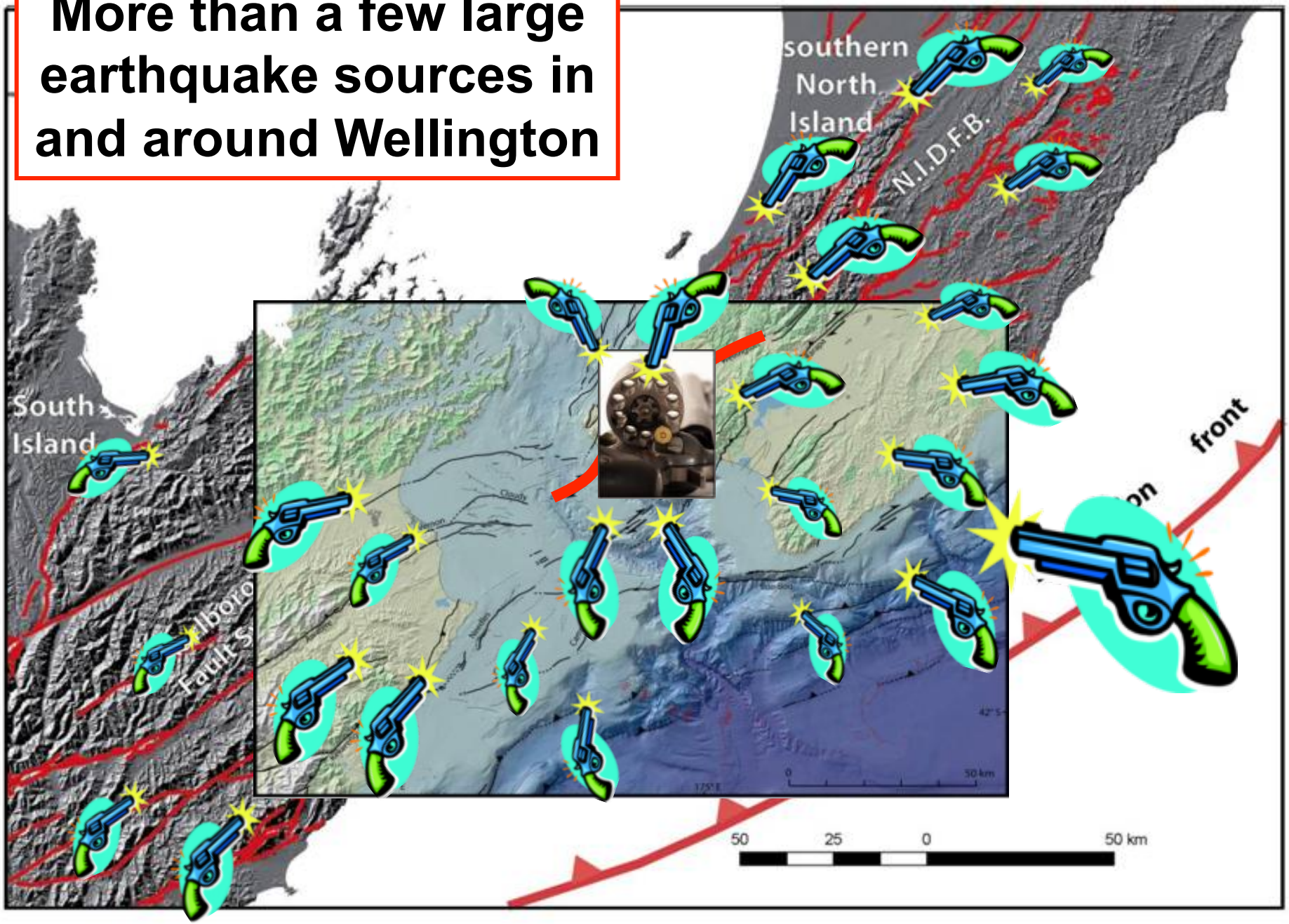
Some likelihood conclusions

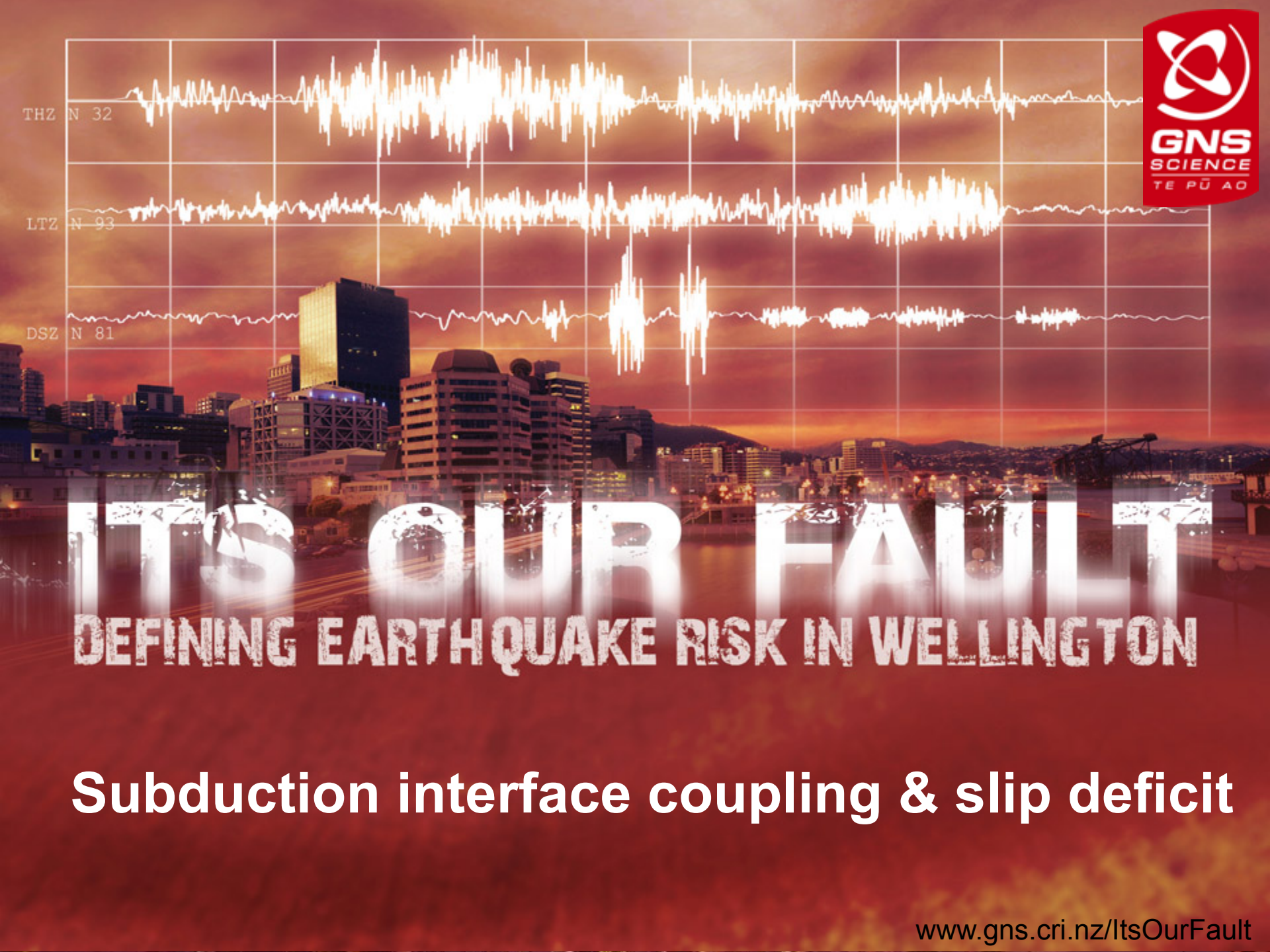
- Significant reduction in the likelihood of a really big earthquake on the Wellington Fault over the next hundred years.

This is Good News!

- **However, no room for complacency**. There are other earthquake sources in, and around, the region that can produce significant damage and loss.

