



QuakeCoRE FP2 Meeting  
21 March 2017

## Damage in Wellington Waterfront Area following the 2016 Kaikoura Earthquake

University of Auckland Reconnaissance Team

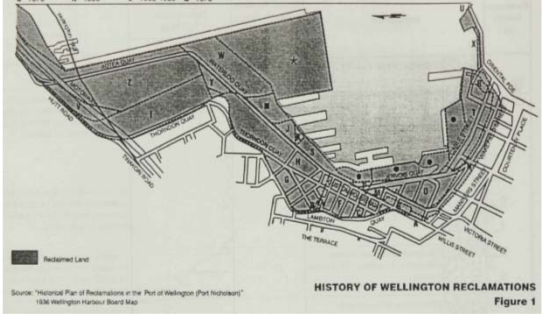
  
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 FACULTY OF ENGINEERING

### History of Reclamation

  
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LEGEND (Date of Reclamation Construction)


A 1852	H 1876	D 1889	V 1904	● 1972
B 1857-1863	I 1882	P 1893	W 1904-1916	● 1968
C 1859	J 1882	Q 1893-1901	X 1906	
D 1864	K 1882	R 1895	T 1916-1913	
E 1865	L 1884	S 1901-1903	Z 1924-1932	
F 1865-1867	M 1885	T 1901-1914	* 1972	
G 1870	N 1885	U 1903-1925	■ 1972	



HISTORY OF WELLINGTON RECLAMATIONS  
Figure 1

(from Murashev and Palmer 1998) 2


### Typical Soil Profile

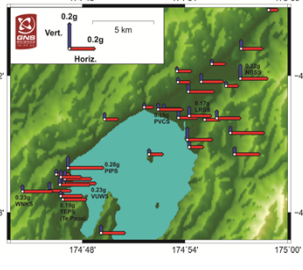
  
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Example Depth (m)	Description	Typical Standard Penetration Test Data (Blows / 300mm)	Typical Cone Penetrometer Test Data (Cone Resistance (kN))	Geotechnical Assessment
1	Compact Gravel FILL	10 - 20		This competent crust
2	End-tipped gravel fill (dense GRAVEL with silt and sand)	2 - 10		Generally coarse and free draining giving low liquefaction potential. However, earthquakes induced settlement could be expected on severe shaking.
3	CR			
4				
5	Hydraulic fill (very loose SAND and soft silt)	0 - 4		Sands have been assessed to have high liquefaction potential. A potential for lateral spreading on soft silts or liquefied sands identified at some sites.
6				
7	Holocene beach and marine sediments (compact SAND loose for parts)	15 - 30		Generally found to be compact with relatively low liquefaction potential. However, locally the beach sands have been found to be loose with a moderate liquefaction potential.
8				
9	Pleistocene silt/clay and colluvium (dense GRAVEL with sand and silt interbedded with lenses of soft SILT)	30 - 50 (Gravel)		Gravels provide bearing stratum for piles. Design needs to consider effect of settlement on pile settlement and bearing capacity.
10				
11		15 - 30 (Silt)		
12				
13				
14				
15				
16				
120	Gyreswacke bedrock			

(from Murashev and Palmer 1998) 3

### Strong Motion Record

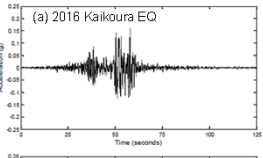
  
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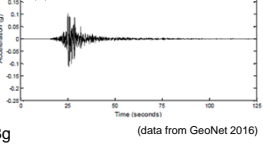
(from Little 2016)

#### FKPS station (N-S component)

(a) 2016 Kaikoura EQ



(b) 2013 Cook Strait EQ





(data from GeoNet 2016)

- Victoria University Law School (VUWS): 0.23g
- Te Papa Museum (TEPS): 0.19g
- Frank Kitts Park (FKPS): 0.19g
- BNZ building (CPLB): 0.25g

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### UoA Recon Route (16-18 Nov 2016)

