Appendix C – Geotechnical Assessment

Whanganui District Council

Mill Road Structure Plan

Geotechnical Assessment

October 2017

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1. Introduction

1.1 Introduction

Whanganui District Council (WDC) are developing a Structure Plan for the Mill Road Manufacturing Zone, to enable the WDC to identify the rate of investment for infrastructure within this site and to support uptake of the existing zoned land.

This report provides a high-level geotechnical assessment within the Mill Road area based on a desktop review of the readily available information. The following has been prepared for WDC in accordance with the proposal '*Mill Road Manufacturing Area Structure Plan – fee proposal*' provided by GHD dated 4 July 2017.

The purpose of this report is to present and summarise the information gathered from the study. After issuing this report, it is understood that this information will be utilised to inform the type and location of stormwater infrastructure and potential costings.

1.2 Scope of this report

The scope of this report is to provide information as to the potential geotechnical hazards that may affect the Structure Plan Area ("the area"). The report utilises existing data and evidence from Third Parties along with geological and geotechnical knowledge of the area to assess its general suitability for development, as follows:

- Current and historic aerial photographs of the area;
- Topographic data for the area;
- Geological maps for the area;
- Published geotechnical hazard maps for the area;
- Previous ground investigation data within or in close proximity to the area;
- Knowledge from previous work completed in the vicinity of the site;
- Anecdotal evidence from various sources; and,
- Recommendations for investigations.

The potential for geotechnical hazards have been categorised and illustrated within the report, with recommendations as to mitigation measures and/or further investigation to reduce their associated impact where applicable.

Please note that this report and the enclosed recommendations are for the sole use of WDC, to aid the Mill Road Structure Plan only. The information enclosed should be investigated fully for use beyond that stated within the report. Please refer to Section 6 for additional Scope and Limitations of this report.

1.3 General Site Setting

The Mill Road study area is on the outskirts of urban Whanganui, and is approximately 107 hectares in size. The site is predominantly pastoral greenfield at present with some existing industrial development covering approximately 10 hectares of area in two separate 'pockets'. There are three residential dwellings already onsite. The entire site is zoned 'Manufacturing Zone' in the Whanganui District Plan.

The study area is bounded to the south by the residential section suburb of Castlecliff. To the West, the study area is bounded by Castlecliff also, but the land use is more rural-residential in

nature. To the north, the land is used for rural purposes, and to the west, leading back towards central Whanganui, the Study Area is bounded by rural land connects to Mosston Road, an arterial road serving Whanganui East.

The Site is located approximately 2.1 km from the coast, and the topography is dominated by sand dune morphology, with a large relict dune feature running east-west across the site. The general surface gradient of the site is from north to south, towards the Whanganui River, with some undulating areas associated with the sand deposits. The Whanganui River enters the South Taranaki Bight approximately 1.4 km south of the site at its closest point. The coastal marine area is located approximately 1.7 km south-west of the site. The dune features typically range between 1 m to 3 m in height, and appear to be approximately aligned east to west across the site.

2. Published Geological Information

2.1 Geology

In accordance with the "Geology of the Taranaki Area", Institute of Geological and Nuclear Sciences (IGNS), 1:250,000 Scale Geological Map 7, 2008, the site is indicated to be underlain by loose, poorly consolidated sand mainly in fixed dunes (Q1d).

A list of boreholes and associated bore data within 2 km of the centre of the Site was obtained from Horizons Regional Council[1]. The bore search yielded 43 bore locations[2], and the ten boreholes recently drilled at Springvale[3] have been added to the bore list.

The shallow lithology near the site is generally described in local driller's logs as black and brown sands, with organic materials and bands of peat present to depths of approximately 20 to 25 m below ground level (bgl).

The reviewed bore log data indicates that the shallow lithology is comprised of black sands, with small layers of organic materials encountered at various depths (peat/wood layers, typically less than 0.5 m thick). This lithology is present to approximately 30 m below ground level, where the materials begins to change. In the Springvale area, shells were encountered at depth; whereas approximately 1.8 km north of the Study Area, small bands of iron sand were reported up to a depth of approximately 30 m bgl (Bore ID 790025[3]).

Numerous bore logs for the assessment area describe the deeper geology predominantly as fine-grained "papa" sandstone/mudstone/limestone, encountered at variable depths across the Site (13 m bgl to 100 m bgl). These units are inferred to be part of the upper Rangitikei sequence of marine deposits, which comprises the local basement rock.