More than a few large earthquake sources in and around Wellington





Subduction interface coupling & slip deficit

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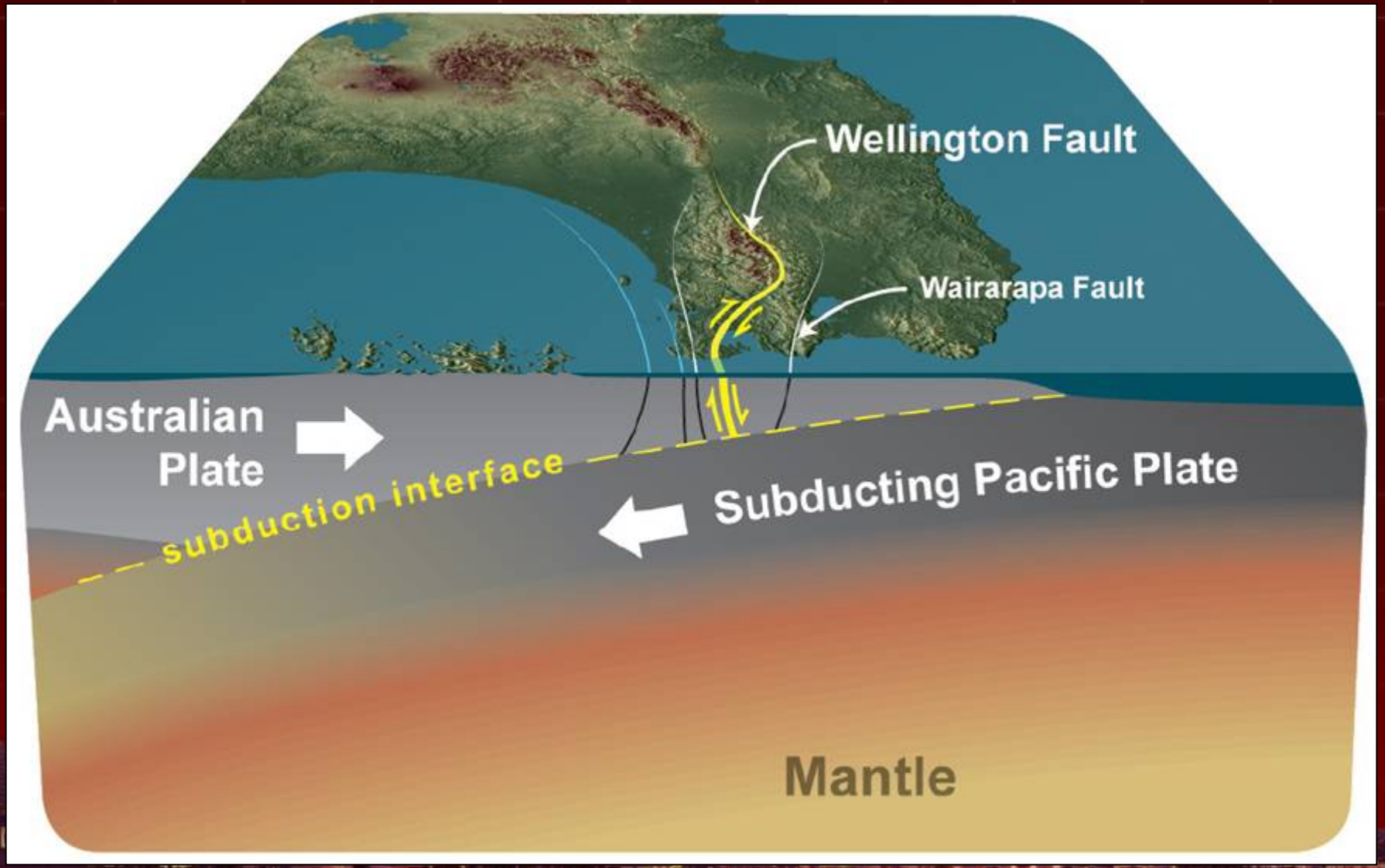
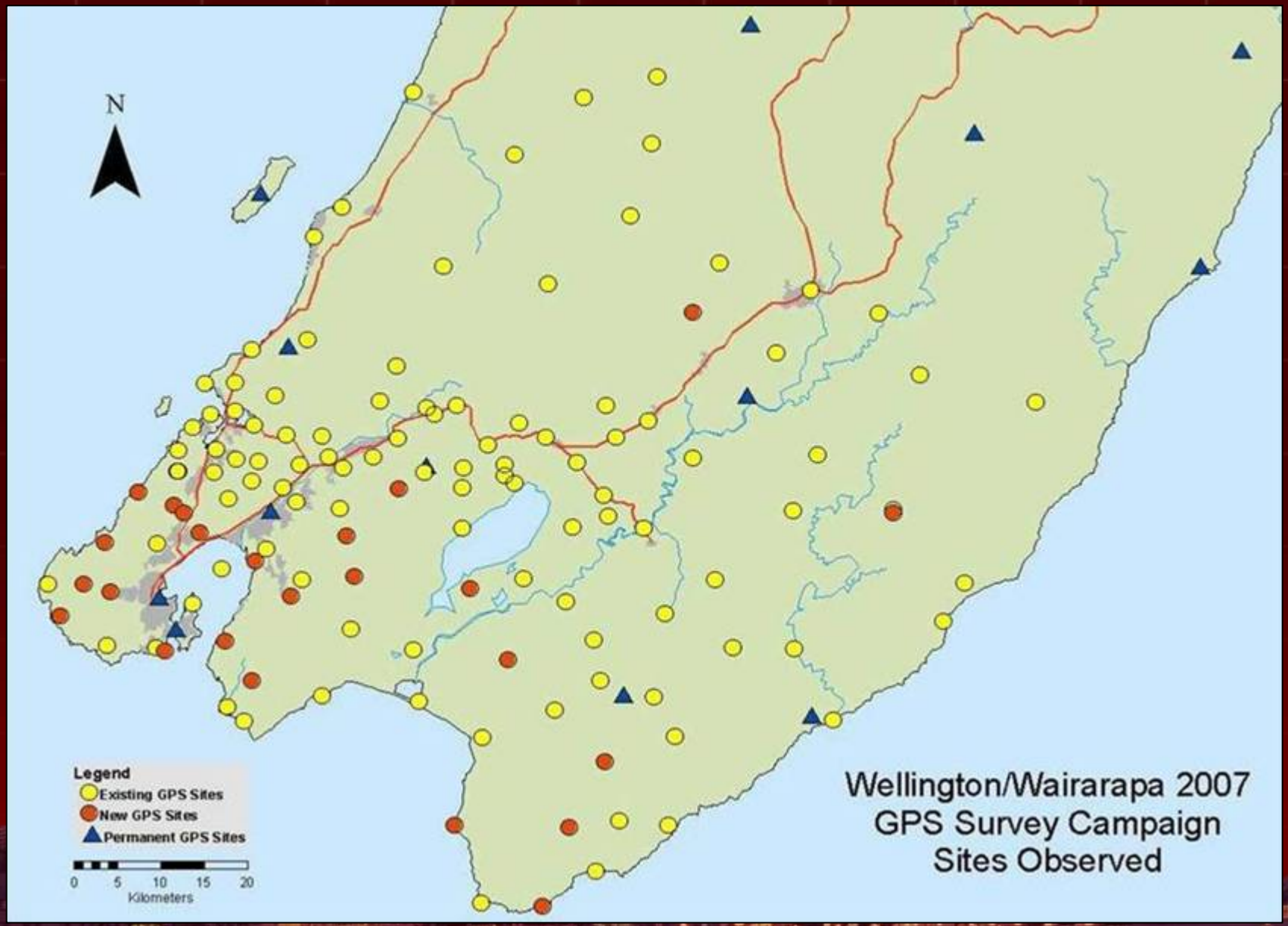
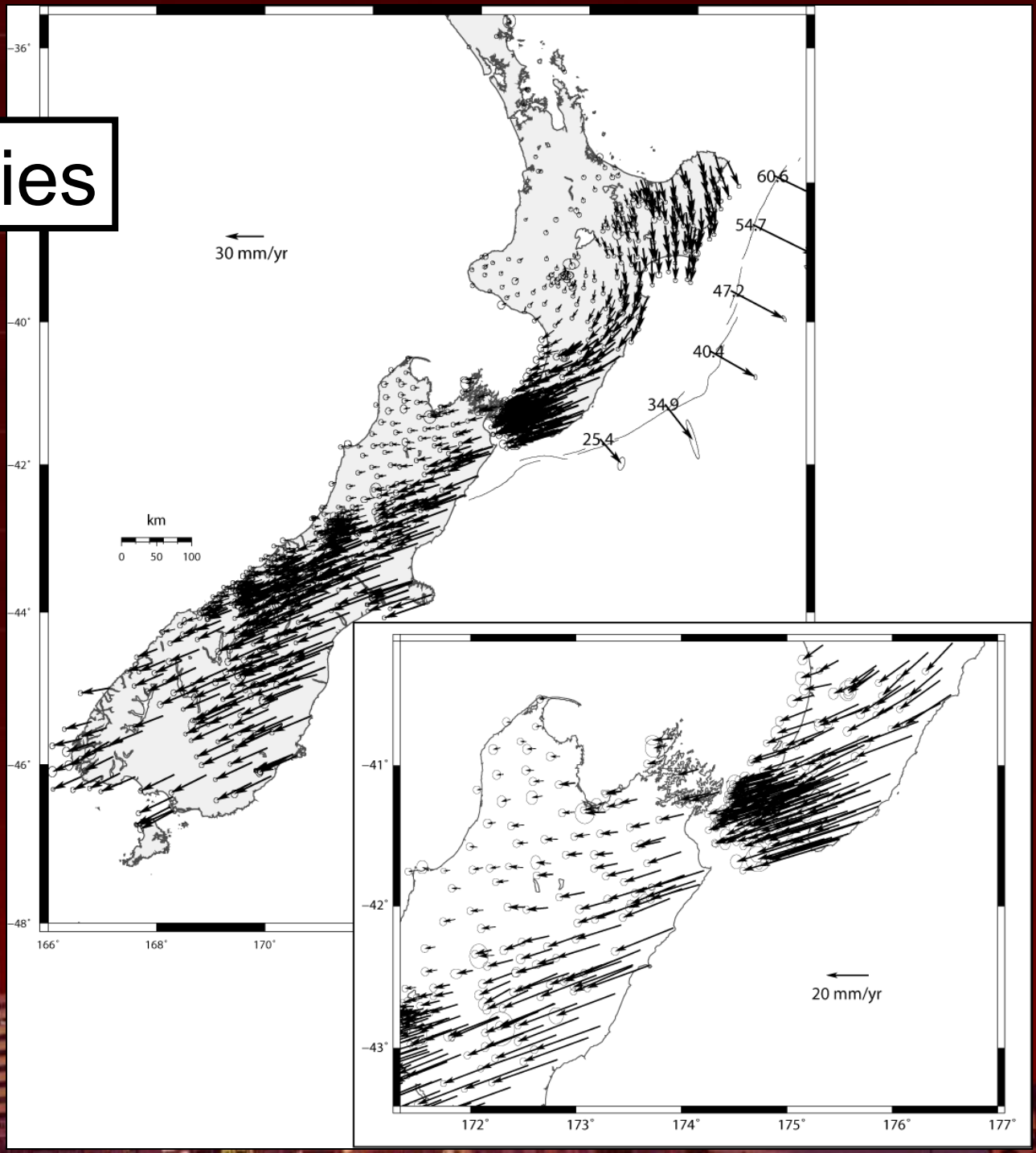
Wellington's Earthquake Setting

