Christchurch City Council

Louisson Courts
BE 1026 EQ2

Detailed Engineering Evaluation

Quantitative Assessment Report

Christchurch City Council

Louisson Courts

Quantitative Assessment Report

Louisson Place, Opawa

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Summary

Louisson Courts
BE 1026 EQ2

Detailed Engineering Evaluation
Quantitative Report - Summary
Final

Louisson Courts, Christchurch

Background
This is a summary of the Quantitative report for the Louisson Courts Complex and it is based on the Detailed Engineering Evaluation Procedure document (draft) issued by the Structural Advisory Group on 19 July 2011, visual inspections on 19 January 2012, available drawings and calculations.

Key Damage Observed

- Significant damage to roof trusses.
- Extensive cracking to block veneers.
- Foundation separation from ground floor slabs.
- Ground floor slab settlement.
- Walls/units separation.

Critical Structural Weaknesses
No critical structural weaknesses have been identified for these buildings.

Indicative Building Strength
Based on available information and following a quantitative assessment, the building's original capacity has been assessed to be less than 34% NBS across the building, as limited by the bracing wall and the compartment block wall.

The foundations are deemed to be inadequate.

Recommendations
It is recommended that:

a) Temporary strengthening works be installed to increase the seismic capacity to at least 34% NBS.
b) Permanent strengthening options be developed for increasing the seismic capacity of the building to at least 67% NBS.

Contents

1 Introduction

Opus International Consultants Limited has been engaged by Christchurch City Council (CCC) to undertake a detailed seismic assessment of the Louisson Courts buildings, located at Louisson Place, Opawa, Christchurch. This assessment has been deemed necessary following the M6.3 Christchurch earthquake on 22 February 2011.

The purpose of the assessment is to determine if the buildings are classed as being earthquake prone in accordance with the Building Act 2004.

The seismic assessment and reporting have been undertaken based on the qualitative and quantitative procedures detailed in the Detailed Engineering Evaluation Procedure (DEEP) document (draft) issued by the Structural Engineering Society (SESOC) on 19 July 2011.

2 Compliance

This section contains a brief summary of the requirements of the various statutes and authorities that control activities in relation to buildings in Christchurch at present.

2.1 Canterbury Earthquake Recovery Authority (CERA)

CERA was established on 28 March 2011 to take control of the recovery of Christchurch using powers established by the Canterbury Earthquake Recovery Act enacted on 18 April 2011. This act gives the Chief Executive Officer of CERA wide powers in relation to building safety, demolition and repair. Two relevant sections are:

Section 38 – Works

This section outlines a process in which the chief executive can give notice that a building is to be demolished and if the owner does not carry out the demolition, the chief executive can commission the demolition and recover the costs from the owner or by placing a charge on the owners' land.

Section 51 – Requiring Structural Survey

This section enables the chief executive to require a building owner, insurer or mortgagee to carry out a full structural survey before the building is re-occupied.

We understand that CERA require a detailed engineering evaluation to be carried out for all buildings (other than those exempt from the Earthquake Prone Building definition in the Building Act). CERA have adopted the Detailed Engineering Evaluation Procedure (DEEP) document (draft) issued by the Structural Engineering Society (SESOC) on 19 July 2011. This document sets out a methodology for both initial qualitative and detailed quantitative assessments.

It is anticipated that a number of factors, including the following, will determine the extent of evaluation and strengthening level required:

1. The importance level and occupancy of the building.

2. The placard status and amount of damage.
3. The age and structural type of the building.
4. Consideration of any critical structural weaknesses.

Christchurch City Council requires any building with a capacity of less than 34% of New Building Standard (including consideration of critical structural weaknesses) to be strengthened to a target of 67% as required under the CCC Earthquake Prone Building Policy.

2.2 Building Act

Several sections of the Building Act are relevant when considering structural requirements:

Section 112 - Alterations

This section requires that an existing building complies with the relevant sections of the Building Code to at least the extent that it did prior to the alteration. This effectively means that a building cannot be weakened as a result of an alteration (including partial demolition).

The Earthquake Prone Building policy for the territorial authority shall apply as outlined in Section 2.3 of this report.

Section 115 – Change of Use

This section requires that the territorial authority is satisfied that the building with a new use complies with the relevant sections of the Building Code 'as near as is reasonably practicable'.

This is typically interpreted by territorial authorities as being 67% of the strength of an equivalent new building or as near as practicable. This is also the minimum level recommended by the New Zealand Society for Earthquake Engineering (NZSEE).

Section 121 – Dangerous Buildings

This section was extended by the Canterbury Earthquake (Building Act) Order 2010, and defines a building as dangerous if:

1. In the ordinary course of events (excluding the occurrence of an earthquake), the building is likely to cause injury or death or damage to other property; or
2. In the event of fire, injury or death to any persons in the building or on other property is likely because of fire hazard or the occupancy of the building; or
3. There is a risk that the building could collapse or otherwise cause injury or death as a result of earthquake shaking that is less than a 'moderate earthquake' (refer to Section 122 below); or
4. There is a risk that other property could collapse or otherwise cause injury or death; or

5. A territorial authority has not been able to undertake an inspection to determine whether the building is dangerous.

Section 122 – Earthquake Prone Buildings

This section defines a building as earthquake prone (EPB) if its ultimate capacity would be exceeded in a 'moderate earthquake' and it would be likely to collapse causing injury or death, or damage to other property.

A moderate earthquake is defined by the building regulations as one that would generate loads 33% of those used to design an equivalent new building.

Section 124 – Powers of Territorial Authorities

This section gives the territorial authority the power to require strengthening work within specified timeframes or to close and prevent occupancy to any building defined as dangerous or earthquake prone.

Section 131 – Earthquake Prone Building Policy

This section requires the territorial authority to adopt a specific policy for earthquake prone, dangerous and insanitary buildings.

2.3 Christchurch City Council Policy

Christchurch City Council adopted their Earthquake Prone, Dangerous and Insanitary Building Policy in 2006. This policy was amended immediately following the Darfield Earthquake on 4 September 2010.

The 2010 amendment includes the following:

1. A process for identifying, categorising and prioritising Earthquake Prone Buildings, commencing on 1 July 2012;
2. A strengthening target level of 67% of a new building for buildings that are Earthquake Prone;
3. A timeframe of 15-30 years for Earthquake Prone Buildings to be strengthened; and,
4. Repair works for buildings damaged by earthquakes will be required to comply with the above.

The council has stated their willingness to consider retrofit proposals on a case by case basis, considering the economic impact of such a retrofit.

If strengthening works are undertaken, a building consent will be required. A requirement of the consent will require upgrade of the building to comply 'as near as is reasonably practicable' with:

- The accessibility requirements of the Building Code.

- The fire requirements of the Building Code. This is likely to require a fire report to be submitted with the building consent application.

Where an application for a change of use of a building is made to Council, the building will be required to be strengthened to 67% of New Building Standard or as near as is reasonably practicable.

2.4 Building Code

The Building Code outlines performance standards for buildings and the Building Act requires that all new buildings comply with this code. Compliance Documents published by The Department of Building and Housing can be used to demonstrate compliance with the Building Code.

On 19 May 2011, Compliance Document B1: Structure was amended to include increased seismic design requirements for Canterbury as follows:

- increase in the basic seismic design load for the Canterbury earthquake region (Z factor increased to 0.3 equating to an increase of 36 – 47% depending on location within the region);

- Increased serviceability requirements.

2.5 Institution of Professional Engineers New Zealand (IPENZ) Code of Ethics

One of the core ethical values of professional engineers in New Zealand is the protection of life and safeguarding of people. The IPENZ Code of Ethics requires that:

Members shall recognise the need to protect life and to safeguard people, and in their engineering activities shall act to address this need.

1.1 Giving Priority to the safety and well-being of the community and having regard to this principle in assessing obligations to clients, employers and colleagues.

1.2 Ensuring that responsible steps are taken to minimise the risk of loss of life, injury or suffering which may result from your engineering activities, either directly or indirectly.

All recommendations on building occupancy and access must be made with these fundamental obligations in mind.

3 Earthquake Resistance Standards

For this assessment, the building's earthquake resistance is compared with the current New Zealand Building Code requirements for a new building constructed on the site. This is expressed as a percentage of new building standard (%NBS). The loadings are in accordance with the current earthquake loading standard NZS1170.5 [1].

A generally accepted classification of earthquake risk for existing buildings in terms of %NBS that has been proposed by the NZSEE 2006 [2] is presented in Figure 1 below.

Description	Grade	Risk	%NBS	Existing Building Structural Performance
Low Risk Building	A or B	Low	Above 67	Acceptable (improvement may be desirable)
Moderate Risk Building	B or C	Moderate	34 to 66	Acceptable legally. Improvement recommended
High Risk Building	D or E	High	33 or lower	Unacceptable (Improvement required under Act)

Improvement of Structural Performance	
Legal Requirement	**NZSEE Recommendation**
The Building Act sets no required level of structural improvement (unless change in use) This is for each TA to decide. Improvement is not limited to 34%NBS.	100%NBS desirable. Improvement should achieve at least 67%NBS
	Not recommended. Acceptable only in exceptional circumstances
Unacceptable	Unacceptable

Figure 1: NZSEE Risk Classifications Extracted from table 2.2 of the NZSEE 2006 AISPBE Guidelines

Table 1 below compares the percentage NBS to the relative risk of the building failing in a seismic event with a 10% risk of exceedance in 50 years (i.e. 0.2% in the next year).