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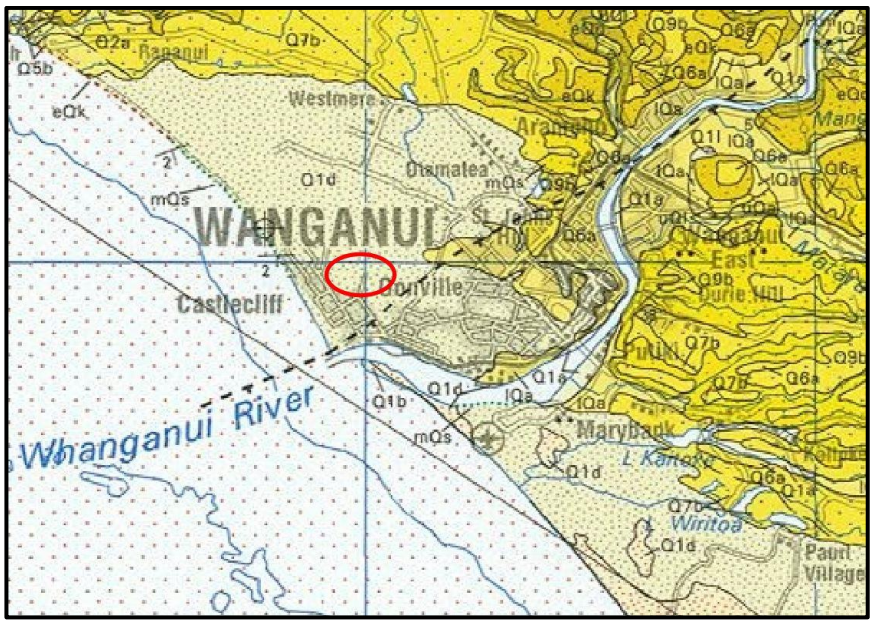
1 Horizons (2017). Geological Borehole Information from Horizons Regional Council. Received by email March 2017.

2 GHD Ltd, 2017a, Mill Road Manufacturing Zone Structure Plan – Groundwater Desktop Review for Whanganui District Council *in prep* at time of writing

3 GHD Ltd, 2017b. Springvale Structure Plan – Hydrogeological Drilling Investigation - Factual Results. Letter prepared for Whanganui DC, 16 October 2017.

Figure 1: Site geological map[4]



2.2 Earthquakes

GNS Science reports[5] that at least nine times since the 1840s Whanganui has been struck by earthquakes that have generated moderate to strong levels of shaking. Those earthquakes have caused damage to earthquake prone structures, liquefaction (including lateral spreading), disruption to key lifeline services, and some landsliding. Return periods for MM6, MM7 and MM8 levels of shaking (Modified Mercalli Intensity of shaking) are estimated to be 10 years, 50 years and 350 years respectively. The earthquake epicentres were both nearby and further afield (see Table 1):

Table 1: Earthquakes with felt effects in Whanganui since 1840[6]

Year	MMI	Magnitude	Epicentre Location
1843	8?	7.5	Wanganui
1848	6-7	7.1	Marlborough
1855	7-8	c 8.2	Wairarapa
1897	7		North of Wanganui
1929	6	7.8	Buller – Murchison Area
1931	6	7.8	Napier
1934	6-7	7.6	Pahiatua
1942	5-6	7.2	Masterton
1942	5-6	7.1	Wairarapa

[4] Geology of the Taranaki Area, Scale 1:250,000. Institute of Geological and Nuclear Sciences, Geological Map 7, 2008.

[5] Van Dissen, R., Craig, M., and Pondard, N. (2012) Wanganui City – Earthquake Hazard Summary. GNS Science Consultancy Report 2012/142, May 2012.

[6] Van Dissen, R., Craig, M., and Pondard, N. (2012) Wanganui City – Earthquake Hazard Summary. GNS Science Consultancy Report 2012/142, May 2012

2.3 Known Active Faults

There are many active faults located within the lower-central North Island region, however only those considered most likely to have an adverse effect on the site are detailed in Table 2.

Table 2: Summary of Significant Active Faults[7]

Known Active Fault	Direction from site	Distance from site[8]	Max. likely magnitude	Avg. recurrence interval[9] (years)
Wellington	SE	80 km	7.2~7.6	~600 years
Ruahine	SE-E	83 km	6.8-7.3	2,800-5,000 years
Leedstown	SE	39 km	Not est.	5,000-10,000 years
Rangitikei Offshore	SE	~50 km	7.2	3,830 years
Waitotara	NW	~35 km	7.0-7.1	3,800-9,290 years
Mohaka	SE-E	88 km	7.1	~1,000 years

2.4 Liquefaction Susceptibility

The liquefaction susceptibility map generated for Wanganui District Council by GNS Science[10] covers only approximately 65% of the structure plan area. For the areas that it covers it indicates that the majority of the site has, for the majority, a low susceptibility for liquefaction with only minor subsidence and isolated cracks and fissures to be expected in a seismic event of Modified Mercalli Intensity (MMI) 9. Discrete sections of the plan area have a moderate susceptibility where minor subsidence and isolated cracks and fissures are to be expected in a seismic event of an MMI 8 seismic event, with moderate subsidence and minor cracks and fissures to be expected in a seismic event of an MMI 9 seismic event.