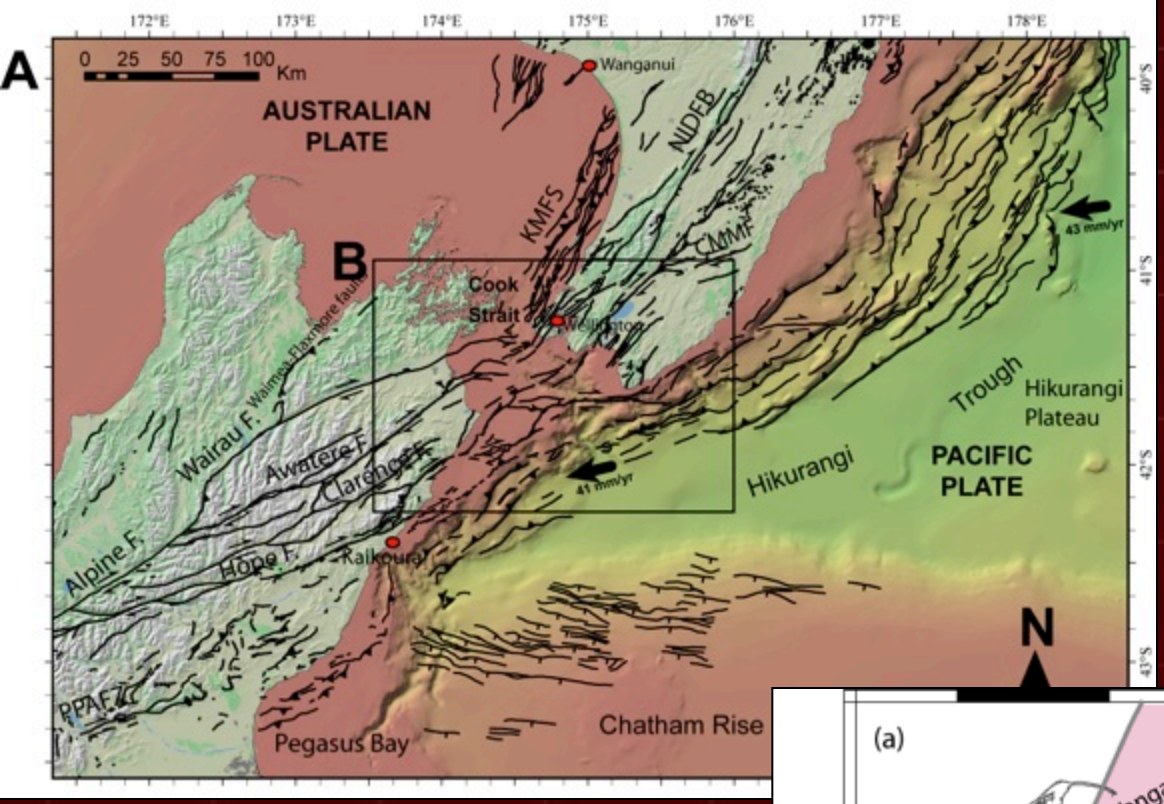


GPS Survey Campaign



GPS Velocities





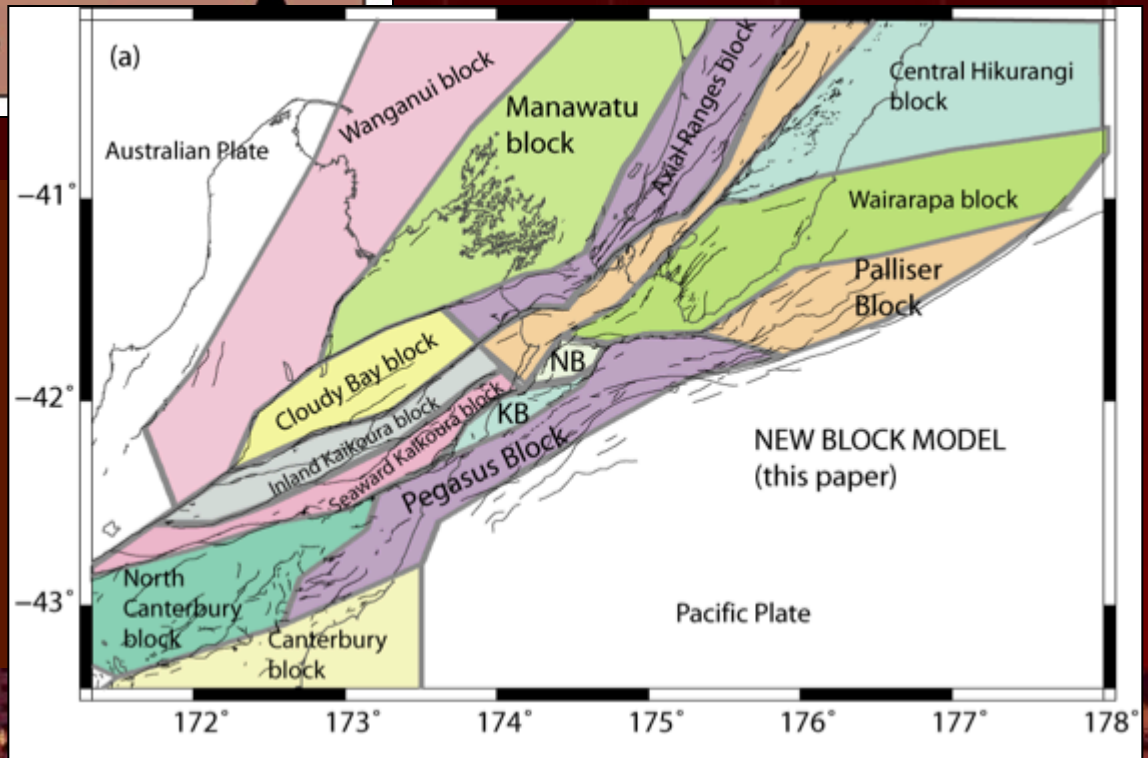
Modelling GPS Data

Jointly invert:

1) GPS velocities &
2) Active fault slip rate and location data

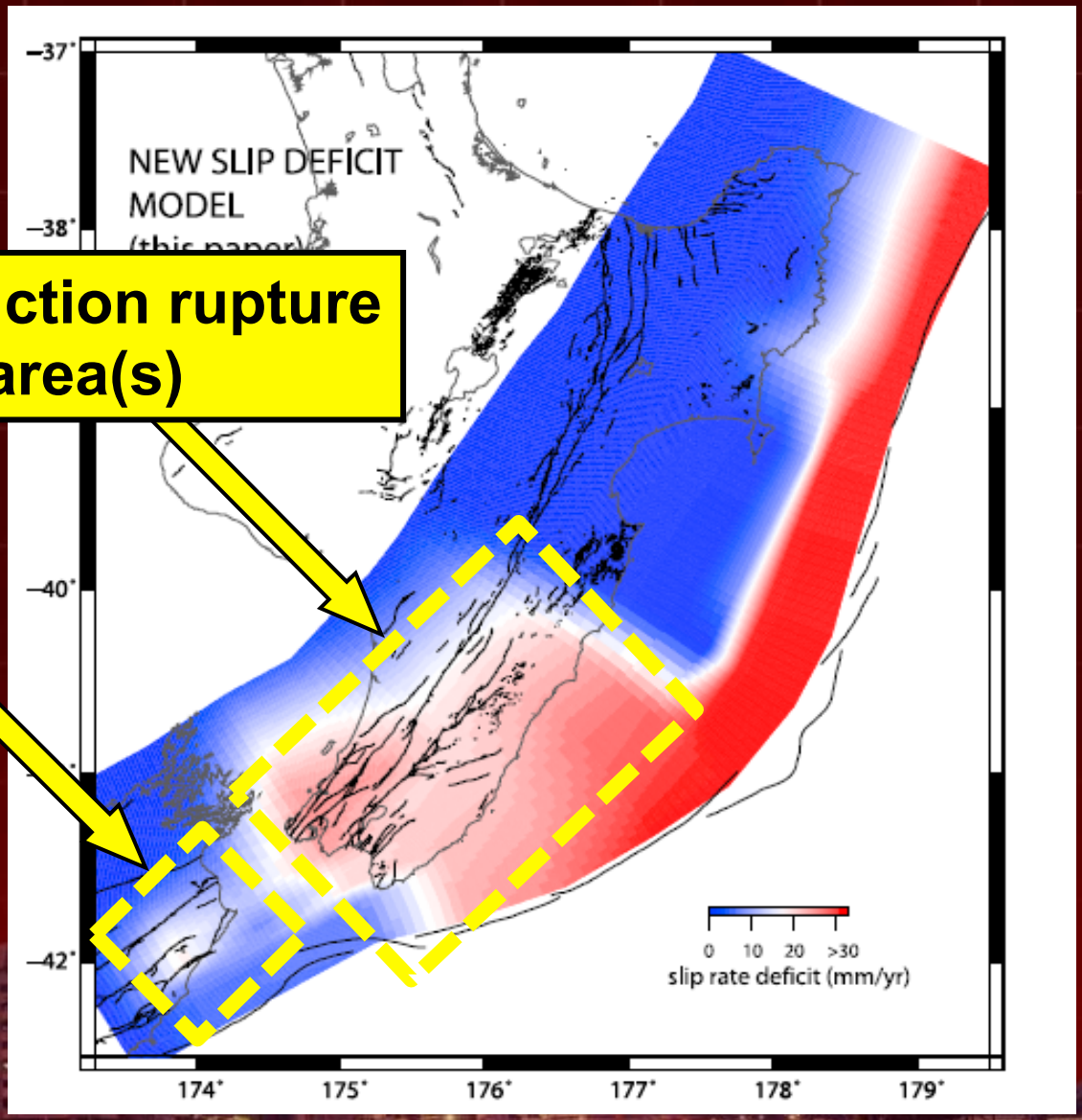
Solve for:

1) Poles of rotation of tectonic blocks &
2) Degree of interseismic coupling on faults in the region (including subduction interface)



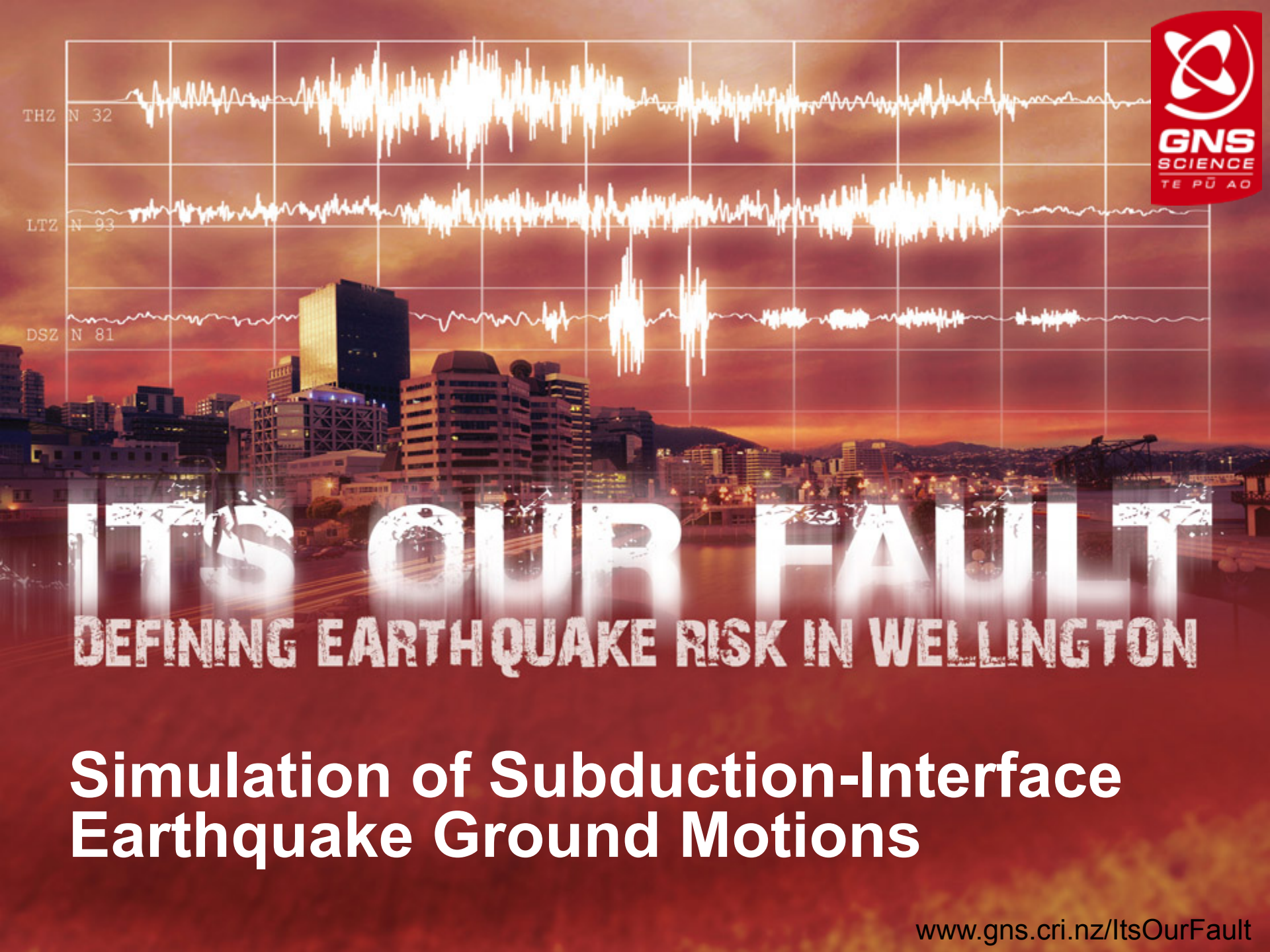
(Wallace et al. JGR)

‘Slip Deficit’ on the Subduction interface



Possible subduction rupture source area(s)

(Wallace et al. JGR)