Table 1: %NBS compared to relative risk of failure

Percentage of New Building Standard (%NBS)	Relative Risk (Approximate)
>100	<1 time
80-100	1-2 times
67-80	2-5 times
33-67	5-10 times
20-33	10-25 times
<20	>25 times

3.1 Minimum and Recommended Standards

Based on governing policy and recent observations, Opus makes the following general recommendations:

3.1.1 Occupancy

The Canterbury Earthquake Order[1] in Council 16 September 2010, modified the meaning of "dangerous building" to include buildings that were identified as being EPB's. As a result of this, we would expect such a building would be issued with a Section 124 notice, by the Territorial Authority, or CERA acting on their behalf, once they are made aware of our assessment. Based on information received from CERA to date and from the DBH guidance document dated 12 June 2012 [6], this notice is likely to prohibit occupancy of the building (or parts thereof), until its seismic capacity is improved to the point that it is no longer considered an EPB.

3.1.2 Cordoning

Where there is an overhead falling hazard, or potential collapse hazard of the building, the areas of concern should be cordoned off in accordance with current CERA/territorial authority guidelines.

3.1.3 Strengthening

Industry guidelines (NZSEE 2006 [2]) strongly recommend that every effort be made to achieve improvement to at least 67%NBS. A strengthening solution to anything less than 67%NBS would not provide an adequate reduction to the level of risk.

It should be noted that full compliance with the current building code requires building strength of 100%NBS.

3.1.4 Our Ethical Obligation

In accordance with the IPENZ code of ethics, we have a duty of care to the public. This obligation requires us to identify and inform CERA of potentially dangerous buildings; this would include earthquake prone buildings.

[1] This Order only applies to buildings within the Christchurch City, Selwyn District and Waimakariri District Councils authority

4 Building Description

4.1 General

The Louisson Courts development consists of 13 units and is situated in very close proximity to the Heathcote River. As Figure 2 below depicts, Units 1 and 2 are semi-detached buildings. Units 3 to 8 and 9 to 13 are arranged in terraces.

Figure 2: Louisson Courts Layout

Each unit is a single storey timber structure with an external block veneer and a timber trussed roof covered with concrete tiles. Between units there are compartment walls which consist of partially filled blockwork to the height of the roof ridge. It is assumed that the buildings are founded on shallow strip foundations.

Each unit is approximately 8m long by 6m wide. The apex of the roof is approximately 4m from ground level, with a ceiling height of approximately 2.4m. All internal timber stud walls are lined with plasterboard on both sides. The external structure is timber framed with an external block veneer.

The date of construction of the development is 1979.

4.2 Gravity Load Resisting System

The roof structure consists of timber trusses and is clad externally with concrete tiles. The roof trusses are supported by timber stud walls, which are 2.4m in height. The compartment blockwork walls are non-loadbearing walls and provide fire separation between adjacent units.

It can be assumed that all loadbearing walls and blockwork are constructed on shallow foundation beams. The ground floor construction consists of concrete slab-on-grade and the slab is not tied to the foundation beams.

4.3 Seismic Load Resisting System

Seismic loads in both principal directions are resisted by timber stud walls lined with plasterboard. The roof structure comprises of timber roof trusses, clad in concrete tiles, with horizontal timber braces at the eaves level and in the roof plane.

The partially filled compartment blockwall cannot be considered to provide resistance to horizontal loads. The only fixings observed to these walls were the timber framed walls perpendicular to the blockwork.

The concrete ground slabs are not tied to the foundation beams or the compartment walls.

5 Survey

This report is based on site inspection records and photographic evidence. The following site inspections were undertaken by Opus engineers:

- A rapid assessment was carried out by an Opus Structural Engineer after the September earthquake.
- A site visit by an Opus Structural Engineer on the 22nd of August 2012.
- A Level Survey was carried out by Opus Surveyors on 22 August.

Design calculations or structural drawings for the development have been unavailable. The layout drawings have been produced by Opus based on a site measurement survey.

6 Damage Assessment

Evidence of ground liquefaction was observed during the rapid assessment survey.

All units suffered extensive damage to the walls, floors and roofs. The main cause of this damage was the liquefaction of the ground and the resulting differential settlement. The differential settlement occurred across the site, causing severe damage to block veneers and slabs to subside. Damage to slabs has been observed in several locations.

The following damage was observed in all units:

- Severe cracking to block veneers, with Unit 3 being particularly affected.
- Damage to timber truss members.

- Separation between concrete floors and walls/foundations.
- Separation between timber framing and compartment wall blockwork.
- Ground floor settlement and sloping.
- Cracking in timber frame wall linings.
- Cracking in floor slabs, with Unit 3 being particularly affected.
- Settlement, rotation, bowing of compartment blockwork walls. A copy of the level survey results are shown in Appendix C.

7 General Observations

The timber building elements have generally performed well under seismic conditions, which is to be expected for a timber framed single storey structure.

The main points of concern for the buildings on this site relate to ground liquefaction, differential settlement and the performance of the compartment wall.

Due to the non-intrusive nature of the original survey, many connection details could not be ascertained.

8 Detailed Seismic Assessment

8.1 Critical Structural Weaknesses

As outlined in the Critical Structural Weakness and Collapse Hazards draft briefing document, issued by the Structural Engineering Society (SESOC) on 7 May 2011, the term 'Critical Structural Weakness' (CSW) refers to a component of a building that could contribute to increased levels of damage or cause premature collapse of the building.

No CSW were identified for these buildings.

8.2 Seismic Coefficient Parameters

The seismic design parameters based on current design requirements from NZS1170.5:2004 and the NZBC clause B1 for this building are:

- Site soil class D, clause 3.1.3 NZS 1170.5:2004;
- Site hazard factor, Z=0.3, B1/VM1 clause 2.2.14B;
- Return period factor R_u = 1.0 from Table 3.5, NZS 1170.5:2004, for an Importance Level 2 structure with a 50 year design life;

- μ = 1.25 for the timber frame with plasterboard wall linings and for partially filled blockwork masonry.

8.3 Detailed Seismic Assessment Results

A summary of the structural performance of the building is shown in the following table. Note that the values given represent the worst performing elements in the building, as these effectively define the building's capacity. Other elements within the building may have significantly greater capacity when compared with the governing element.

Table 2: Summary of Seismic Performance

Structural Element/System	Failure mode and description of limiting criteria	Critical Structural Weakness and Collapse Hazard	% NBS based on μ = 1.25
Walls parallel to the compartment wall	In plane bracing capacity of the timber stud wall. Insufficient information to assess connections.	No	53%
Internal Wall perpendicular to the compartment wall	In plane bracing capacity of the timber stud wall. Insufficient information to assess connections.	No	16%
External Wall perpendicular to the compartment wall	In plane bracing capacity of the timber stud wall. Insufficient information to assess connections.	No	28%
Roof bracing[1]	Insufficient information to assess.	No	n/a
Compartment wall in plane	In plane shear capacity	No	>100%
Compartment wall out-of- plane[2]	Out of plane bending capacity	No	20%
Foundations/ ground floor slab	Foundation beams separated from slab-on--grade ground floor.	No	<34%

Note 1. It is estimated that timber bracing elements do not have sufficient capacity to withstand block wall loadings, should they be expected to.

Note 2. The compartment wall is checked as a cantilever. If it has adequate support at roof level to span between roof and foundation, its percentage NBS will increase to over 100.

8.4 Discussion of Results

The buildings have a calculated capacity of less than 34% NBS, as limited by the concrete blockwalls, timber frame internal walls and foundation capacities.

Ground liquefaction and compartment wall pounding are structural issues associated with these buildings, in addition to the inadequate bracing capacity in some timber frame walls. The compartment wall's excessive displacement and pounding significantly damaged the roof trusses and has also damaged wall elements adjacent to the compartment wall.

The timber walls' bracing capacity is less than 34%.

As the buildings have an overall capacity of less than 34% NBS, they are defined as being earthquake prone in accordance with the Building Act 2004.

8.5 Limitations and Assumptions in Results

The observed level of damage suffered by the buildings was deemed low enough to not affect their capacity. Therefore the analysis and assessment of the buildings was based on them being in an undamaged state. There may have been damage to the buildings that was unable to be observed during assessments that could cause the capacity of the buildings to be reduced; therefore the current capacity of the buildings may be lower than that stated.

The results have been reported as a %NBS and the stated value is that obtained from our analysis and assessment. Despite the use of best national and international practice in this analysis and assessment, this value contains uncertainty due to the many assumptions and simplifications which are made during the assessment. These include:

- Simplifications made in the analysis;
- Assessments of material strengths based only on site inspections and engineering judgment;
- The normal variation in material properties which change from batch to batch;
- Approximations made in the assessment of the capacity of each element, especially when considering the post-yield behaviour.

9 Geotechnical Assessment

Signs of significant liquefaction were observed during the rapid site assessment.

It has been reasonably assumed that the buildings have been constructed on shallow strip footings with ground supported floor slabs. Significant differential settlement of the floor slabs has occurred and the foundation beams have separated from the ground floor slabs.

The GNS Science indicates that there is 13% probability of another M6 or greater earthquake occurring in the next 12 months in Canterbury region. It confirms that there is currently a risk of liquefaction and further settlements occurring at this site.

A copy of the full geotechnical desktop study can be found in Appendix D.

10 Remedial Options

Any remedial options for increasing the seismic capacity above 67% NBS would need to address the capacity of the foundations and ensure that they can accommodate significant differential settlement.

11 Conclusions

(a) The buildings have a seismic capacity of less than 34% NBS and are therefore classed as earthquake prone in accordance with the Building Act 2004.

(b) The seismic capacity is limited by the inadequate foundations and by the capacities of the timber frame walls and blockwork walls.

(c) Strengthening work is required to increase the overall building capacity to at least 67% NBS.

12 Recommendations

(a) Temporary strengthening works should be installed in order to increase the seismic capacity to at least 34% NBS.

(b) Permanent strengthening options should be developed to increase the seismic capacity of the building to at least 67% NBS.

13 Limitations

(a) This report is based on an inspection of the structure with a focus on the damage sustained from the Canterbury Earthquake sequence only. Non – structural damage is not included in this report.

(b) Our professional services are performed using a degree of care and skill normally exercised, under similar circumstances, by reputable consultants practicing in this field at the time.