For a more detailed site-specific liquefaction assessment, intrusive ground investigation is required.

2.5 Slope Stability

As the site topography consists of undulating sand dunes, further investigation is required to assess slope instability and identify mitigation measures.

2.6 Site Sub-Soil Class

In accordance with NZS 1170.5:2004, and given the information reviewed to date a site sub-soil class of **D – Deep or Soft Soil Sites** should be adopted for this site. Site specific geotechnical intrusive information may result in a revision of this soil class.

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7 http://data.gns.cri.nz/af/ - GNS Science Active Faults Database

8 Begg, J.G, & Mazengard, C., 1996. Geology of the Wellington area, scale 1:50,000. Institute of Geological and Nuclear Sciences geological map 22. 1 sheet + 128p. Lower Hutt, New Zealand: Institute of Geological and Nuclear Sciences.

9 Stirling, et al.; 2010. "National Seismic Hazard Model for New Zealand", *Bulletin of the Seismological Society of America*, Vol 102, No. 4, pp. 1514-1542.

10 Van Dissen, R., Craig, M., and Pondard, N. (2012) Wanganui City – Earthquake Hazard Summary. GNS Science Consultancy Report 2012/142, May 2012

2.7 Flood Hazard Mapping

The site is not located within the FPM Modelled 200 year Flood Extent[11].

2.8 Tsunami Zones

The site is not located within the Tsunami Evacuation Zones mapped by Whanganui District Council, as shown in Figure 2.

Figure 2: Tsunami Evacuation Zones[12]

2.9 Geomorphology

The topography of the area, close proximity to the coast, recent aerial information and ground conditions outlined within this report indicate that the area is dominated by wind-blown sand dune morphology.

Hollows within the ridges appear waterlogged and boggy indicating poor drainage within the area and high groundwater levels beneath the area.