Simulation of Subduction-Interface Earthquake Ground Motions

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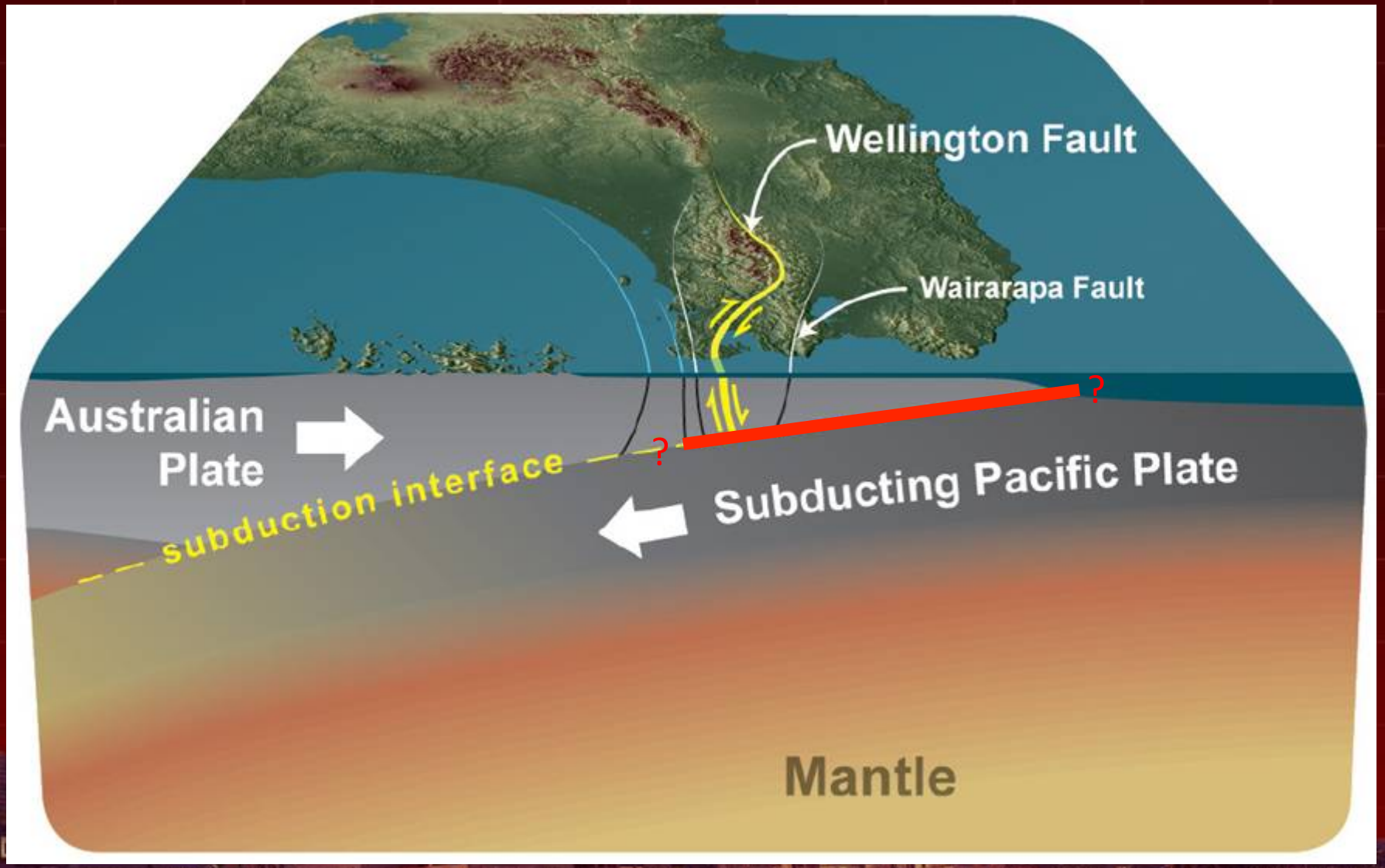
Wellington's Earthquake Setting



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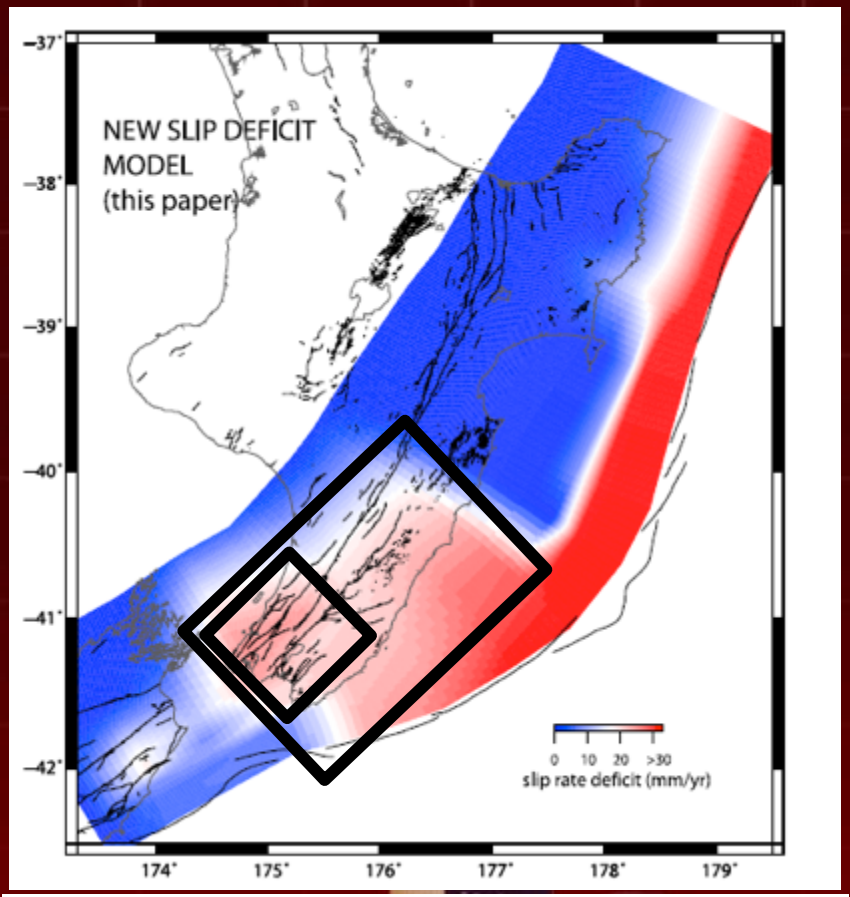
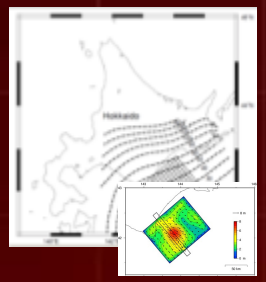
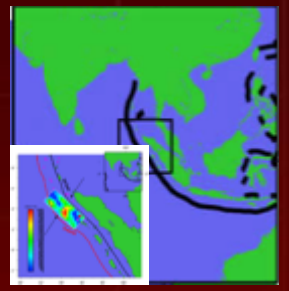


Wallace et al. (2012), Stirling et al. (2012)

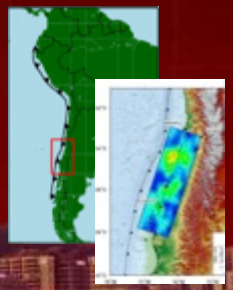
- Simple fault models
- Asperity-like models
- Historical events