(c) This report is prepared for the CCC to assist with assessing remedial works required for council buildings and facilities. It is not intended for any other party or purpose.

14 References

[1] NZS 1170.5: 2004, *Structural design actions, Part 5 Earthquake actions,* Standards New Zealand.

[2] NZSEE: 2006, *Assessment and improvement of the structural performance of buildings in earthquakes,* New Zealand Society for Earthquake Engineering.

[3] Engineering Advisory Group, *Guidance on Detailed Engineering Evaluation of Earthquake Affected Non-residential Buildings in Canterbury, Part 2 Evaluation Procedure*, Draft Prepared by the Engineering Advisory Group, Revision 5, 19 July 2011.

[4] Engineering Advisory Group, *Guidance on Detailed Engineering Evaluation of Non-residential buildings, Part 3 Technical Guidance*, Draft Prepared by the Engineering Advisory Group, 13 December 2011.

[5] SESOC, *Practice Note – Design of Conventional Structural Systems Following Canterbury Earthquakes*, Structural Engineering Society of New Zealand, 21 December 2011.

Appendix A – Photographs

Photo 1: Cracking to block veneer

Photo 2: Cracking to block veneer

Photo 3: Cracking to block veneer

Photo 4: Ground slab separation from the foundation beam

Photo 5: Ground slab separation from the foundation beam

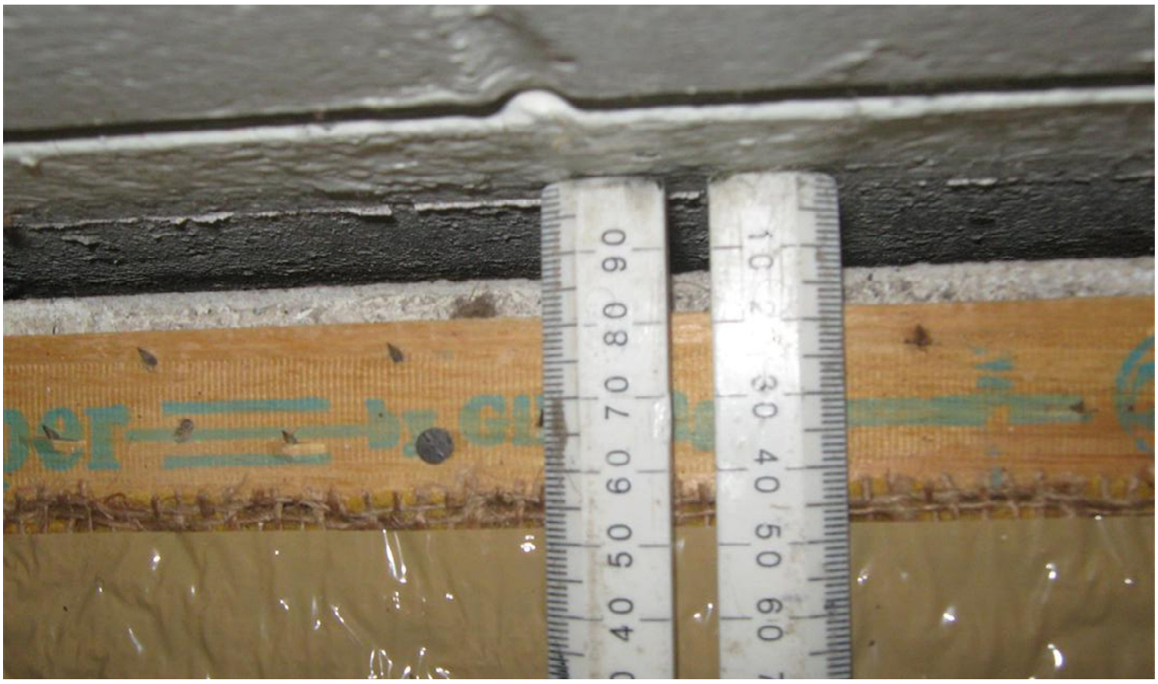
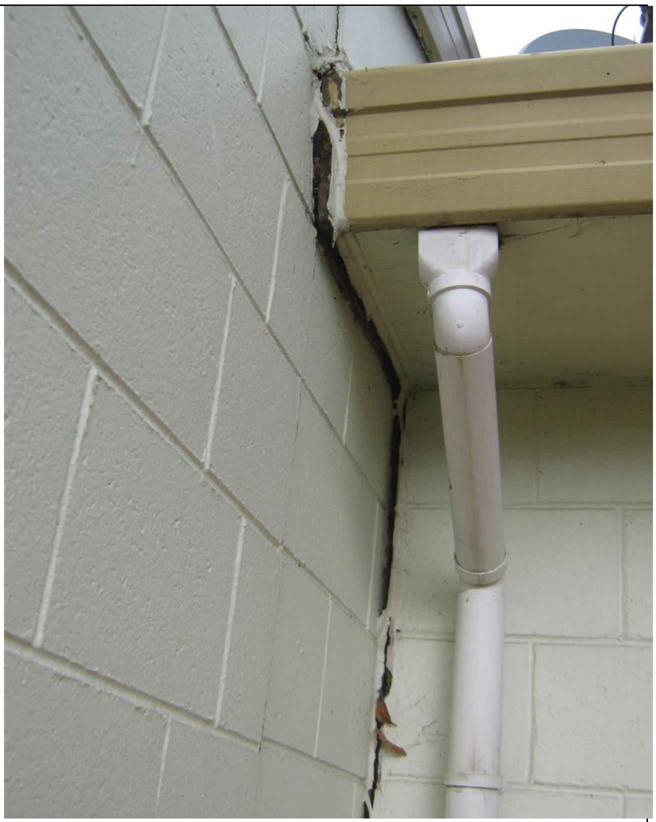


Photo 6: Ground slab separation from the foundation beam

Photo 7: Ground floor settlement

Photos 8 – 11: Blockwall separation

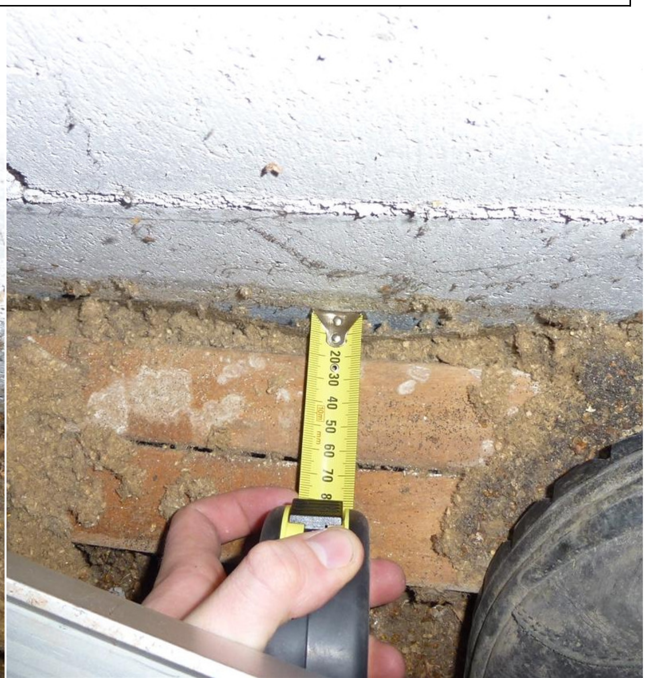
Photos 12 – 15: Breaking of roof trusses

