

Rotorua Museum Seismic Upgrade Stage 1A – Data Collection Geotechnical Desk Study

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Published Data – Natural Hazards

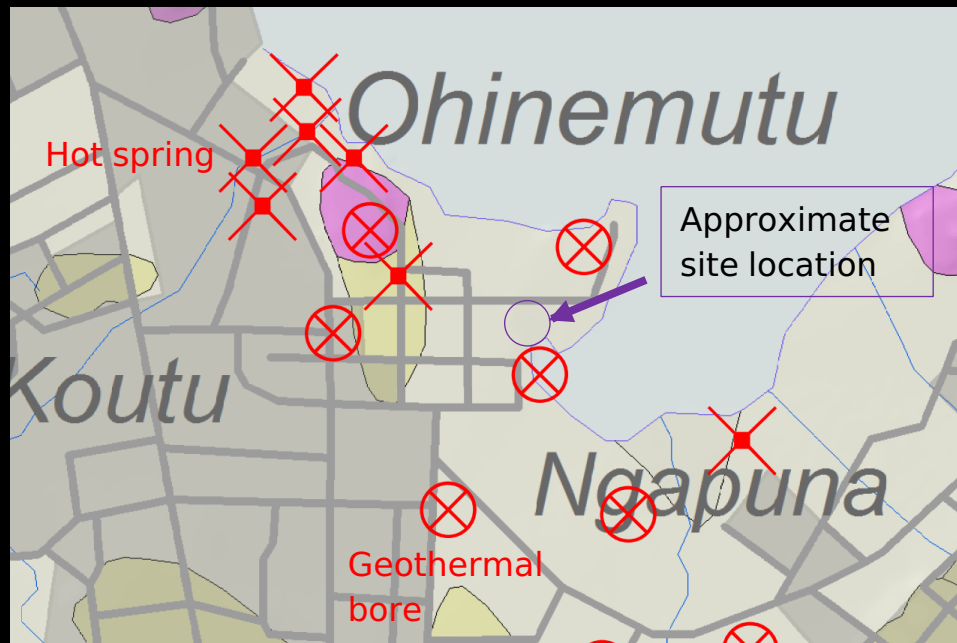
- The GIS map¹ indicates the following potential natural hazards:
 - Existing geothermal field suitable for urban use
 - Presence of soft ground (Holocene swamp deposits and Holocene lake or delta sediments)
- Moderate liquefaction susceptibility²

¹ http://geodev.rdc.govt.nz/HTML5_EXT/Index.html?viewer=GeyserView

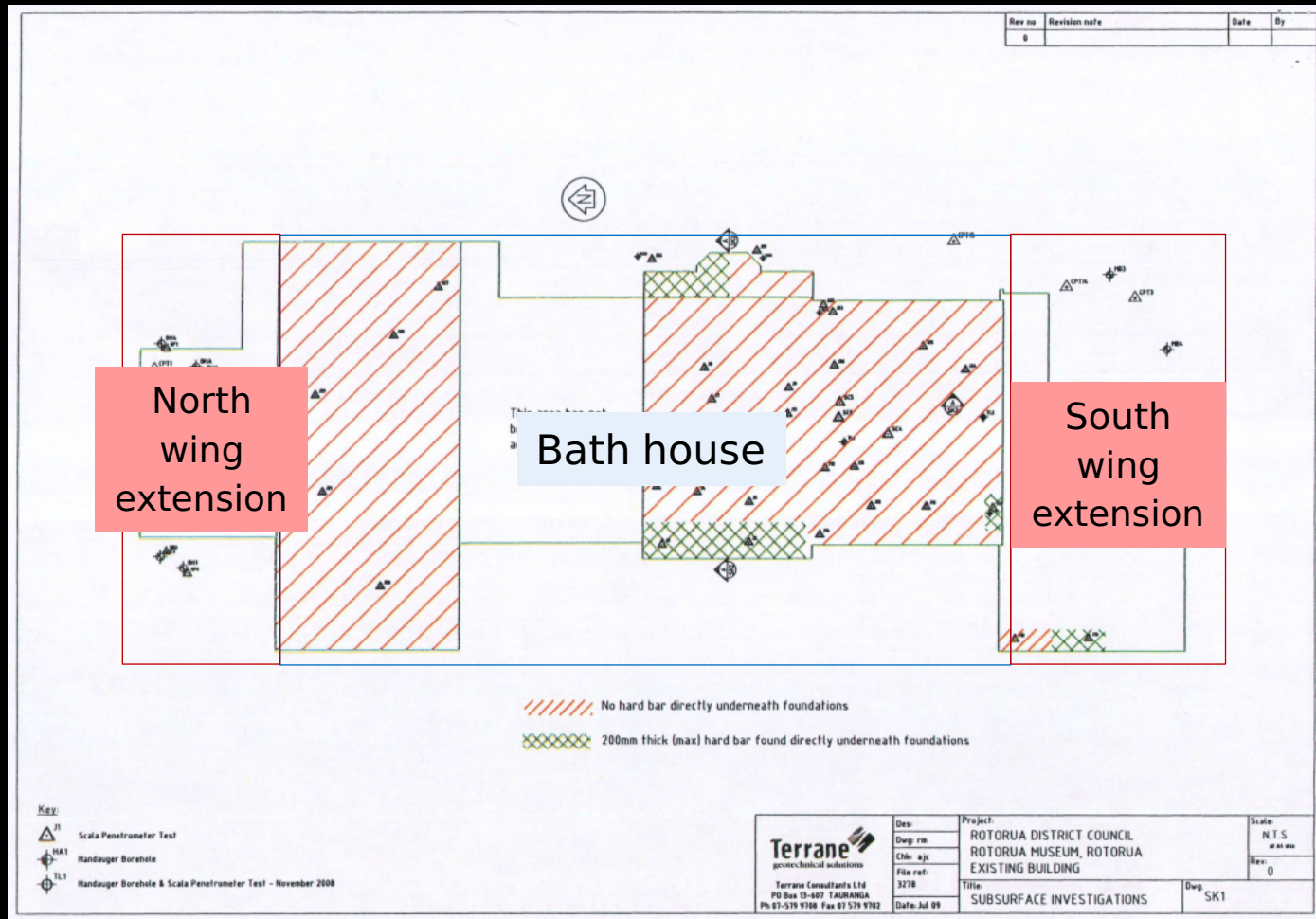
² Institute of Geological & Nuclear Sciences Limited (1999), Liquefaction Hazard within the Environment BOP region, Scale 1:500 000