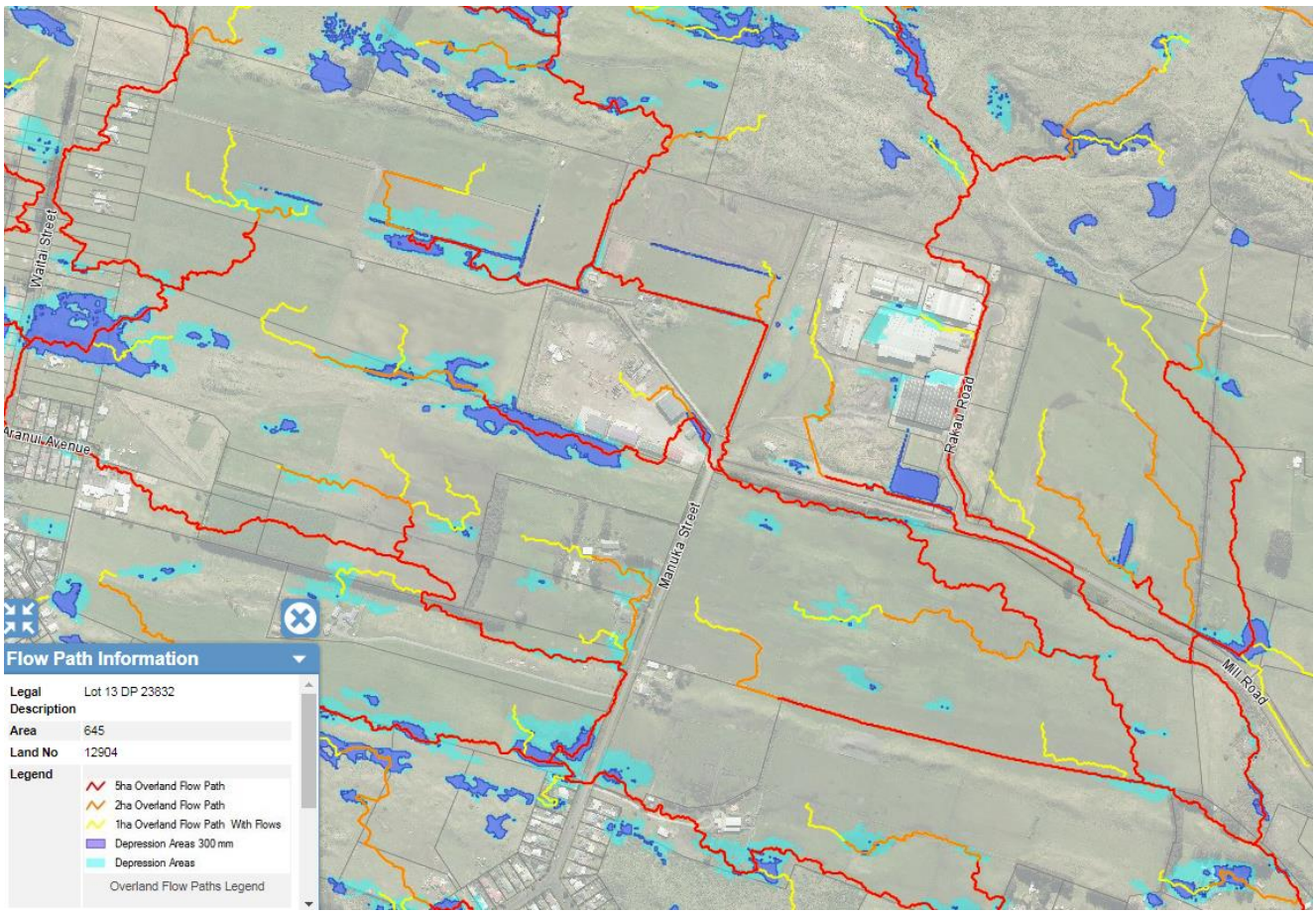
2.10 Overland Flow

Overland flow paths are mapped by Whanganui District Council, as shown in Figure 3. Overland flow may lead to surface scour along dune slopes. Further investigation is needed in order to assess the need for potential erosion mitigation measures.

11 http://horizons.govt.nz/ - Horizons Regional Council

12 https://mangomap.com/wdc/maps/57491/tsunami-evacuation-zones#zoom=15&lat=-39.925272&lng=174.99341&layergroups=wdc%3Afde04c8c-af6a-11e6-a2cc-06c182e4d011,wdc%3A6fc47cbe-af58-11e6-bb09-06c182e4d011,wdc%3Abda81bba-c6f1-11e6-9adc-06c182e4d011&bck=bingmap_hybrid

Figure 3: Overland Flow Paths[13]



2.11 Potential Effects of Dewatering

The desktop geotechnical report prepared for the nearby Springvale development[14] suggests that historical drainage of the land for residential, market garden and agricultural purposes has resulted in subsidence and settlement (based on anecdotal evidence).

Settlement related to drainage/dewatering typically occurs in compressible materials (such as peat) when groundwater levels are lowered below the lowest natural seasonal groundwater level. This can occur from such installations as the proposed swale.

Organic units, including peat layers, are recorded at shallow depth at several locations within the assessment area. As such, the risk of settlement resulting from any proposed excavations to enable stormwater drainage should be investigated.

3. Site Walkover

A site walkover was conducted on 12 September by a suitably qualified and experienced Environmental Scientist from GHD. The purpose of this visit was to broadly assess the area, the

13 http://maps.whanganui.govt.nz/IntraMaps/MapControls/EasiMaps/index.html?configId=00000000-0000-0000-0000-000000000000&form=2fb1ccb7-bfdd-4d20-b318-5a56d52d7fe7&project=WhanganuiMapControls&module=OverlandFlowPaths&layer=Land

14 GHD Ltd, 2012, Report for Springvale Structure Plan – Initial Review of Geotechnical Information for Wanganui District Council

likely underlying ground conditions and provide information regarding the geographic features via visual assessment only.

Information gathered on site was in general agreement with the geological and geomorphological evidence gained during the desktop phase of this investigation. The following was observed on site to add to the information already gained:

- Evidence of small-scale slope instability was noted within the sand dunes (see Figure 4).
- Standing water was observed in low points between dunes in several locations (see Figure 5).

Figure 4: View to west along ridge of E-W dune

Figure 5: Ponded water in a topographic low south of Mill Road

Drilling investigations were completed by GHD[15] on 22 September 2017 at the neighbouring Springvale Structure plan area (the 'Springvale Site'). The Springvale Site is a similar project commissioned by Whanganui DC, and is located east of the Study Area. These sites are considered to be comparable; where the Springvale Site is located within the same east-west black Holocene sand dune system as the Mill Road Study Area, and has similar characteristics, including hummocky dunes and standing water in areas of low topography.

4. Discussion

4.1 Geotechnical Hazards Present

The following (Table 3) is a list of geotechnical hazards considered to have potential to affect the area. This list was generated utilising the information gained during this assessment, and provides an indication of the likelihood of the hazard eventuating.