Unit 1

Unit 2

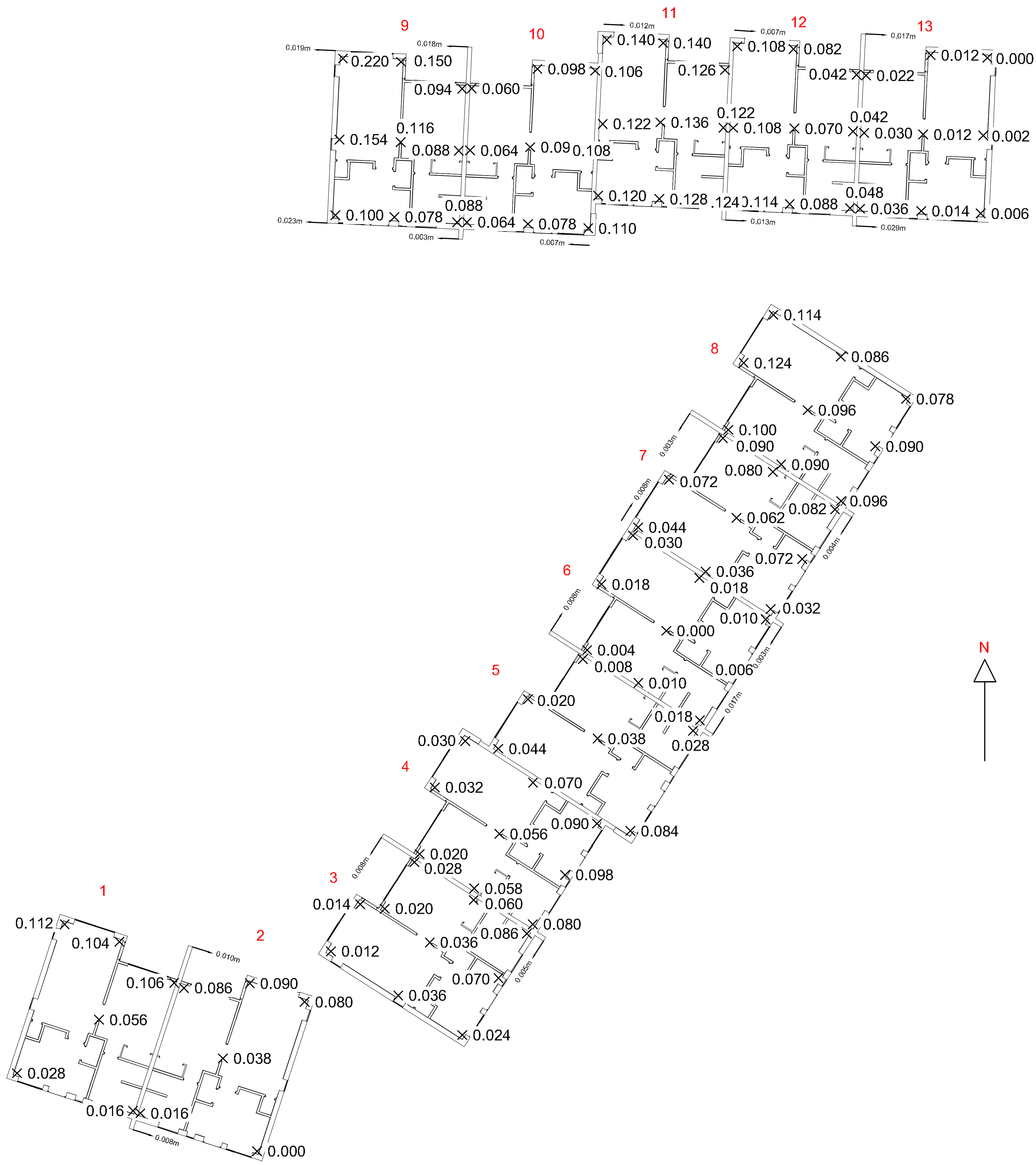
Unit 3

Photos 16 – 18: Breaking of roof trusses



Photos 19 – 22: Blockwall separation

Appendix B – Level Survey Results



Original Sheet Size A3 [420x297]

Plot Date

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Revision	Amendment	Approved	Revision Date

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Drawn | Designed | Approved | Revision Date

Project No. ####

Scale

Project ####

Sheet

Line 1
Line 2

Drawing No. ####

Sheet No.

Revision

Appendix C – Geotechnical Desktop Study

7th November 2012

Matt Cummins
Project Manager
Capital Programme Group
Christchurch City Council

6-QUCC1.74

Dear Matt

Louisson Courts- Phase 1 Geotech Assessment – Stage 1

1. Introduction

The Units 1-13 of Louisson Courts on Louisson Place were subjected to severe ground shaking during the Magnitude 7.1 Darfield 2010 and Magnitude 6.3 Christchurch 2011 earthquake and subsequent aftershocks. The following report summarises the findings of a geotechnical desktop study and site walkover completed by Opus International Consultants (Opus) for the Christchurch City Council on the 4th September 2012.

The purpose of the geotechnical study is to assess the current ground conditions and the potential geotechnical hazards that may be present at the site, and determine whether further subsurface geotechnical investigations are necessary.

It is our understanding this is the first inspection by a Geotechnical Engineer of this property following the earthquakes. Various structural inspections and assessments have been undertaken by Opus.

This geotechnical desk study forms part of a Detailed Engineering Evaluation prepared by Opus, and has been undertaken without the benefit of any site specific investigations and is therefore preliminary in nature.

2. Desktop Study

2.1 Site Description

The site comprising Units 1-13 of Louisson Courts is located at the south end of Louisson Place approximately 170m south of the Ford Street / Louisson Place intersection in the Opawa suburb of Christchurch City. The Heathcote River is located approximately 10m to the east of the units, whilst there is a stream tributary forming the southern site boundary.

The residential units comprise three main blocks of single storey structures with tiled roof and timber framing with 100mm thick concrete block veneer.

The site is thought to have been located on or adjacent to a former fill site of The Christchurch Gas Works. A contamination assessment has not been included in the scope of this desk study.

2.2 Structural Drawings

No geotechnical report or records of ground investigations associated with the construction of the buildings are on Christchurch City Council's property file.

A site plan providing the layout of the units has been made available and includes the details of the room types within the units. An internal floor level survey has also been completed by Opus (refer to plans in Appendix A).

Based on CCC drawings obtained for housing developments constructed at a similar time to Louisson Courts, we expect the units are founded on approximately 250mm wide strip footings.

2.3 Regional Geology

The published geological map of the area, (Geology of the Christchurch Urban Area 1:25,000, Brown and Weeber, 1992) indicates the site is underlain by alluvial sand and silt overbank deposits belonging to the Yaldhurst member of the Springston Formation of Holocene age.

A groundwater table depth of less than 1m is also indicated on the published map by Brown and Weeber (1992).

2.4 Expected Ground Conditions

A review of the Environmental Canterbury (ECan) Wells database showed three wells located within approximately 60m of the property (refer to Site Location Plan and borehole logs in Appendix B).

Following the earthquake sequence, the Earthquake Commission (EQC) have undertaken additional borehole and cone penetrometer (CPT) testing in Christchurch. The cone penetration test CPT OPA 16 (refer Appendix D), was carried out within 5m of the northern site boundary.

The stratigraphy below Louisson Courts, inferred from the ECan boreholes and the EQC Investigations, is shown in Table 1 below;

Stratigraphy	Thickness (m)	Depth Encountered from (m) bgl
TOPSOIL / FILL	0.6m	Surface
Soft to firm CLAY / SILT	2.4m	0.6m
Medium dense SAND	4.4m	3.0m
Loose SAND	2.8m	7.4m
Dense SAND	7.4m	10.2m
Very loose SILT / SAND	7.6m	17.6m
Dense to very dense SAND and GRAVEL (Riccarton Formation)	-	25.2m+

Table 1 Inferred Ground Conditions

The level recorded on the CPT log indicates the groundwater is approximately 1.5m below the ground surface. The ECan boreholes simply state the water level is 'artesian' and this is likely to relate to the Riccarton Gravel Formation at depth.

2.6 Liquefaction Assessment

The 2004 Environment Canterbury (ECan) Solid Facts Liquefaction Study indicates the site is in an area designated as 'moderate liquefaction ground damage potential'. According to this study, based on a low groundwater table, ground damage is expected to be moderate and may be affected by up to 300mm of ground subsidence.

Inspection of maps provided by the EQC in the Canterbury Geotechnical Database (Project Orbit) has been carried out. Printouts of the pertinent maps discussed as follows are presented in Appendix D.

Examination of post-earthquake aerial photos has identified that the site lies in an area interpreted to have had minor observed liquefaction at the ground surface after the 22 February 2011 event. The site is not indicated as being in an area with observed liquefaction at the ground surface after either the 13 June 2011 or 23 December 2011 aftershocks.

The post-earthquake ground surface observations has identified that the site lies in an area that experienced no lateral spreading but minor to moderate quantities of ejected material after the February 2011 event. No liquefaction or lateral spreading was observed for the June or December 2011 events.

Inspection of the Observed Crack Location Map has identified a number of cracks between 10mm to 200mm wide that were observed on site. These are shown to be located mainly on the west side of the units, refer Appendix D.

The vertical elevation change (LIDAR) map indicates that the site has generally subsided by between 0m to 0.5m, with the most subsidence located at the eastern part of the site closest to the Heathcote River.

Minor cosmetic damage to wall linings occurred as a result of the 4th September 2010 event. No foundation damage was observed following the September 2010 event.

2.7 Christchurch City Council Flood Management Maps

The site is shown to be part of the Flood Management Area. CCC has recently released revised plans with updated floor levels for properties in the Heathcote catchment. Floor levels are not currently available on the CCC website. Actual floor levels for each property will be set as part of the building consent process.

3. Site Walkover Inspection

A walkover inspection of the exterior of the building and surrounding ground was carried out by an Opus Geotechnical Engineer on 4th September 2012. The following observations were made (refer to the Walkover Inspection Plan and Site Photos attached to this report):

All Units are constructed of a concrete slab on grade type foundation. This equates to a C2 type structure in accordance with the Department of Building and Housing "Revised guidance on repairing and rebuilding houses affected by the Canterbury Earthquake Sequence", dated November 2011.

Units 1 to 2

- Minor hairline cracks in concrete foundation and small gaps (<5mm) between the footpath slab and wall (photos 1 and 2)
- Cracks in the path around the building and gaps between slabs and ground, also note misalignment of downpipe with grating (photos 3 & 4)
- Difference in levels between the path and lawn on the south end (photo 5)
- Suspected ground fissures south of the units close to the stream / tributary, evidence of lateral spread cracking (photo 6)

Units 3 to 8

- Cracks 2mm, 6mm and 1mm width in the foundation on the southern end of the units (photos 7, 8 and 9 respectively) with cracks extending between the wall blockwork (photo 10)
- Hairline cracks up to 2mm to 4mm width around the west and north ends of the units (photo 11 to 15)
- Cracks in path around the building and minor gap between slab and ground (photos 16 to 19)
- Paving slab distortions along boundaries (photo 20)

Units 9 to 13

- Cracks 1mm to 5mm width on south end of units (photos 21 and 22)
- Distortion and cracks in path around the units (photos 23 and 24).

Other Observations

There is a 20° to 25° steep, 2.5m to 3.5m high slope on the western side of the site, leading up to the fence boundary (photo 25). The ground beyond the fence is generally flat and level. The slope is likely to be a historic river terrace of the Heathcote. There are paths on this slope and small retaining walls (typically height 0.25m or less) on the bank. The retaining walls are generally vertical to 5° off vertical, with a slight lean towards the downhill side.

There is a manhole cover to a chamber in the car park area north east of the units which has heaved upwards approximately 25mm to 30mm (photo 26).

With reference to the cracks identified in Project Orbit, the following comments are made:

- The crack located on the East end of units 1-2 is likely to be the gap observed between the path floor slabs and the wall foundation. However, this is generally also observed around the other units.

- The crack parallel with the North side of units 1-2 is indicated in the garden areas to the side of the path and was not observed on site. However, cracks and gaps in the paving were observed in the North West end.

- The crack indicated in the lawn area to the west of units 3 to 8 was not identifiable on site (photo 27).