  
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Google

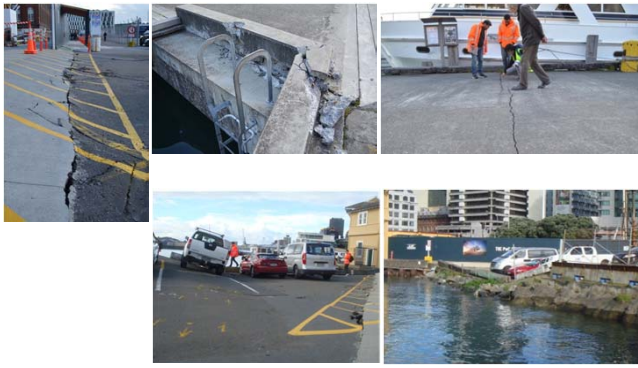
### Condition at Zone A

  
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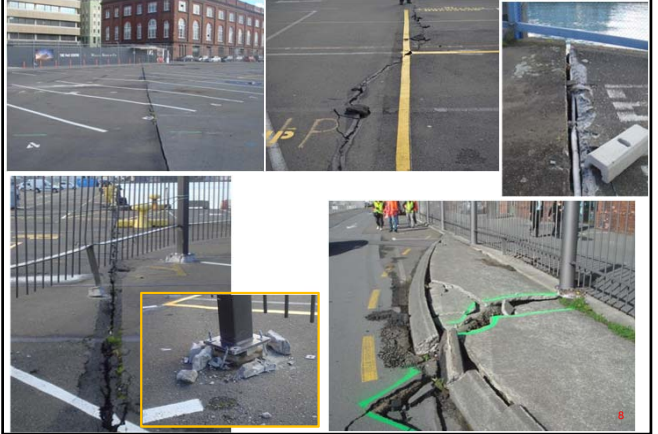
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### Condition at Zone B



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### Condition at Zone B



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### Condition at Zone B



9

### Condition at Zone B



#### BNZ Bldg.

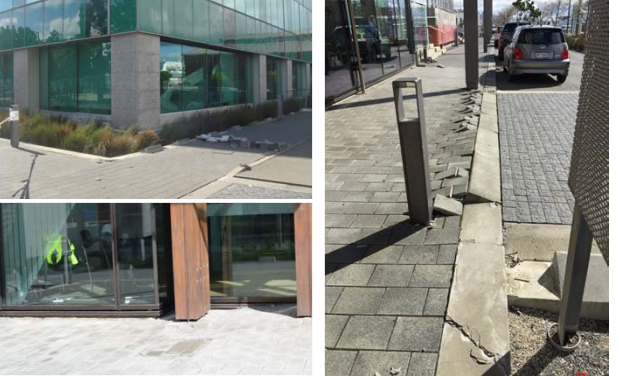


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### Condition at Zone B



#### Statistics NZ Bldg.

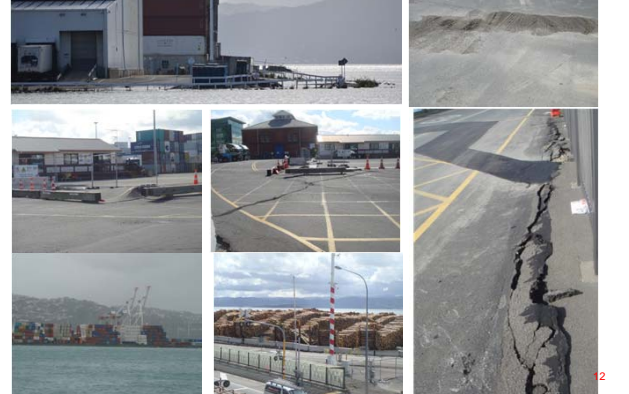


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### Condition at CentrePort



#### View from outside



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### Condition at CentrePort

View from inside (c/o TV3 footages)

CentrePort, Wellington

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### Condition at CentrePort

Following 2013 Cook Strait EQ (from Hancock et al. 2013)

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### Condition at CentrePort

Following 2013 Cook Strait EQ

(from Hancock et al. 2013)

### Performance of Improved Ground

Te Papa Museum (from Palmer 2006)

2013 condition (after Hancock et al. 2013)

### Performance of Improved Ground

Westpac Stadium (from Palmer 2006)

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### Other Observed Damage

Bldg @ 61 Molesworth St.