2003 Japan Mw 8.3





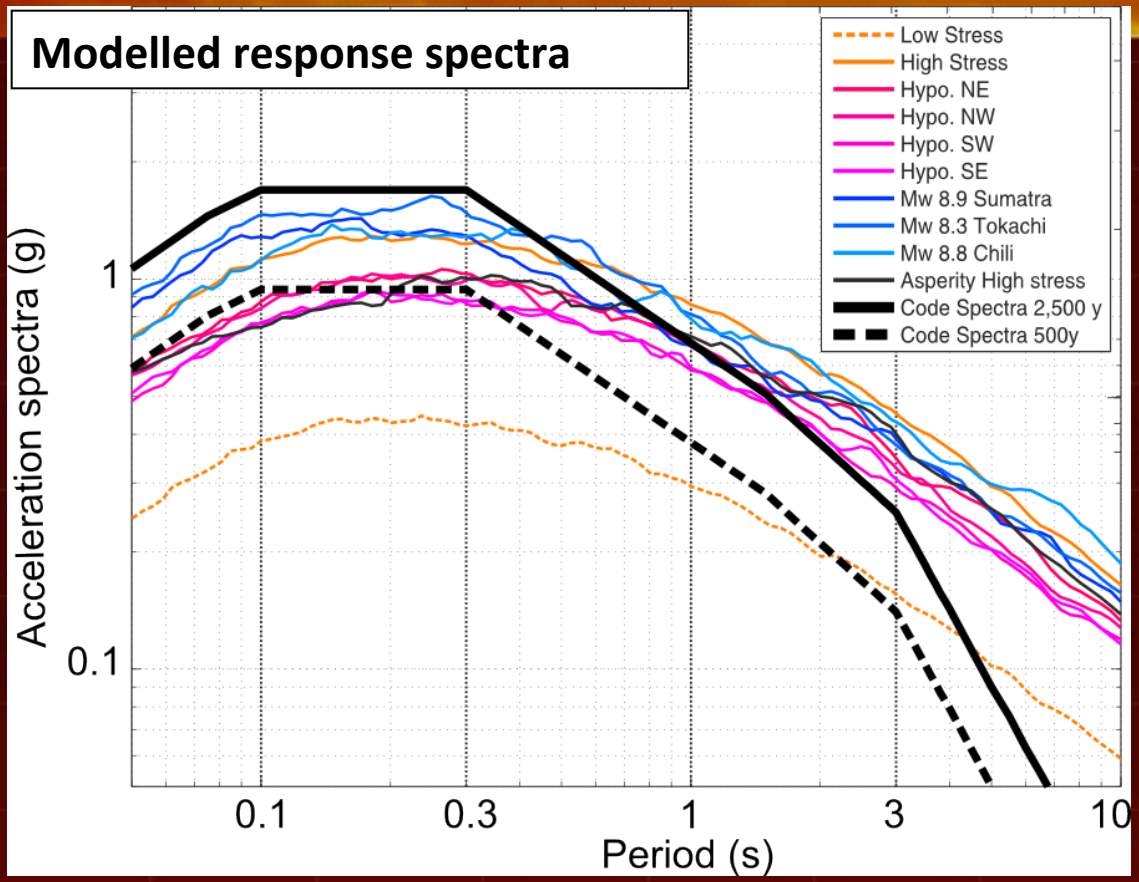
2004 Sumatra Mw 9.1



2010 Chili Mw 8.8

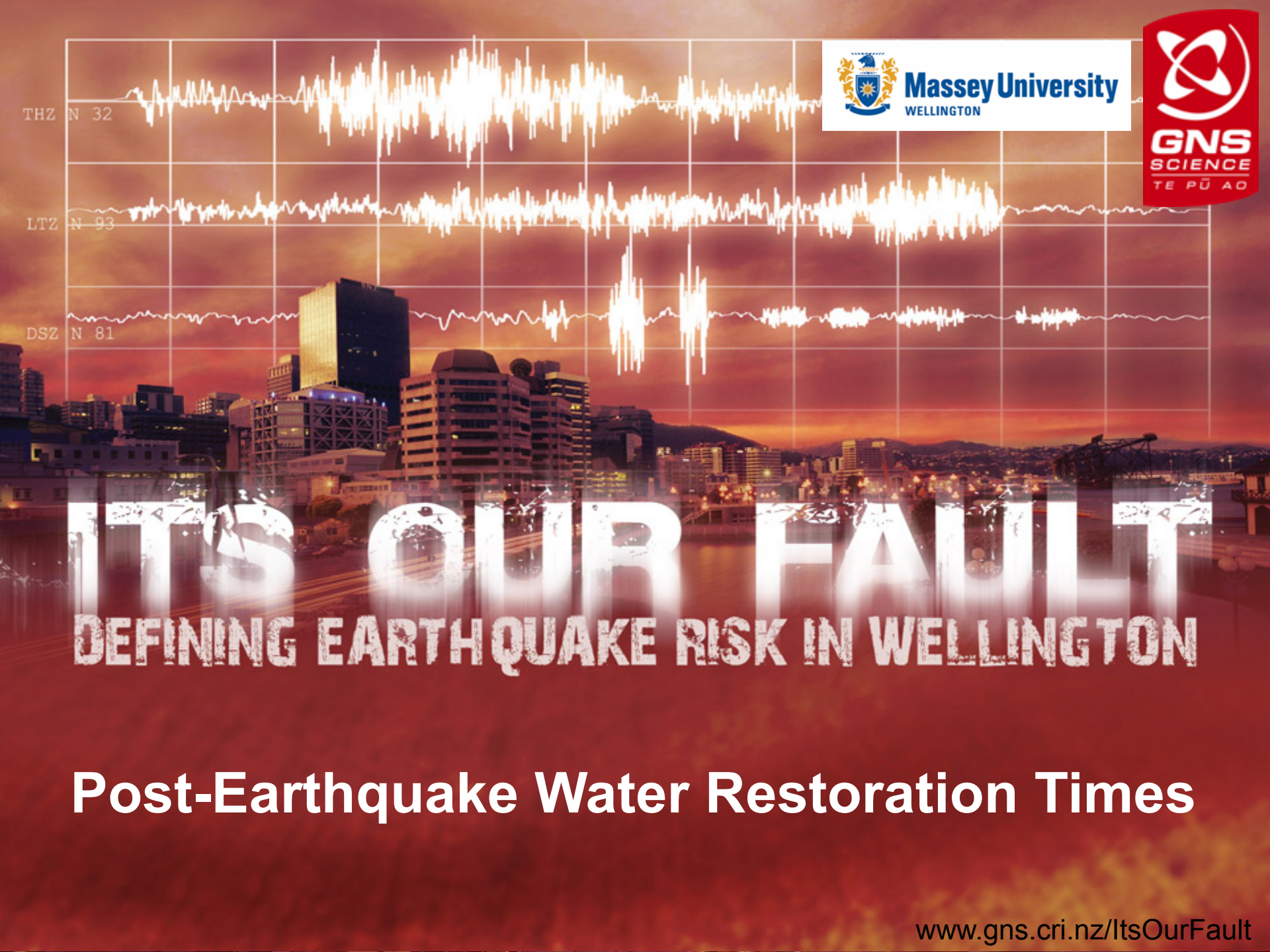
(Holden et al.)

Summary of models



(Holden et al.)

- Segmented (smaller) interface rupture scenarios appear to be largely encompassed by current design spectra
- More extreme (larger) ruptures may exceed current design spectra
- Potential implications with regards to National Seismic Hazard Model currently being investigated

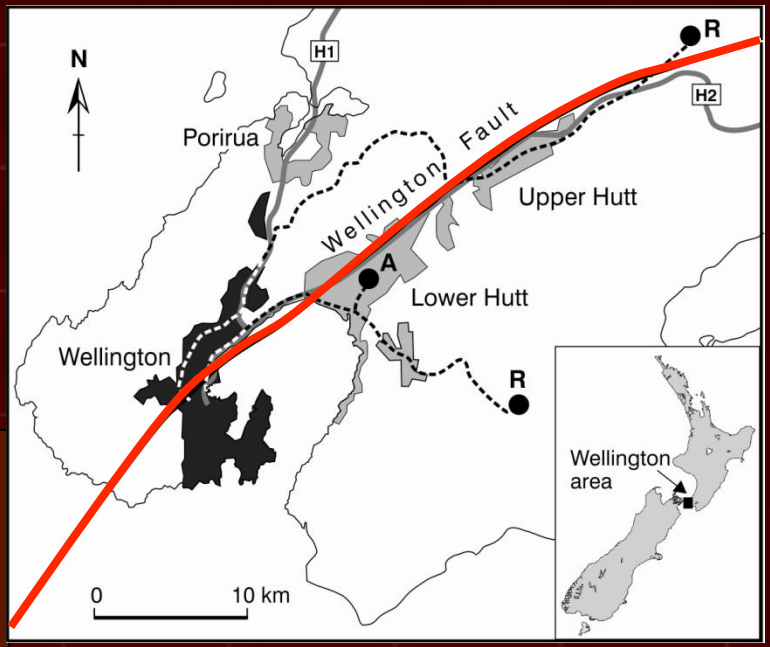


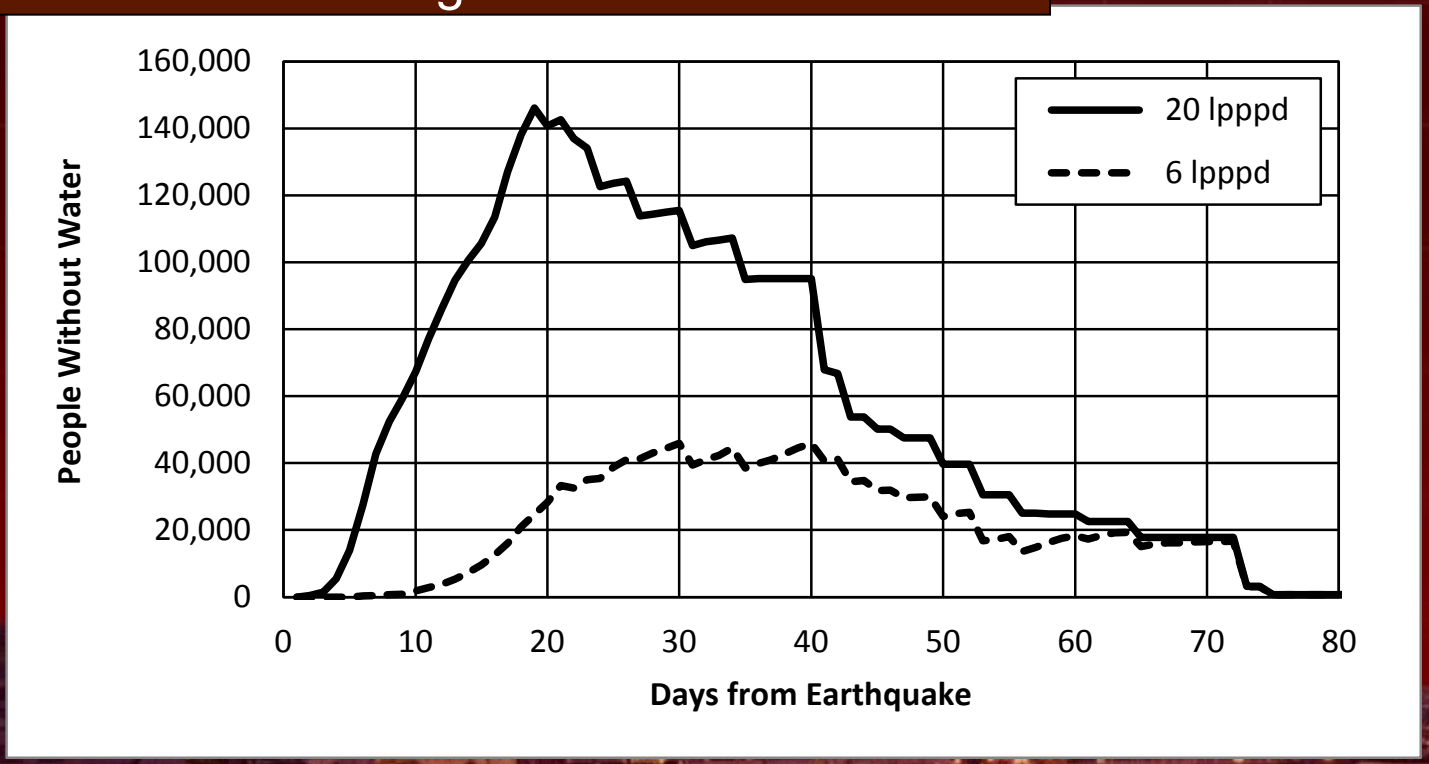
Post-Earthquake Water Restoration Times

www.gns.cri.nz/ItsOurFault

Water Restoration Times

Numbers of people without water in Wellington City following a M 7.5 earthquake on the Wellington-Hutt Valley segment of the Wellington Fault