- Cracks were noted in the building foundation of units 9-13, as was some distortion of the path. There are 10mm to 20mm wide horizontal gaps between each of the units 9 to 13 (separations in the roof guttering observed). This horizontal movement is likely to be associated with lateral spreading towards the Heathcote.

4. Level Survey

An internal floor level survey was completed by Opus on the 22nd August 2012. The annotated site plan is included in Appendix A. The differential settlement recorded within each unit is summarised in Table 2 below:

Unit Number	Differential Settlement - mm	General Direction of fall	General observed crack width of foundation
1	96mm	Southeast	<1mm
2	90mm	Southeast	<1mm
3	74mm	West	<1mm to 6mm
4	70mm	West	-
5	76mm	Northwest	2mm to 5mm
6	30mm	South	-
7	58mm	South	-
8	46mm	East	<1mm to 4mm
9	142mm	East	1mm
10	50mm	West	5mm
11	20mm	South	<1mm to2mm
12	72mm	East	<1mm to 2mm
13	36mm	East	-

Table 2: Differential settlement, direction and observed crack widths in foundation

It should be noted that the foundation at some of the units was obscured by vegetation and therefore the observed crack widths provided above should be taken as a general indication only.

5. Discussion

Damage has occurred to the units at Louisson Courts due to the Canterbury Earthquake Sequence following the 4 September 2010 earthquake. The damage extends to and includes the concrete slab on grade foundation. Based on the observed damage at firewalls, it appears the floor slabs are not connected or tied into the existing concrete footings.

The floor slab level survey results indicate up to 145mm of differential settlement has occurred within each unit. Units 1 to 2 appear to have settled towards the east, whilst units 3 to 8 appear to have settled both towards the south and north. Units 9 and 10 appear to have settled towards the west, whilst the units 11, 12 and 13 settled towards the east (Heathcote River). Total differential settlement recorded across units 9 to 13 is 220mm. Foundation repair and relevelling solutions for the complex will need to be undertaken for entire blocks of units

The gaps observed between units 9 to 13, combined with the crack patterns recorded by EQC and observed on site, indicates that the site has suffered from lateral spreading towards the Heathcote River and minor lateral spread towards the stream tributary on the southern boundary.

Level survey and observation confirm there has been seismically induced settlement on the site as a result of the February 2011 event. The areas around the paths and the edge of the unit foundations appear to be the main areas where cracking has been observed.

Further site specific investigations and assessment are required to determine the liquefaction and lateral spreading potential of the site.

GNS Science indicates an elevated risk of seismic activity is expected in the Canterbury region as a result of the earthquake sequence following the 4 September 2010 earthquake. Recent advice[1] indicates there is a 13% probability of another Magnitude 6 or greater earthquake occurring in the next 12 months in the Canterbury region. Therefore there is currently a risk of liquefaction and further differential settlements occurring at this site, dependant on the location of the epicentre. It is expected that the probability of occurrence is likely to decrease with time, following periods of reduced seismic activity.

6. Recommendations

A site specific investigation comprising initially Cone Penetrometer Tests (CPT's) and test pits is recommended to assess the liquefaction potential of the site, to quantify the lateral spreading risk and to identify conceptual foundation repair, relevel or rebuild options.

We recommend the following:

- A total of five CPT's, comprising three CPT's to 20m depth and two CPT's to 30m depth or refusal. Due to restricted access to parts of the site, a small rig will need to be used for this work. The CPT rig may not penetrate shallow gravel or dense sand layers if encountered on site.
- Three test pits to expose the underside of the foundation of each unit and to determine the bearing capacity of shallow soils. A hand auger Scala test should then be carried out within the test pit to 3m depth or refusal.

[1] GNS Science reporting on Geonet Website: http://www.geonet.org.nz/canterbury-quakes/aftershocks/ updated on 07 September 2012.

The Proposed Ground Investigation Plan is provided in Appendix E.

Limitation

This report has been prepared solely for the benefit of Christchurch City Council as our client with respect to the brief. The reliance by other parties on the information or opinions contained in the report shall, without our prior review and agreement in writing, be at such parties' sole risk.

<u>Figures:</u>
Site Photographs
Site Location Plan
Walkover Inspection Notes

<u>Appendices:</u>
Appendix A: Site Plan and Floor Level Survey Drawings
Appendix B: Environment Canterbury Borehole Logs
Appendix C: CPT-OPA-16
Appendix D: Project Orbit Output
Appendix E: Proposed Ground Investigation Plan


Photo 1: Hairline crack in foundation on south side of Unit 1 to 2

Photo 2: Slight separation (<5mm) between foundation and concrete path


Photo 3: Cracks on path around south end of Units 1 to 2, with tilted blocks lining path.

Photo 4: Crack (<1mm to 10mm wide) around path on north west end of Unit 1 to 2

Photo 5: Difference in lawn and path levels on south side of unit 1 and 2

Photo 6: Suspected scarps / cracks on slope close to stream south of Units 1 and 2.

Photo 7: 2mm wide crack in foundation on southern end of Units 3 to 8

Photo 8: 6mm wide crack in foundation on southern end of Units 3 to 8

Photo 9: 1mm wide crack in foundation on southern end of Units 3 to 8


Photo 10: Step cracks on south side of Units 3 to 8


Photo 11: Hairline crack on south west corner of Units 3 to 8

Photo 12: Cracks (up to 10mm wide) on west end of Units 3 to 8


Photo 13: Hairline cracks on west end of Units 3 to 8

Photo 14: Crack (up to 4mm wide) on slab in north west part of Units 3 to 8


Photo 15: Crack (less than 5mm wide) on northern end of Units 3 to 8

Photo 16: Crack (less than 5mm wide) in path close to south west part of Unit 3 to 8

Photo 17: Separation on north west corner of unit 3 to 8

Photo 18: Slab separations on east end of Units 3 to 8

Photo 19: Slab separations on east end of Units 3 to 8

Photo 20: Paving slab distortion east of Units 3 to 8


Photo 21: Crack (1mm wide) on south end of Units 9 to 13

Photo 22: Crack (2mm wide) on south end of Units 9 to 13

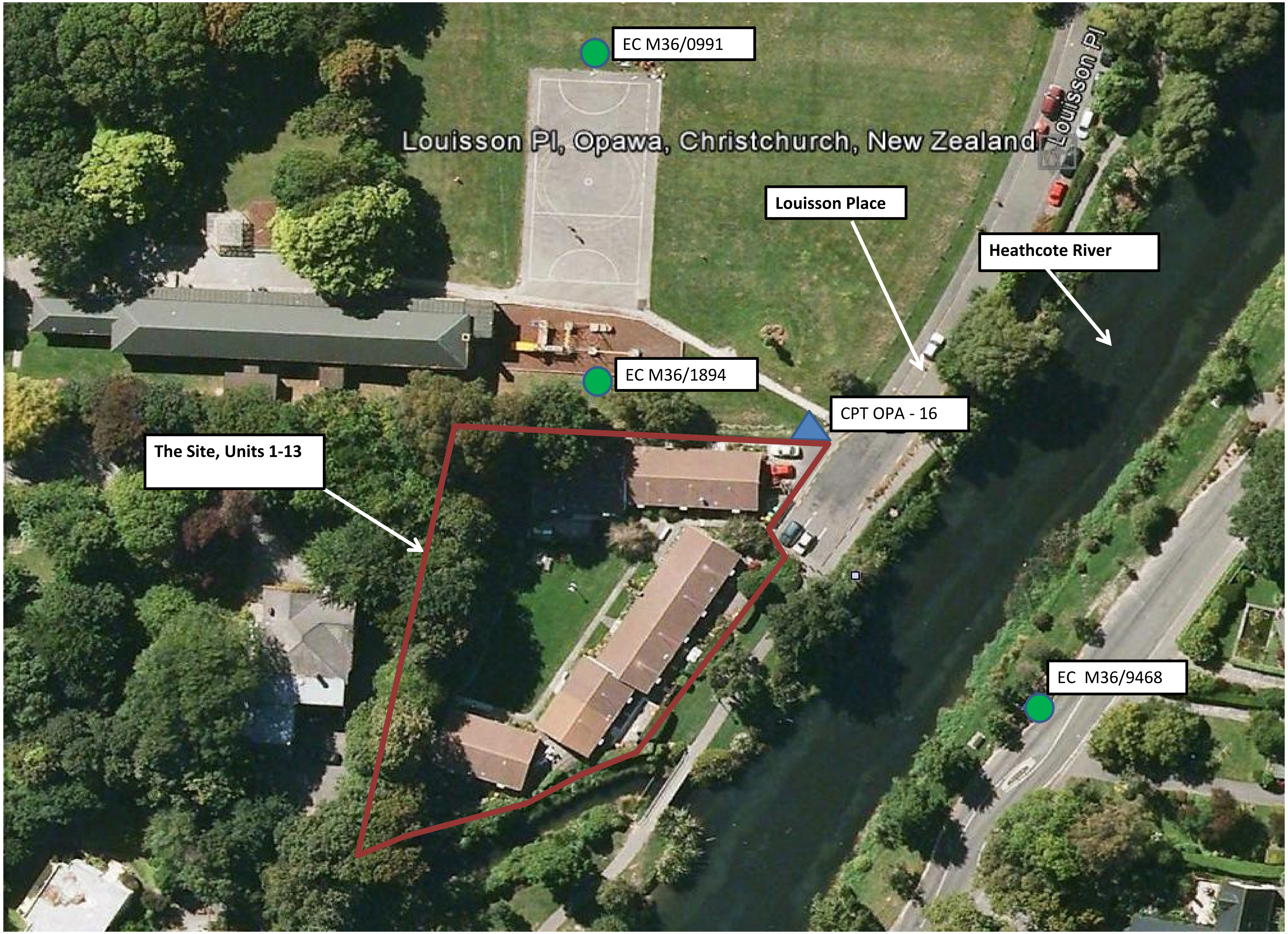

Photo 23: Distortion on path on south end of Units 9 to 13

Photo 24: Separation of path slabs on north east end of Units 9 to 13

Photo 25: Landscaped bank on western side of site. Units 9-13 in right corner of photo.