Published Data – Site Geology

The published geology for the site indicates the site is, in general, underlain by Holocene river deposits comprises alluvial gravel, sand, silt, mud and clay with local peat, includes modern river beds.



Geotechnical Desk Study



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Bath House

- Constructed in 1906-1907
- No records of subsurface information from the original design
- Soil investigation carried out by Kerslake and Partners in 1985-1986
 - Unknown purpose
 - Only partially available information
- Earthquake strengthening project 2008 – 2010
 - Geotechnical design by Terrane Consultants Ltd
 - Structural design by Sigma Consultants Ltd
 - Geotechnical design peer review by ICE GEO & CIVIL Ltd

Bath House – seismic strengthening 2008/2010, available information

- Terrane (2009), *“Rotorua bathhouse/museum building, Rotorua, Investigation of existing foundations”*, ref. 3278.02-01, 30 July 2009
- GNS Science (2009), *“Petrological Study of Samples Excavated from the Rotorua Museum Construction Site”*, 27 July 2009
- Terrane (2009), *“Rotorua Museum Building, Queens Drive: Existing Building, Geotechnical Engineering Inputs, ref. 3278.02.r2, 11 August 2009*
- ICE GEO & CIVIL (2010), *“Rotorua Museum Existing Building Remediation: Geotechnical Peer Review, 24 March 2010*
- Sigma (2010), *“Rotorua museum of art and history – Earthquake prone building assessment”*, 14 May 2010
- Terrane (2010), *“Rotorua District Council, Rotorua Museum Building, Foundation Strengthening Project, Geotechnical Factual Report”*, ref. 3278.02FactRep.doc, 14 May 2010
- Terrane (2010), *“Rotorua Museum Building: Foundation Strengthening Project, Tarawera Gallery Injection Grouting – Completion Report, ref. 3278.02-06, 23 August 2010*

Bath House – seismic strengthening 2008/2010, available information

- Soil investigation consists of scala penetration tests (≈ 57 no), trial pits (≈ 11 no), hand augers (≈ 4 no), machine drilled boreholes (≈ 9 no), CPTs (≈ 4 no) and laboratory tests was carried out as a part of seismic strengthening project and South/North wing extension design in 2008 - 2010.

Majority

of in-situ soil investigation was supervised by Terrane Consultants Ltd

- Laboratory tests consist of Bulk density and void ratio test (9no), CD Triaxial test (2no), UU Triaxial test (2no), pH and Sulphate test (2no)

- Geothermal investigation by GNS Science Ltd in 2008 - 2009

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Bath House – seismic strengthening 2008/2010, soil investigation results

- The foundations of the original part of the Museum building are underlain by highly variable, soft to extremely soft soils to a depth of approximately 2.9m in the south-western corner, 1.8m in the south-eastern corner and central parts and 1.2m to 2.0m at the northern part. Under the central and northern part the low strength soil comprise sensitive geothermally altered pumiceous silt. GNS identified silica sinter, 0.3m to 0.5m BGL
- The ground conditions underneath the building being more adverse than beyond the external walls
- The soil would be classified as having a collapsible structure