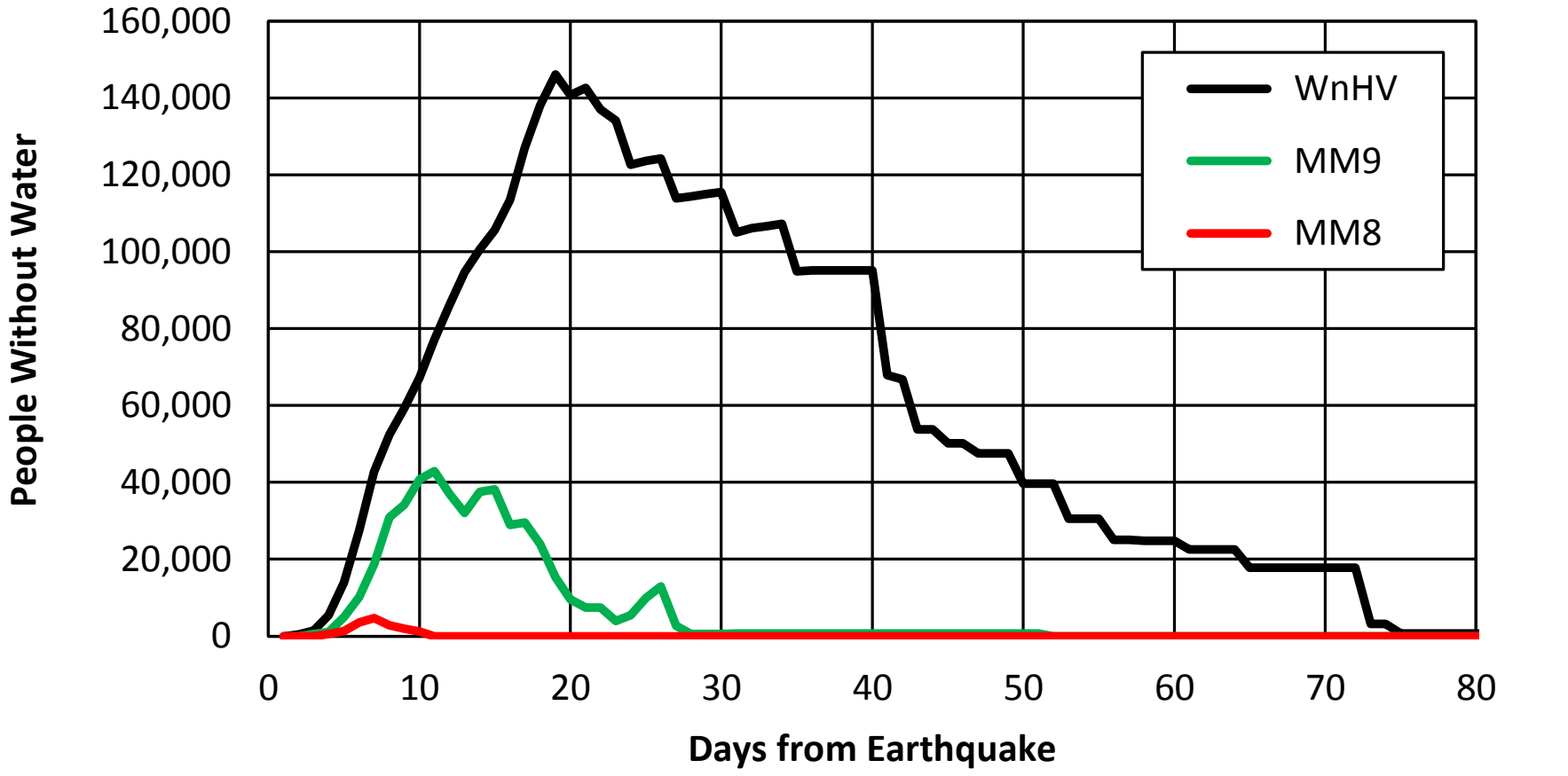




(Cousins et al.)

Water Restoration Times

Numbers of people without water in Wellington City for three major earthquake scenarios



(Cousins et al.)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DEFINING EARTHQUAKE RISK IN WELLINGTON
A Team Effort
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It's Our Fault – Likelihood team

- **Geological Investigations**
  - R. Van Dissen, K. Clark, U. Cochran, M. Hemphill-Haley, R. Langridge, N. Litchfield, N. Pondard, W. Ries, H. Seebeck, P. Villamor
  - P. Barnes, G. Lamarche, J. Mountjoy
  - T. Little, R. Carne, D. Ninis, U. Rieser, E. Schermer, E. Smith
- **Wellington Geodetic & GPS Studies**
  - L. Wallace, J. Beavan, N. Palmer
- **Synthetic Seismicity Modelling**
  - R. Robinson, N. Litchfield, R. Van Dissen
- **Conditional Probability of Rupture of Wellington, Wairarapa & Ohariu Faults**
  - D. Rhoades, R. Langridge, N. Litchfield, R. Robinson, R. Van Dissen, P. Villamor
  - T. Little, R. Carne, D. Ninis, E. Smith
- **Project Facilitation**
  - H. Brackley, K. Berryman, A. King, T. Webb

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It's Our Fault – Effects team

- **Geological, Geotechnical & Subsoil Class Characterisation**
  - G. Dellow, P. Barker, J. Begg, B. Fry, B. Lukovic, M. Keiner, G. McVerry, N. Perrin, M. Rattenbury, B. Stephenson, R. Van Dissen
  - S. Semmens
  - D. Boon
- **Geophysical Parameterisation**
  - B. Fry, P. Barker, R. Benites, Z. Bruce, B. Stephenson
- **Subduction Interface Earthquake Motions**
  - C. Francois-Holden, J. Zhao, G. McVerry
- **Liquefaction**
  - G. Dellow, R. Beetham, M. Keiner, N. Perrin, S. Read. F. Aubertin
  - S. Semmens
- **Ground Motion Modelling**
  - C. Francois-Holden, R. Benites, G. Dellow, B. Fry, A. Kaiser, G. McVerry, J. Zhao
- **Project Facilitation**
  - H. Brackley, K. Berryman, A. King, R. Van Dissen, T. Webb

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It's Our Fault – Impacts team

- **Engineering Stream**

  J. Cousins, R. Buxton, G. Dellow, C. Francois-Holden, A. King, G. McVerry, W. Smith

- **Social Science Stream**

  D. Johnston, J. Beban, J. Becker, W. Saunders, K. Wright

- **Project Facilitation**

  H. Brackley, R. Van Dissen, T. Webb, A. King, K. Berryman

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It's Our Fault – Publications

Project Overview

Van Dissen, R., Barnes, P., Beavan, J., Cousins, J., Dellow, G., Francois-Holden, C., Fry, B., Langridge, R., Litchfield, N., Little, T., McVerry, G., Ninis, D., Rhoades, D., Robinson, R., Saunders, W., Villamor, P., Wilson, K., Barker, P., Berryman, K., Benites, R., Brackley, H., Bradley, B., Carne, R., Cochran, U., Hemphill-Haley, M., King, A., Lamarche, G., Palmer, N., Perrin, N., Pondard, N., Rattenbury, M., Read, S., Semmens, S., Smith, E., Stephenson, W., Wallace, L., Webb, T., Zhao, J., 2010, It's Our Fault: better defining earthquake risk in Wellington. *in proceedings,* 11th IAEG Congress, Auckland, New Zealand, 5-10 September, 2010: 737-746.

Van Dissen, R., Berryman, K., King, A., Webb, T., Brackley, H., Barnes, P., Beavan, J., Benites, R., Barker, P., Carne, R., Cochran, U., Dellow, G., Fry, B., Hemphill-Haley, M., Francois-Holden, C., Lamarche, G., Langridge, R., Litchfield, N., Little, T., McVerry, G., Ninis, D., Palmer, N., Perrin, N., Pondard, N., Semmens, S., Stephenson, W., Robinson, R., Villamor, P., Wallace, L., Wilson, K., 2009, It's Our Fault: Better Defining the Earthquake Risk in Wellington - Results to Date & a Look to the Future. *in proceedings*, New Zealand Society for Earthquake Engineering Technical Conference, Christchurch, New Zealand, 3-5 April, 2009. Paper No. 48, 8p.

Likelihood Phase

Wellington Fault

Langridge, R., Van Dissen, R., Rhoades, D., Villamor, P., Little, T., Litchfield, N., Clark, K., Clark, D., 2011, Five thousand years of surface ruptures on the Wellington fault: implications for recurrence and fault segmentation. *Bulletin of the Seismological Society of America* 101 (5): 2088-2107. doi: 10.1785/0120100340.

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Rhoades, D.A., Van Dissen, R.J., Langridge, R.M., Little, T.A., Ninis, D., Smith, E.G.C., Robinson, R., 2011, Re-evaluation of conditional probability of rupture of the Wellington-Hutt Valley segment of the Wellington Fault. *Bulletin of the New Zealand Society for Earthquake Engineering* 44: 77-86.

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It's Our Fault – Publications

Wairarapa Fault

Carne, R.C., Little, T.A., Rieser, U., 2011, Using displaced river terraces to determine Late Quaternary slip rate for the central Wairarapa Fault at Waiohine River, New Zealand. *New Zealand Journal of Geology and Geophysics* 54 (2): 217-236. doi: 10.1080/00288306.2010.532224.

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Schermer, E.R., Little, T.A., Rieser, U., 2009, Quaternary deformation along the Wharekauhau fault system, North Island, New Zealand: Implications for an unstable linkage between active strike-slip and thrust faults. *Tectonics* 28: TC6008, doi:10.1029/2008TC002426.

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Cook Strait active faulting

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Pondard, N., Barnes, P.M., 2010, Structure and paleoearthquake records of active submarine faults, Cook Strait, New Zealand: Implications for fault interactions, stress loading, and seismic hazard. *Journal of Geophysical Research* 115, B12320. doi:10.1029/2010JB007781.

Subduction zone earthquake geology & geodesy

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Clark, K., Hayward, B., Cochran, U., Grenfell, H. R., Hemphill-Haley, E., Mildenhall, D., Hemphill-Haley, M., Wallace, L., 2011, Investigating subduction earthquake geology along the southern Hikurangi margin using paleoenvironmental histories of intertidal inlets. New Zealand *Journal of Geology and Geophysics* 54 (3): 255-271.

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Wallace, L.M., Barnes, P., Beavan, J., Van Dissen, R.J., Litchfield, N.J., Mountjoy, J., Langridge, R.M., Lamarche, G., Pondard, N., 2012. The kinematics of a transition from subduction to strike-slip: an example from the central New Zealand plate boundary. *Journal of Geophysical Research* 117, B02405, doi:10.1029/2011JB008640

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It's Our Fault – Publications

Wellington region synthetic seismicity

Robinson, R., Van Dissen, R., Litchfield, N., 2011, Using synthetic seismicity to evaluate seismic hazard in the Wellington region, New Zealand. *Geophysical Journal International*: doi: 10.1111/j.1365-246X.2011.05161.x.

Robinson, R., Van Dissen, R., Litchfield, N., 2009, It's Our Fault – synthetic seismicity of the Wellington region: final report. *GNS Science Consultancy Report* 2009/192: 36 p.

Effects Phase

Wellington & Lower Hutt geological & geotechnical characterisation

Boon, D., Perrin, N.D., Dellow, G.D., Van Dissen, R., Lukovic, B., 2011, NZS1170.5:2004 site subsoil classification of Lower Hutt. *in proceedings*, 9th Pacific Conference on Earthquake Engineering, Auckland, New Zealand, 14-16 April, 2011: Paper 013, 8 p.

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Semmens, S., Perrin, N.D., Dellow, G., Van Dissen, R., 2011, NZS 1170.5:2004 site subsoil classification of Wellington City. *in proceedings*, 9th Pacific Conference on Earthquake Engineering, Auckland, New Zealand, 14-16 April, 2011: Paper 007, 8 p.

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Holden, C., Zhao, J., 2011. Modelling strong ground motions for subduction events in the Wellington region, New Zealand. *in proceedings*, 9th Pacific Conference on Earthquake Engineering, Auckland, New Zealand, 14-16 April, 2011: Paper 229.

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It's Our Fault – Publications

Impacts Phase

Aftershock hazard

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Engineering component

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Social Science component

Beban, J.G., Coomer, M.A., McBride, S., 2012, Addressing earthquake hazards – a review of council policy and plans within the Wellington region. *GNS Science Report* 2012/31: 52 p.

Johnston, D.M., McClure, J., Becker, J.S., Paton, D., Finnis, K., Leonard, G.L., Wright, K., in review, Community understanding of earthquake and tsunami risk in Wellington, New Zealand. Cities at Risk: Living with Perils in the 21st Century, Risk Perceptions and Behaviours: submitted.

Johnson, D., Coomer, M., McClure, J., Becker, J., Wright, K., 2011, A bibliography of social research on the earthquake risk in Wellington, New Zealand: 1848 to 2010. *GNS Science Report* 2011/11: 26p.