Photo 26: Manhole cover and chamber that has heaved 25mm-30mm.


Photo 27: Lawn area on west of units 3-8, view to north. Units 3-8 on right of photo.



Key:

- ECan Borehole Location
- CPT-OPA
- Site Boundary

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Christchurch, New Zealand
Tel: +64 3 363 5400 Fax: +64 3 365 7857

Project: Units 1-13 Louisson Place
Geotechnical Desk Study

Project No.: 6-QUCC1.74

Client: Christchurch CC

Site Location Plan - NTS

Drawn: Geotechnical Engineer

Date: 4th September 2012

CPT_1476
1 to 2mm wide cracks on path
distortion on bitumen path surface
Unit 9-13
Suspected hairline crack in Fdn
hairline & 2mm open cracks
Louisson Place
Slight heave around manhole
1mm wide crack in foundation
5mm crack & blocks displaced on Fdn
1-2mm crack in Fdn.
hairline crack in Fdn
Separation of floor slab and wall blocks 25mm
4mm wide crack on slab
Approximate position of fence boundary
Shed
Landscaped bank and paths 20-25°
←2mm crack
Displacement of wall blocks over foundation of 1-5mm
Unit 3-8
2-3mm wide crack in Fdn
Crack on path
Paving slab distortion and separation from wall (1-2mm approx)
Cracks on path around property from hairline to 1cm separation
hairline cracks in concrete Fdn
2mm wide Fdn crack
6mm wide Fdn crack
1mm wide Fdn crack
Heathcote River
N
Low height stone retaining wall
Unit 1-2
Public Path
Small hairline crack in foundation and 3mm separation of floor path slabs and wall
Crack in concrete path
Scarps/terraces on bank
30°
1°-2° tilt of path
Path bridge
Slight distortion and suspected cracks on bank
Garden bank on lawn path boundary
Stream/Tributary
Landscaped/Landfill Area?
Site Walkover Observations Plan (NTS)
Google earth
© 2012 Whereis® Sensis Pty Ltd
Imagery Date: 3/4/2009
2004
43°33'24.22" S 172°39'57.29" E elev 6 m
Eye alt 108 m

Appendix A:

Site Plan and Floor Level Survey Drawings

1 Site Plan
1 : 200

Revisions		
No.	Amendment	Date

Please Note:
All Contractors to follow in strict accordance with plans. Any variations to the design or specified products will need to be approved by contacting the Designer prior to any changes made. Any changes made without prior approval will not be accepted.

OPUS
PROPERTY SERVICES

Project
Christchurch City Council
Louisson Courts

Sheet Title
Site Plan

Project Number	Date		Dwg Status
6-QUCC1.74	24 August 2012		Sketch

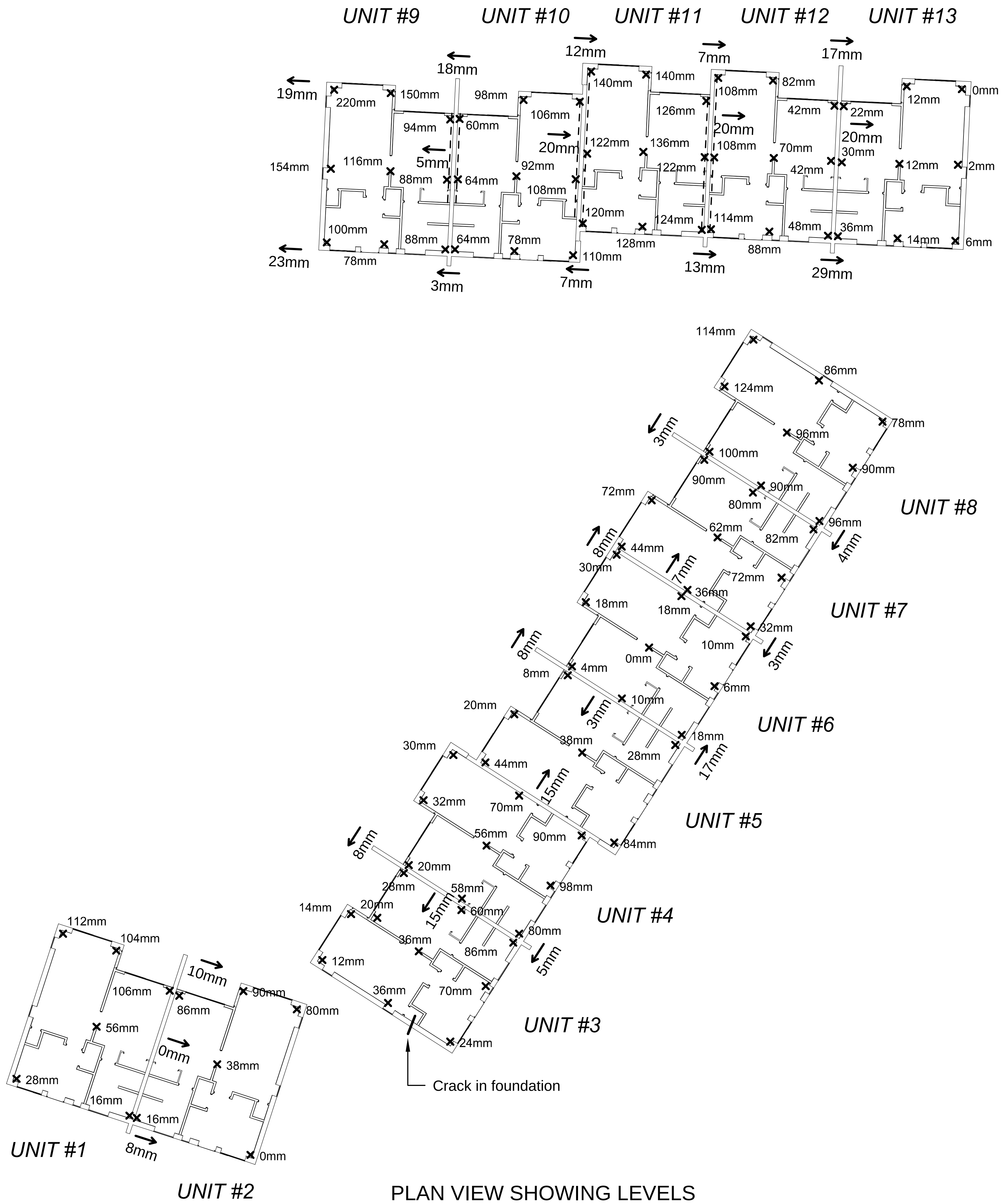
Scale	DIPs Number	Code	Sheet No	Revision
1 : 200			100	R0

Drawn By: C Dunn
Checked By: G Steetskamp

P:\Projects\6-QUAKE.01\CCC_Residential units\Louisson Place\Drawings\Existing Floor Plans.rvt

Original sheet size A3 (420x297) Plot date: 12/09/2012 8:32:17 a.m.

0 10mm 50 100



PLAN VIEW SHOWING LEVELS

1:200

× 24mm	Level of floor
← 5mm	Direction and distance of shift in firewall
– – – –	Opening in floor slab by firewall (units #9, #10, #11 & #12)

N

1:200 @ A3

Original Sheet Size A3 [420x297]

Plot Date 04/09/12 @ 13:30

OPUS

Christchurch Office
P O Box 1482
Christchurch 8140, New Zealand
+ 64 3 363 5400

Project: Christchurch City Council, Louisson Courts, Louisson Place, Opawa, Christchurch, Levels

Sheet: Plan View Showing Levels

Project No.: 6-QUCC1.74

Scale: 1:200 @ A3

Drawing No.: 6/1366/283/2604

Sheet No.: 100

Revision: R0

Appendix B:

Environment Canterbury Borehole Logs

Borelog for well M36/0991

Gridref: M36:830-390 Accuracy : 4 (1=high, 5=low)
Ground Level Altitude : 1.9 +MSD
Driller : Job Osborne (& Co/Ltd)
Drill Method : Hydraulic/Percussion
Drill Depth : -72.19m Drill Date : 3/05/1920

Environment Canterbury Regional Council

Water Level: Artesian

Depth(m)	Full Drillers Description	Formation Code
- 27.7m	Blue sand & clay	sp-ch
- 41.7m	Brown shingle	ri
- 47.2m	Brown sand	br
- 60.3m	Brown shingle	li-1
- 68.5m	Brown sand & clay	li-2
- 72.2m	Brown shingle	li-3

Scale(m): -10, -20, -30, -40, -50, -60, -70

Borelog for well M36/1894

Gridref: M36:8300-3895 Accuracy : 4 (1=high, 5=low)
Ground Level Altitude : 2.3 +MSD
Driller : J W Horne (& Co)
Drill Method : Unknown
Drill Depth : -41.79m Drill Date : 4/02/1978

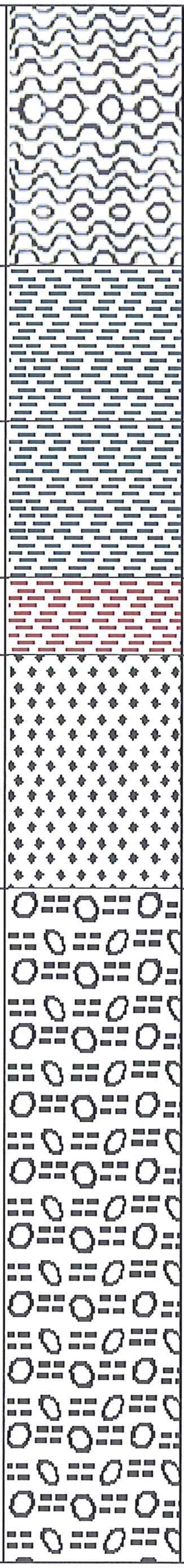
Environment Canterbury Regional Council

Water Level: Artesian

Depth(m)	Full Drillers Description	Formation Code
-0.60m	Topsoil	sp
-4.30m	Sandy Yellow clay	sp
-7.30m	Blue pug	sp
- 18.9m	Blue sand	ch
- 19.5m	Peat	ch
- 28.7m	Blue & Grey pug	ch
- 32.0m	Sand & bits of gravel	ri
- 33.2m	Clean loose gravel	ri
- 36.0m	V. sandy small gravel	ri
- 36.6m	Sand & claybound gravel	ri
- 37.5m	Sand	ri
- 38.7m	Sandy gravel	ri
- 41.5m	Loose Water-bearing gravel	ri
- 42.6m	Brown sand, bottom of gravel bed	br