Bath House – seismic strengthening 2008/2010, soil investigation results

- The underlain soil contains cavities
- HA encountered warm to hot ground already around 1.7m BGL
- The rock samples tested by GNS were pieces of silica sinter deposited from a geothermal hot-spring
- Samples were pristine (intact), fragile, unmodified or unaltered subsequent to their formation

Bath House – seismic strengthening 2008/2010, mitigation measures

- Terrain proposed injection grouting below the existing building
- Peer review (ICE GEO&CIVIL) in general agreed with Terrain design with the following comments:
 - Field trials needs to be performed
 - The effect of the grouted mass on the ground surface temperature under the museum needs to be assessed
 - The possible effects on the hydrothermal pressures under and around the grouted mass need to be considered
 - The long term durability of the grout under sulphate and acid attack needs to be determined (including the possibility of ground swelling)
- There was not found any reply of Terrain to ICE GEO&CIVIL

Bath House – seismic strengthening 2008/2010, mitigation measures

- There is existing document of performed injection grouting below Tarawera Gallery - Terrane (2010), *“Rotorua Museum Building: Foundation Strengthening Project, Tarawera Gallery Injection Grouting – Completion Report, ref. 3278.02-06, 23 August 2010*
- The grouting was undertaken between 7 April and 14 June 2010 by Grouting Services Ltd
- The grouting had three passes – 2.5 to 6m (non-pressure), 0.3 to 3m (pressure 30 psi) and 0 to 0.7m (non-pressure)
- The report concludes that the grouting was successful based on the inspections by Terrain and information from contractor

South Wing Extension 2007-2011/12

- available information

- Terrane (2007), *“Rotorua Museum of art and history, Rotorua, Southern extension – cost estimate, ref. 3278, 24 September 2007*
- Terrane (2007), *“Southern extension, Rotorua Museum of art and history, Rotorua – Interim assessment report, ref. 3278, 5 October 2007*
- Terrane (2009), *“Rotorua Bath House, Government Gardens, Rotorua, Proposed South Wing Extension, Geotechnical Design Report”, ref. 3278.SouthExt.desrep, 27 May 2009*
- ICE GEO & CIVIL (2009), *“Rotorua Museum South Wing Extension: Geotechnical Peer Review, 24 June 2009*
- Transmittal to Sigma Consultants from Terrane, *Rotorua Museum Southern Extension, Progress report to 17 November 09, 18 November 2009*

South Wing Extension 2007-2011/12

- available information

- In overall summary, the southern end is affected by an onerous combination of poor ground conditions and an active geothermal system (Ground conditions seem to be worse than in Rotorua Events Centre)
- The soil is high to very highly compressible up to 7m below existing ground level (before construction)
- Groundwater was encountered approximately 3.0 to 3.2m below ground level with seasonal fluctuation of $\pm 1\text{m}$
- The soil investigation shows very high temperature gradient with depth (70 to 80 degrees in depth of 4 to 6.5m below ground level)

South Wing Extension 2007-2011/12

- available information

- Initially 5 options were proposed as:
delete the basement level, accept large settlement, in-situ cooling system, ground improvement and jet grouting with robust monitoring and full-scale field tests before construction
- The CPTs indicating there is no risk of liquefaction (too fine-grained soil underlined by cemented soil)
- Following the GNS study there should be no problem with CO₂ and H₂S. Ground temperature in 1m below existing ground level was 10 to 20 degrees C above ambient

South Wing Extension 2007-2011/12

- detail design and construction

- Foundation on concrete slab with soil replacement up to 2.2m below concrete basement slab (1.9m hard fill + 0.3m crushed dust) and up to 0.8m below lift shafts (0.5m hard fill + 0.3m crushed dust) was proposed and (following limited information as photos and transmittal to Sigma from Terrane during construction) constructed
- A basement level is approximately 1.5m below existing ground level and a lift shaft is approximately 3.5m below existing ground level
- Sub-floor venting system and a membrane underneath the concrete slab was designed by Terrain and constructed