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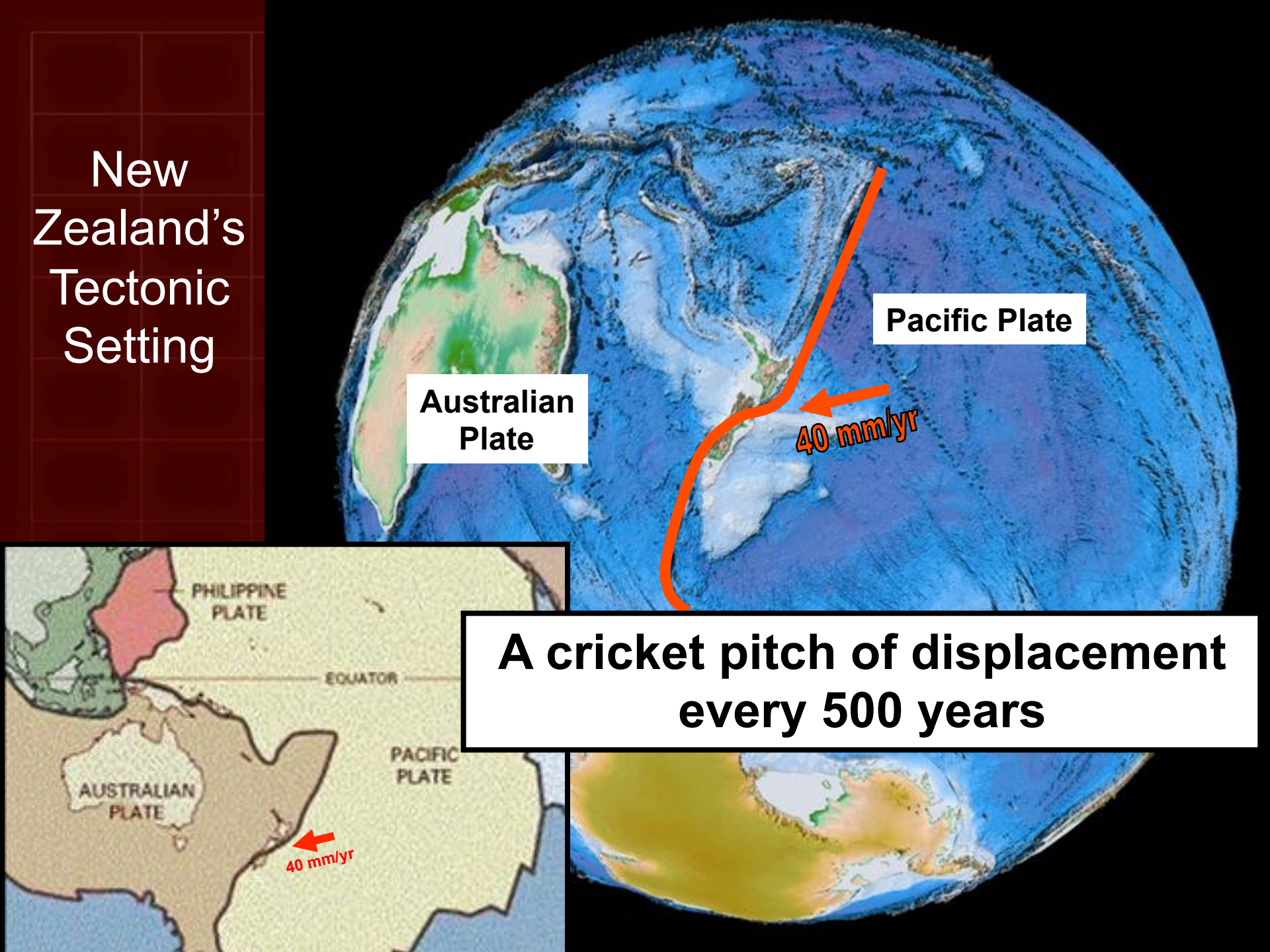
www.gns.cri.nz/ItsOurFault

Russ Van Dissen (on behalf of the It's Our Fault Team)

GeoPRISMS Planning Workshop for New Zealand, April 2013

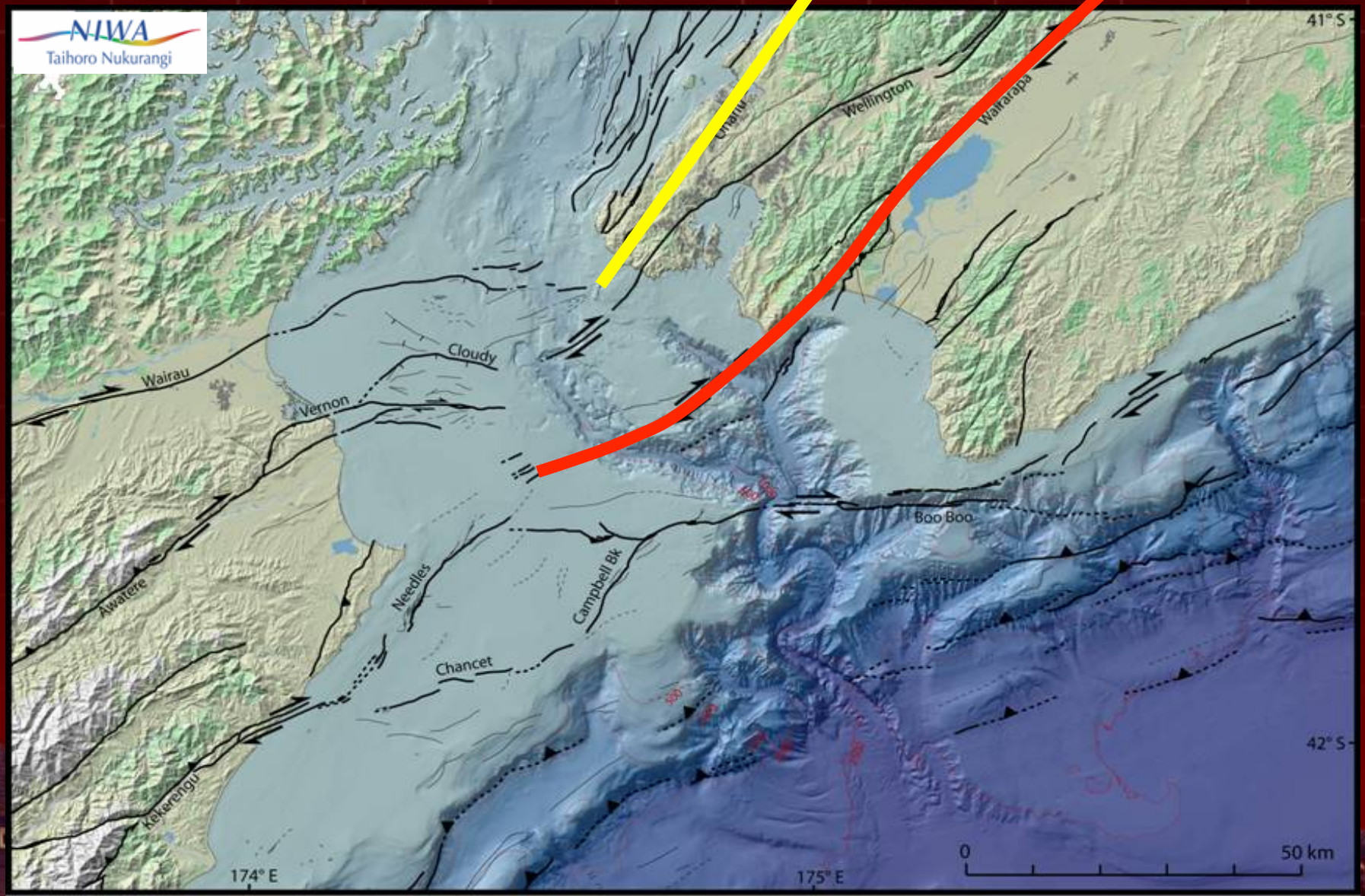
www.gns.cri.nz/ItsOurFault

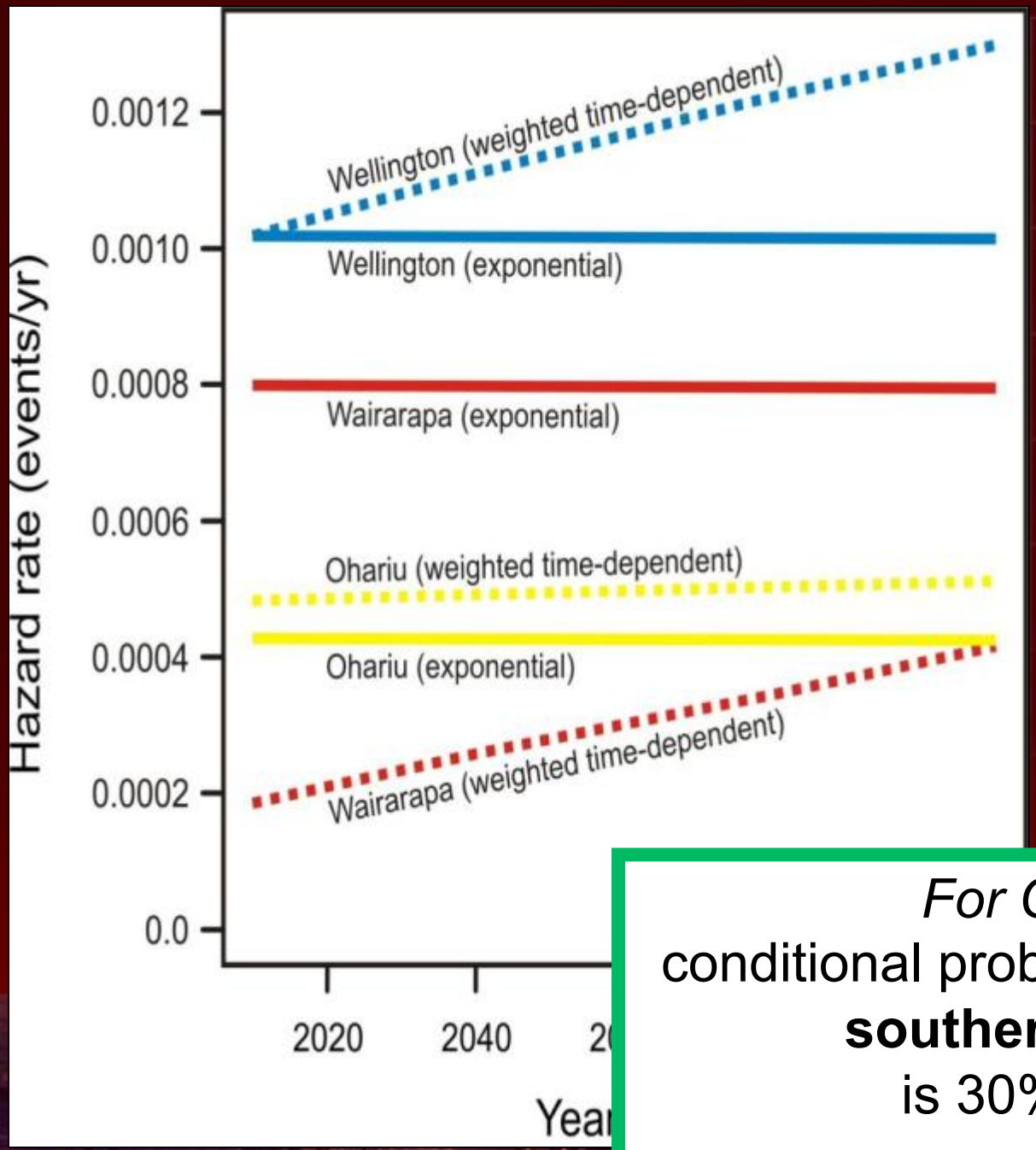
New Zealand's Tectonic Setting



A cricket pitch of displacement every 500 years

Conditional probability of ruputre of the Ohariu Fault & Wairarapa Fault





Results

Comparison of hazard of rupture over the next 100 years for the:

Wellington Fault (blue)

Wairarapa Fault (red)

Ohariu Fault (yellow)

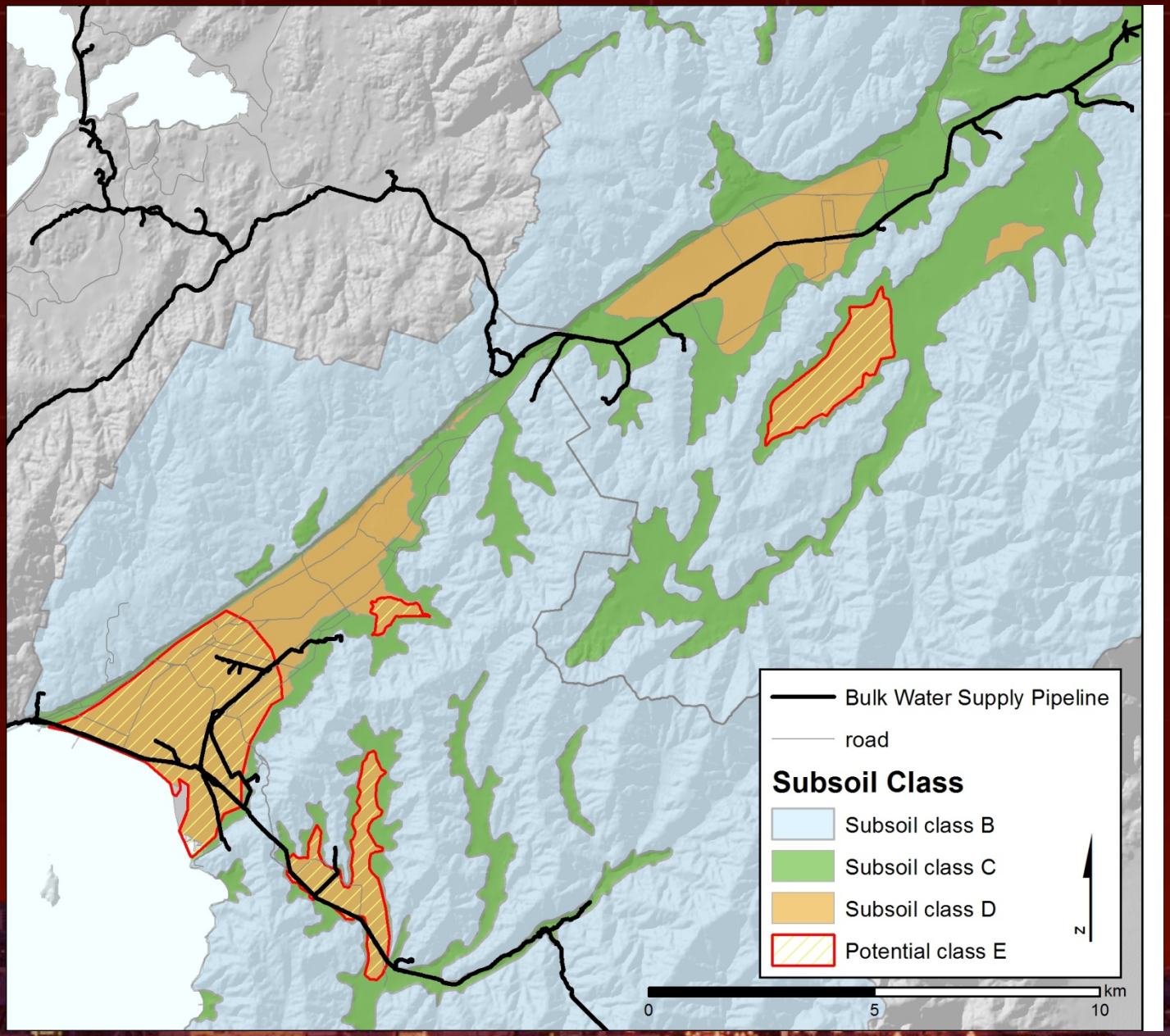
For Comparison:
conditional probability of rupture of the **southern Alpine Fault** is 30% in 50 years

(Berryman et al. Science)

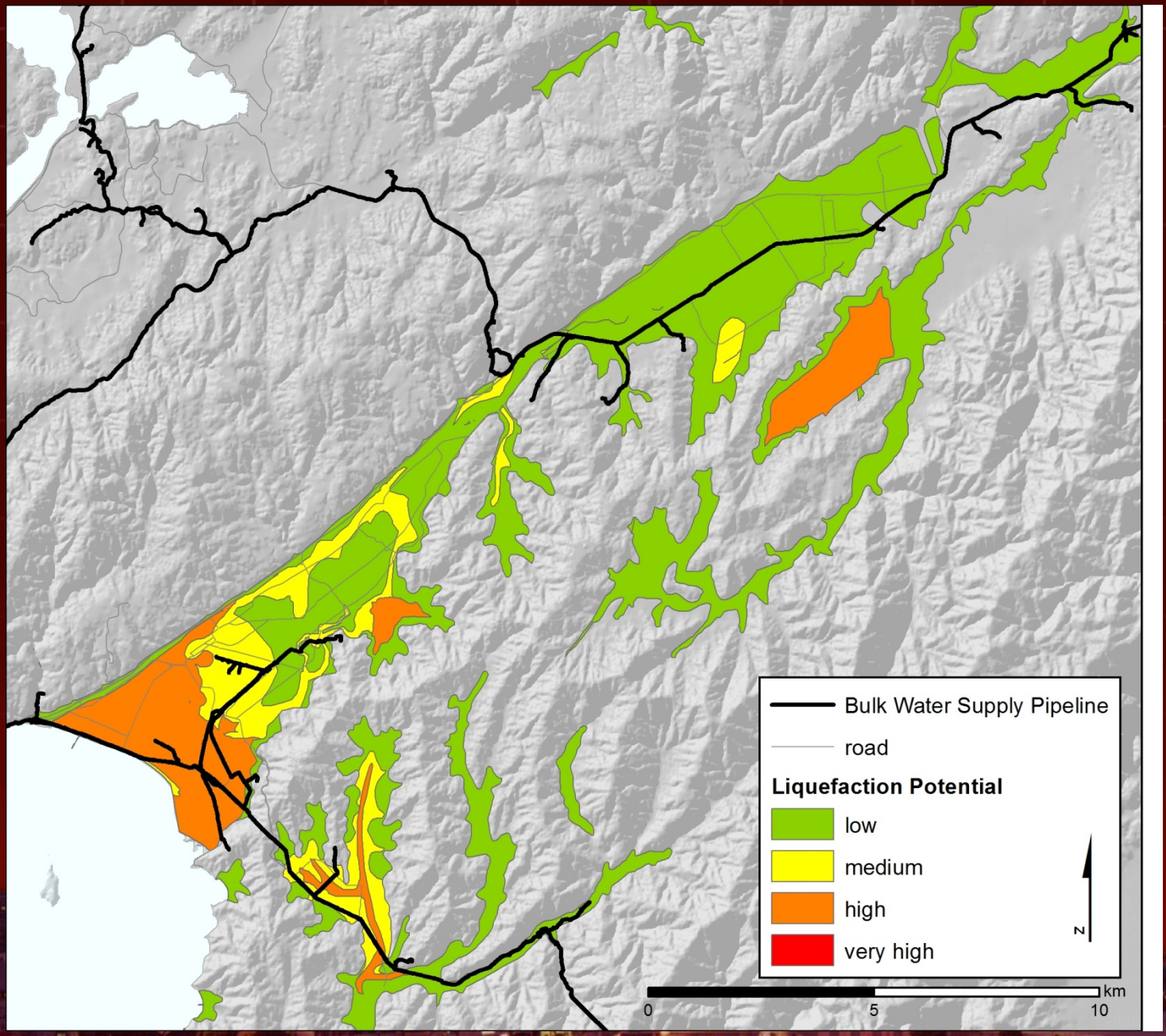
Ground shaking subsoil class & liquefaction susceptibility

www.gns.cri.nz/ItsOurFault

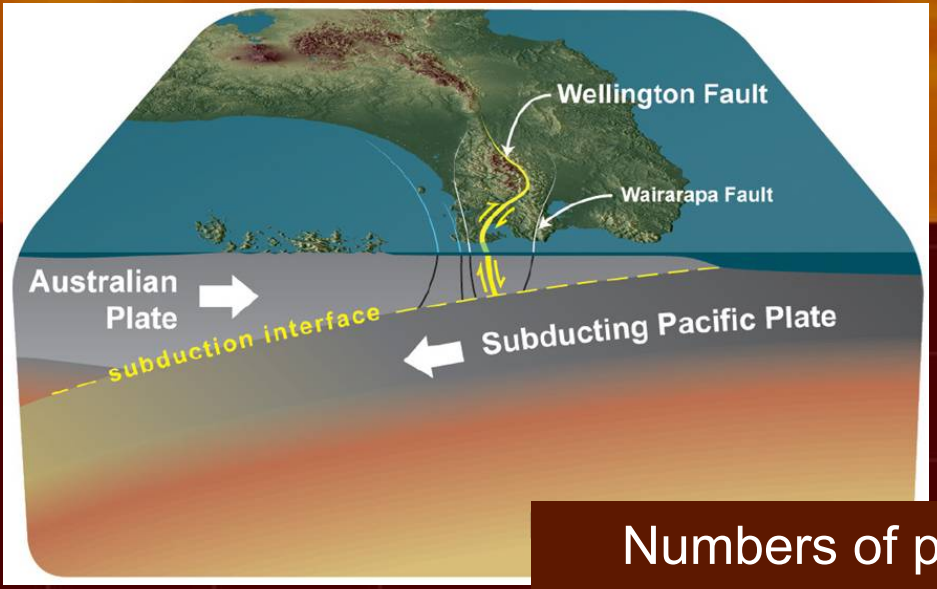
Hutt Valley - Subsoil Class



Hutt Valley - Liquefaction Susceptibility



Post-Earthquake Sheltering Needs



Post-earthquake Sheltering Needs

Numbers of people in buildings in various damage states for buildings OUTSIDE the tsunami evacuation (Yellow Zone), and numbers of people INSIDE the Yellow Zone who are assumed to have self-evacuated

Building Use	DS, None	DS, Light	DS, Moderate	DS, Heavy	DS, Severe	DS, Collapse	Yellow Zone
Dwelling	100,265	134,445	84,663	29,201	3231	1088	68,556
Apartment	3623	3399	2080	788	57	8	5626
Hotel/Motel	684	991	418	272	141	0	1855
Rest-home	1447	1630	1299	456	32	21	617
Hospital/Clinic	3846	2168	703	67	0	0	111
Non-residential	1234	1689	918	414	54	29	3446
Total	111,099	144,322	90,081	31,198	3515	1146	80,211