Borelog for well M36/9468

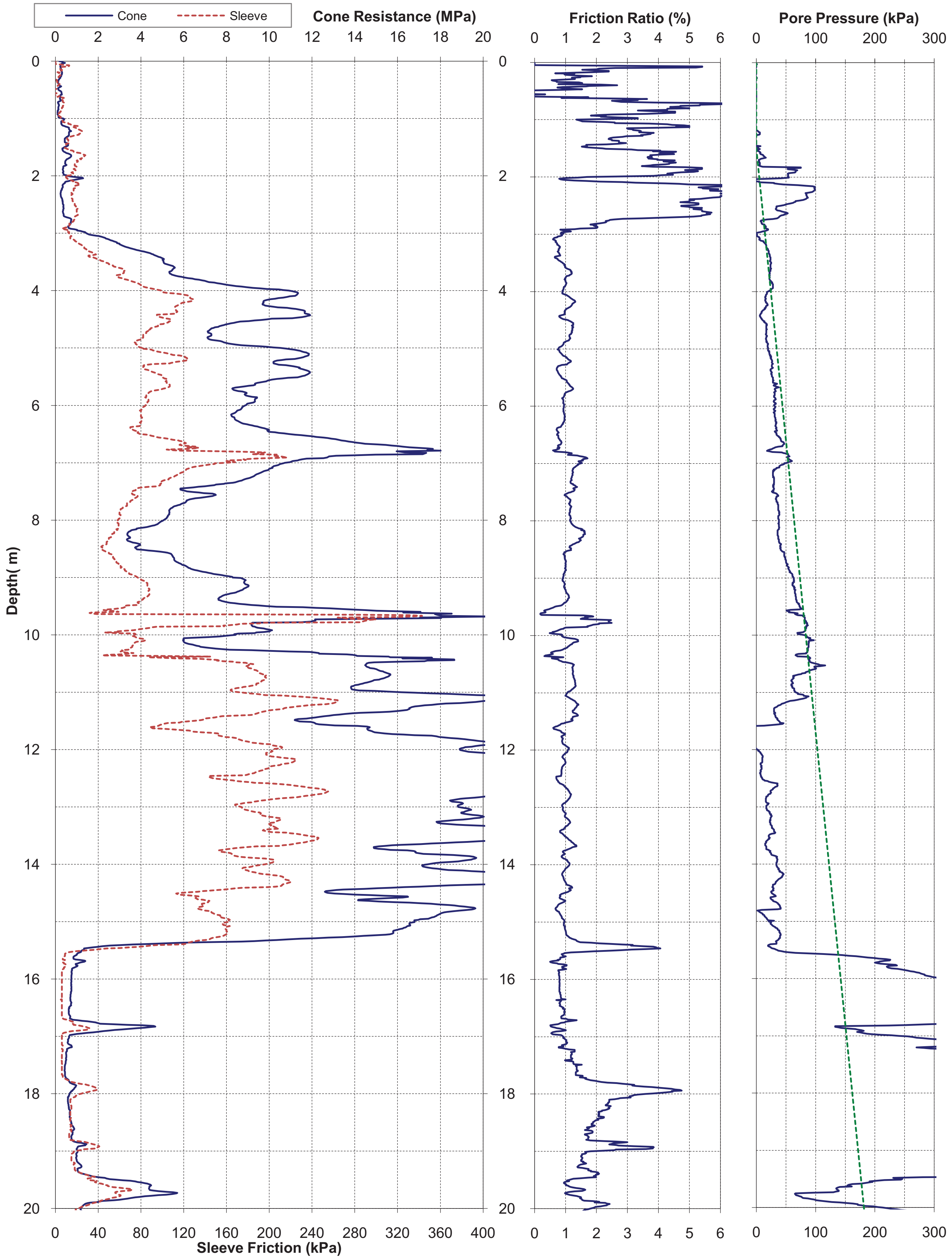
Gridref: M36:83062-38901 Accuracy : 3 (1=high, 5=low)
Ground Level Altitude : 2.3 +MSD
Well name : CCC BorelogID 3255
Drill Method : Not Recorded
Drill Depth : -6m Drill Date :



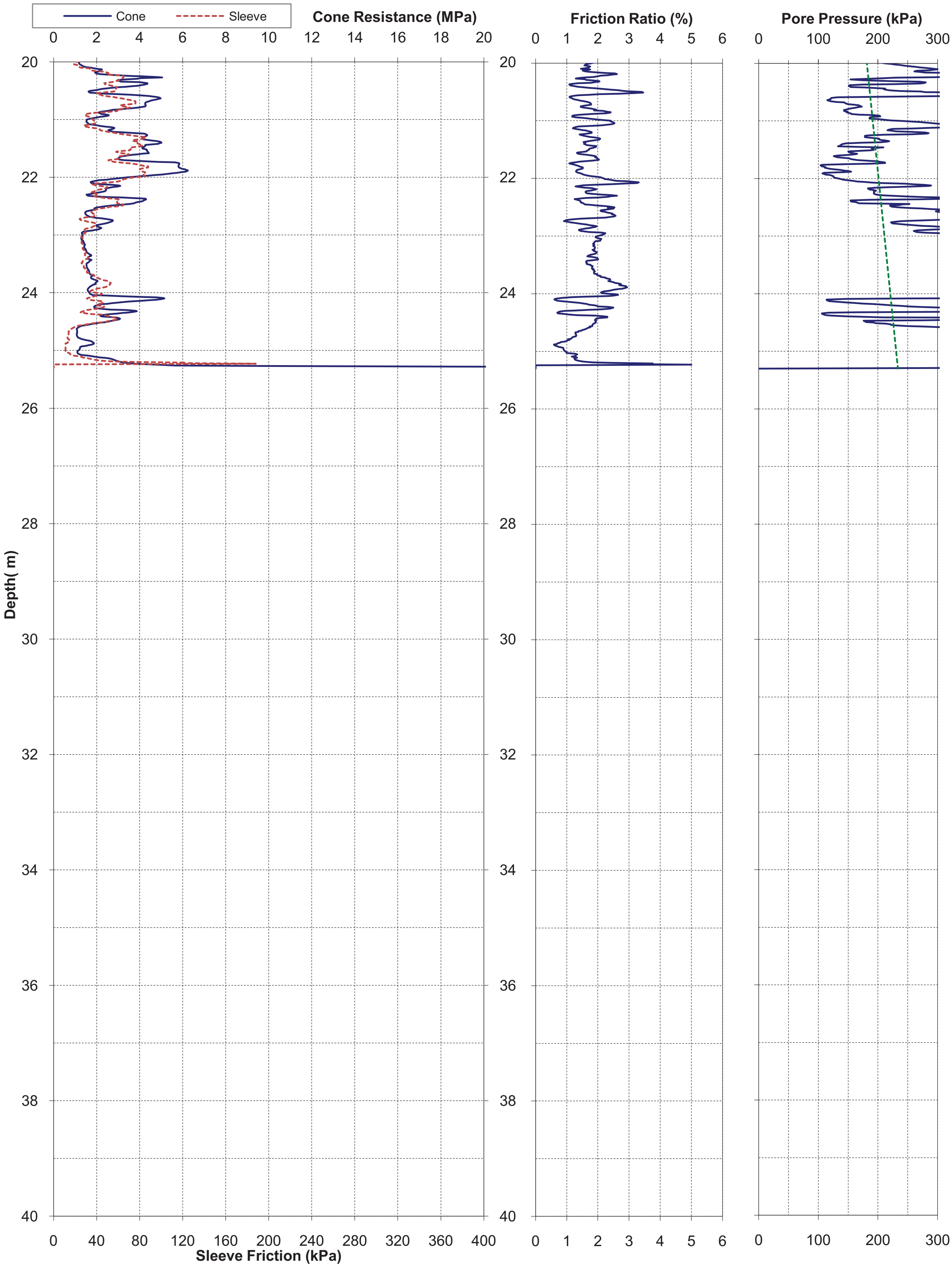
Depth(m)	Full Drillers Description	Formation Code
0 to -1.00m	yellow brown non-cohesive dry uniform silt and topsoil	
-1.00m to -1.60m	grey mottled brown semi-cohesive soft moist uniform low wood pieces clayey silt	
-1.60m to -2.20m	grey brown semi-cohesive soft wet uniform clayey silt	
-2.20m to -2.50m	brown semi-cohesive soft wet uniform low wood pieces clayey silt	
-2.50m to -3.40m	blue grey non-cohesive wet uniform low wood pieces medium sand	
-3.40m to -6.00m	grey non-cohesive wet nonuniform low wood pieces silt and gravel	

Appendix C:
CPT-OPA-16

Project:	Christchurch 2011 Earthquake - EQC Ground Investigations			Page: 1 of 2	CPT-OPA-16
Test Date: 17-May-2011	Location: Opawa			Operator: Perry	
Pre-Drill: 1.2m	Assumed GWL: 1.5mBGL			Located By: Survey GPS	
Position: 2483030.1mE	5738943.1mN	2.096mRL		Coord. System: NZMG & MSL	
Other Tests:				Comments:	