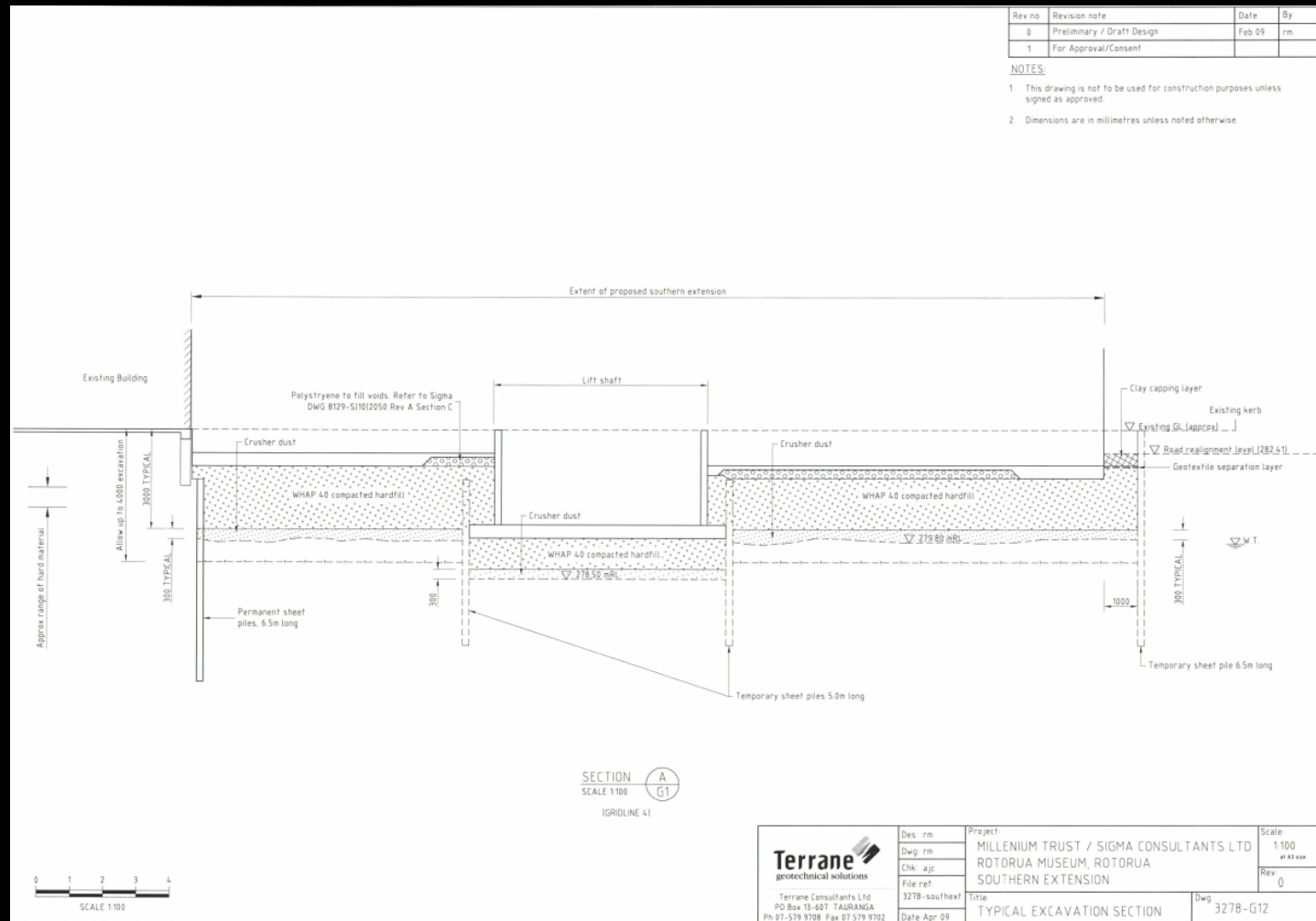
South Wing Extension 2007-2011/12

- detail design and construction

- Designer did not consider heave as a risk (the heave is indicated to be in acceptable limits)
- Post-construction settlement was estimated as 5 to 15mm
- Transmittal to Sigma Consultants from Terrane mention that additional excavation between 500 to 700mm was undertaken in several areas. These locations should be shown in the as-built/certification report which is not available
- Temperature monitoring and cooling of ground with water injection wells was carried out during construction

South Wing Extension 2007-2011/12

- detail design and construction



South Wing Extension 2007-2011/12

- detail design and construction



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North Wing Extension 2007-2011/12 - available information

- Terrane (2007), *“Rotorua Bath House, Government Gardens, Rotorua, Proposed North Wing Extension, Site Investigation Report”*, ref. 3278.1, August 2007

North Wing Extension 2007-2011/12

- available information

- The ground underlying the site is considered to be geotechnically suitable for building loading
- There is no evidence of geothermal risks
- Groundwater was encountered approximately 3.2m below ground level with seasonal fluctuation of $\pm 1\text{m}$
- Downhole temperatures indicate approximately 45 degrees C in 2.5m depth

North Wing Extension 2007-2011/12

- available information

- It seems there is a small risk of liquefaction in sand/silt layers below 6.5m depth
- Foundation is concrete slab at RL 282.87m, 0.4m to 0.9m below existing ground level
- An underfloor gas membrane and venting system was designed and constructed
- It seems that the soil replacement is much smaller in comparison with South wing extension; in drawings is noted 225mm below foundation slab

Thank you!

Questions and Answers

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