Photo by Times Colonist

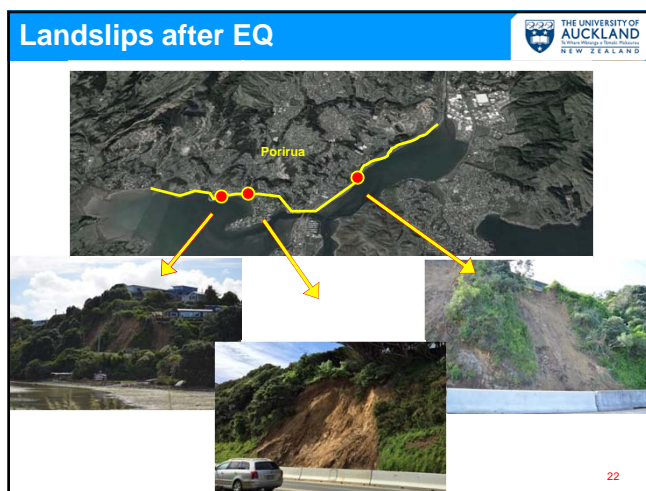
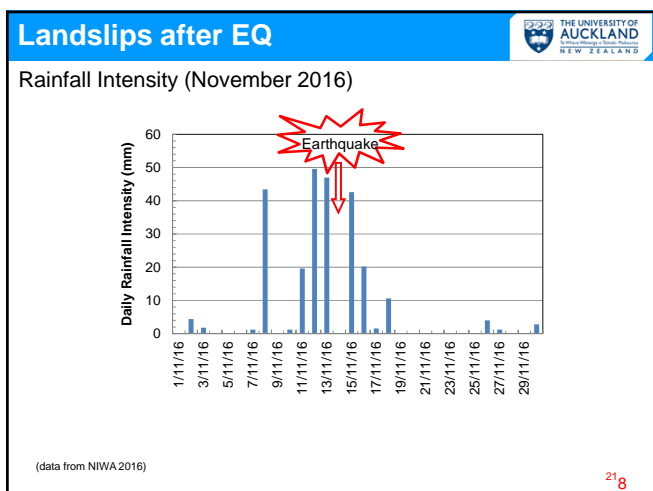
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## Other Observed Damage

### Shell Gully Bridge

## Other Observed Damage

### Wellington CBD



## Summary (1/2)

- Based on the history of Wellington reclamation, ground damage in the form of cracks, ground settlement and fissures, appeared to be **concentrated in recently reclaimed areas, as late as in the 1970s**. Liquefaction-induced ground damage in Wellington was concentrated in the waterfront area north of the Queens Wharf Building.
- Although CentrePort was not accessible, **significant damage can be observed even from outside the port, possibly as a result of soil liquefaction**. Ground subsidence, cracks, differential settlements and other forms of ground movements have been observed within the port. Detailed investigation is recommended to examine the behaviour of the gravelly fill materials.
- Ground adjacent to buildings along the waterfront, such as near the BNZ building, Customhouse building, and Statistics NZ building, **showed evidence of moderate settlement**. Pavement buckling and cracking were also observed. These were mainly the result of ground oscillation and possible densification of the weak embankment fill, but liquefaction may have contributed in some instances.

## Summary (2/2)

- The **improved ground sites** at the location of Te Papa Museum and Westpac Stadium **performed well**, with no significant damage observed; minor ground failure was noted at the boundary between the improved and non-improved grounds of Westpac stadium. It is possible that **these sites were not really tested**, because of the low PGAs experienced by the area.
- The PGAs recorded in this event were **more or less similar to those observed following the 2013 earthquake sequence**; however, the longer duration of shaking and, consequently, the larger number of significant cycles may have contributed to greater liquefaction-induced ground damage observed in this event, especially in the unimproved ground at the CentrePort.
- The heavy rainfall** that occurred immediately before and after the earthquake exacerbated the situation, with several landslips occurring along Paremata Road, Porirua Town. The debris blocked the road and caused significant secondary problems, especially in the aftermath of the quake and succeeding aftershocks.