Project:	Christchurch 2011 Earthquake - EQC Ground Investigations			Page:	2 of 2	CPT-OPA-16
Test Date:	17-May-2011	Location:	Opawa	Operator:	Perry	
Pre-Drill:	1.2m	Assumed GWL:	1.5mBGL	Located By:	Survey GPS	
Position:	2483030.1mE	5738943.1mN	2.096mRL	Coord. System:	NZMG & MSL	
Other Tests:				Comments:		



Appendix D:
Project Orbit Printouts

Important notice

This map and data was prepared and/or compiled for the Earthquake Commission (EQC) to assist in assessing insurance claims made under the Earthquake Commission Act 1993. It was not intended for any other purpose. EQC and its engineers, Tonkin & Taylor, have no liability to any user of this map and data or for the consequences of any person relying on them in any way. Each Canterbury Geotechnical Database (https://canterburygeotechnicaldatabase.projectorbit.com) map and data is made available solely on the basis that:

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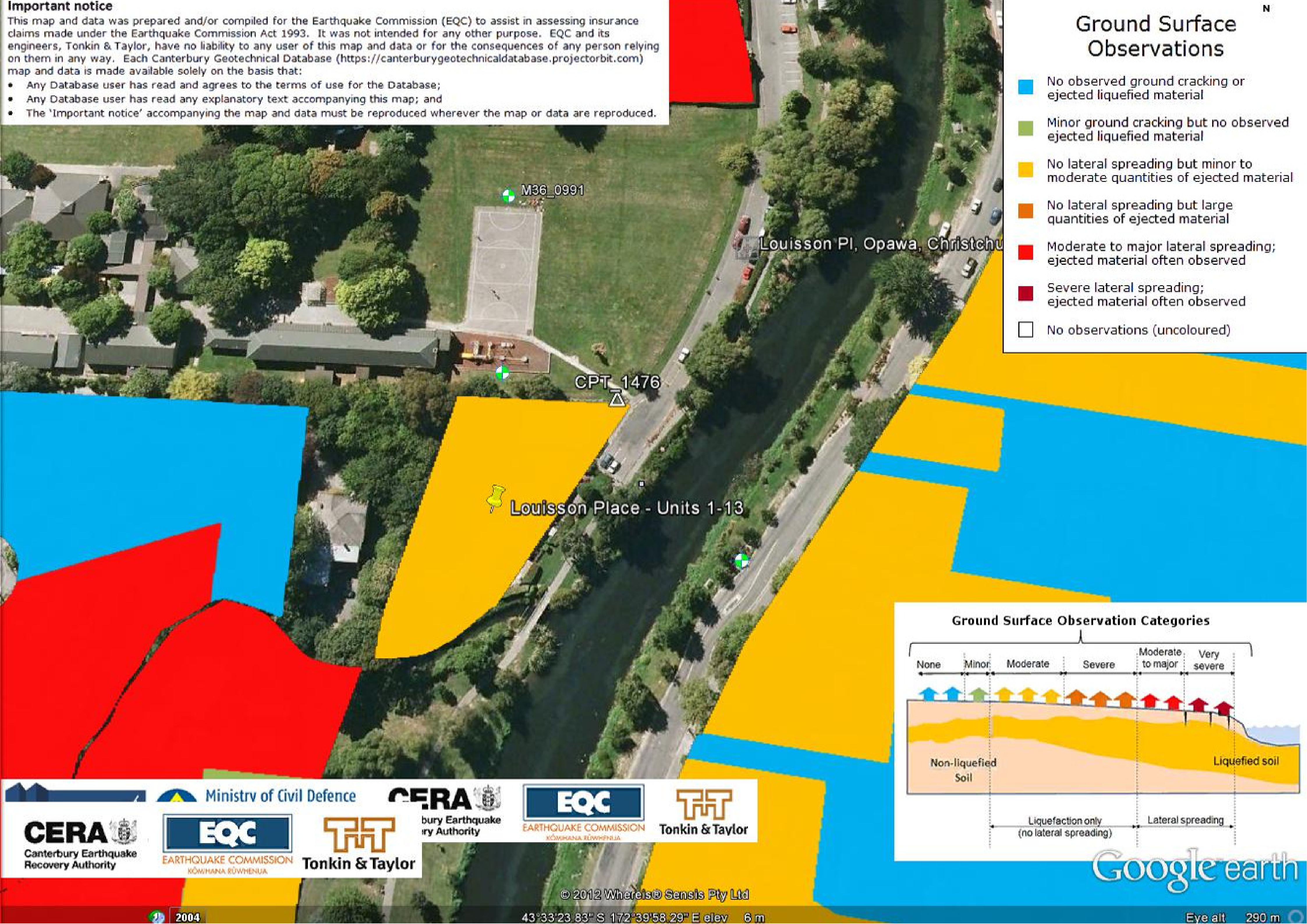
N
Ground Surface Observations
No observed ground cracking or ejected liquefied material
Minor ground cracking but no observed ejected liquefied material
No lateral spreading but minor to moderate quantities of ejected material
No lateral spreading but large quantities of ejected material
Moderate to major lateral spreading; ejected material often observed
Severe lateral spreading; ejected material often observed
No observations (uncoloured)
M36_0991
Louisson Pl, Opawa, Christchu
CPT_1476
Louisson Place - Units 1-13
Ground Surface Observation Categories
None
Minor
Moderate
Severe
Moderate to major
Very severe
Non-liquefied Soil
Liquefied soil
Liquefaction only (no lateral spreading)
Lateral spreading
Ministry of Civil Defence
CERA
Canterbury Earthquake Recovery Authority
EQC
EARTHQUAKE COMMISSION
KŌMIHANA RŪWHENUA
Tonkin & Taylor
© 2012 Whereis® Sensis Pty Ltd
Google earth
2004
43°33'23.83" S 172°39'58.29" E elev 6 m
Eye alt 290 m

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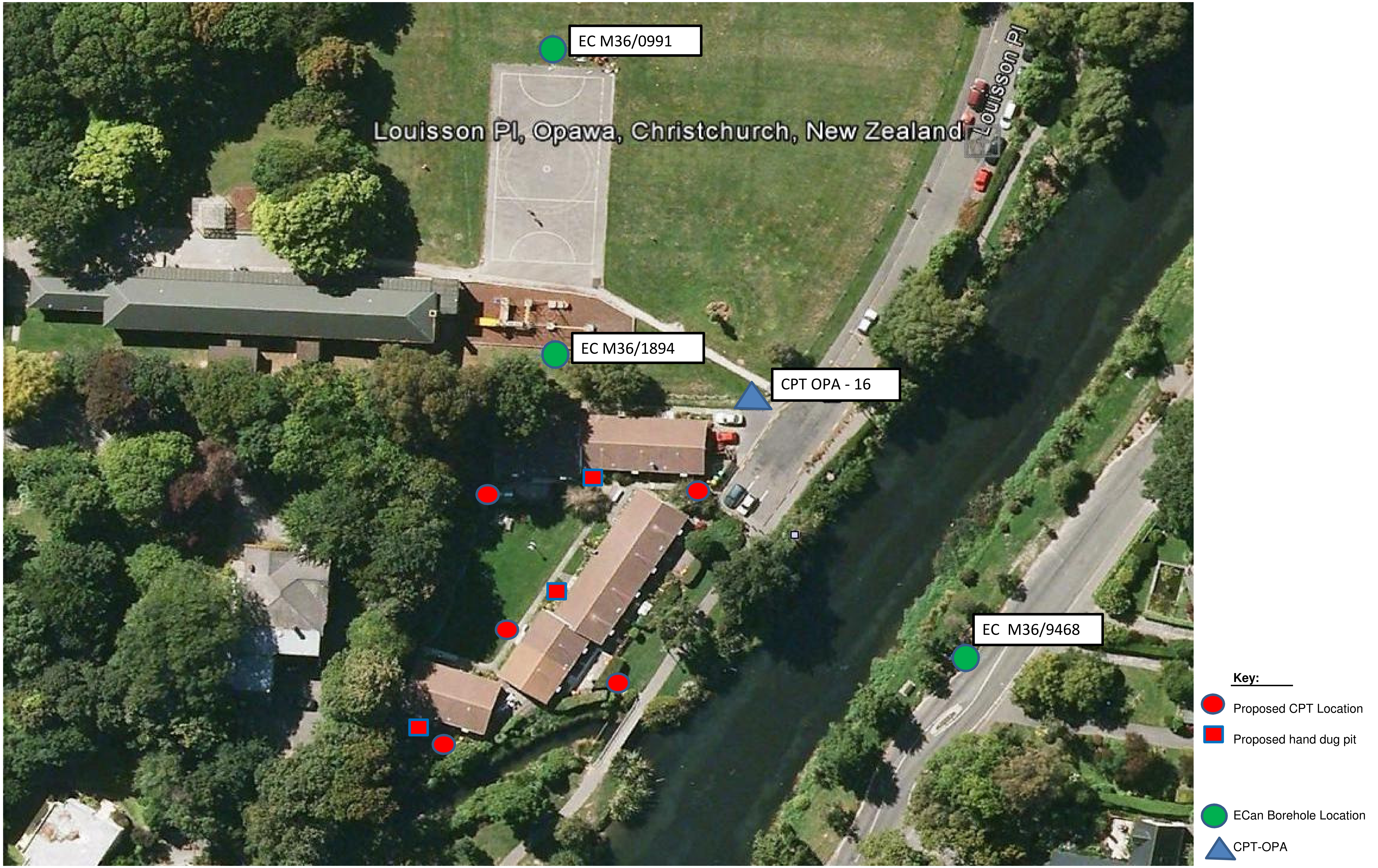
Appendix E:
Proposed Ground Investigation Plan



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Project: Units 1-13 Louisson Place
Geotechnical Desk Study

Project No.: 6-QUCC1.74

Client: Christchurch CC

Proposed Ground Investigation Plan - NTS

Drawn:
Geotechnical Engineer

Date: 6th September 2012

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