Table 3: Geotechnical Hazards Present within the area

Geotechnical Hazards	Likelihood of Hazard Eventuating
High groundwater	High - Evidence to suggest high groundwater levels present
Soft subgrade	High - Evidence of soft, waterlogged surficial ground conditions, likely organic rich in nature
Slope instability	Moderate - Evidence of previous slope instability, only within sand dune areas
Liquefaction / seismically induced densification	Low to Moderate - Loose sand and organic rich deposits, with high groundwater levels and moderate ground shaking potential
Soil erosion and scour	Low to Moderate - increased risk if disturbed soil is not protected or vegetation is removed and not replaced
Seismically induced ground shaking	Low to Moderate - no active fault traces are indicated within the area, no greater risk than the rest of Wanganui
Seismically induced ground rupture	Low - no active fault traces are indicated within the area, no greater risk than the rest of Wanganui
Ground settlement	Low to Moderate – where organic and compressible soils are located (also related to dewatering – see GHDa 2017[16])
Volume reduction due to compaction	High – previous experience indicates that when compacted the volume of sand can reduce by more than half

Other potential hazards have been identified that are not covered by the scope of the report, as follows, however these should be investigated before development of the land is considered:

- Environmental contamination, most likely as a result of agricultural and market garden land uses, potentially including saline intrusion of groundwater;
- Flood risk; and,

[15] GHD, 2017b. Springvale Structure Plan – Hydrogeological Drilling Investigation - Factual Results. Letter prepared for Whanganui DC, 16 October 2017.

[16] GHD Ltd, 2017a, Mill Road Manufacturing Zone Structure Plan – Groundwater Desktop Review for Whanganui District Council *in prep* at time of writing

- Archaeological evidence / previous land disturbance issues.

5. Recommendations

Further investigation is recommended to clarify the site-specific ground conditions and assess risks and mitigation measures. The potential risks at the site are set out in Table 3.

Intrusive ground investigations would likely consist of a specific geotechnical investigation for each proposed building footprint on the site, as well as along proposed roads and utilities. Geotechnical investigations may include a combination of machine boreholes, cone penetration tests (CPTs), hand auger holes with associated scala penetrometers (scalas), and test pits.

5.1 Recommendations

The following section outlines a series of recommendations that should be considered during the subdivision and development of the area. These recommendations are based around the geotechnical hazards presented within this report and other hazards that have been identified but that are not considered specifically geotechnical. The basis of these recommendations is to reduce the observed/anticipated hazards.

Please note that this report is not intended to provide a flood risk assessment. Recommendations regarding flood risk and mitigation are provided as they tie in with earthworks on other geotechnical recommendations and should be investigated by a suitably qualified/experienced engineer/hydrologist prior to development.

5.2 Development Recommendations

These recommendations relate to the development of the area and suggest a series of methods by which the development can be conducted to reduce the potential for geotechnical and other hazards.

Conduct a full hydrological assessment of the area and proposed development to determine the levels required to mitigate against flooding. Outcomes from such a study should allow the following to be determined:

- Proposed section levels – to be raised above proposed roading levels. This is primarily to create surface drainage from sections down to roads in the event of flood events and has been achieved on some adjacent subdivisions, refer to photo plate 4 for illustration;
- Finished floor levels – designed above flood levels for serviceability. This should complement the proposed section levels;
- Design of a swale and below ground drainage system – to efficiently remove stormwater from the area reducing the risk of flooding. This is likely to run in conjunction with the roading network; and,
- Sub-fill drainage – drainage requirements within fill areas and beneath raised sections to enhance the stormwater and raised groundwater flow to the proposed reticulation system.

Plan the development of the area based on an area-wide approach. This will allow continuity throughout the region to facilitate the enclosed recommendations. Development based on current legal boundaries could create stormwater control and building platform issues where a particular region is developed without consideration for the development of adjacent sections.

Earthworks required to facilitate the recommendations outlined above are recommended to be conducted during the subdivision earthworks phase of the development. This will allow the development of a logical infrastructure and stormwater network to be formed.

Conduct civil engineering investigations into the roading networks, subgrade requirements and potential scour of subsoils around service lines.

5.3 Geotechnical and Earthworks Recommendations

This section takes the shallow geotechnical hazards noted within the area as detailed in Section 4 of this report and outlines methods by which these may be overcome/mitigated against. The recommendations within should be subject to further investigation and analysis, including specific geotechnical intrusive investigations. These investigations should be targeted to provide information regarding the hazards outlined within this report as well as any conditions of consent and the District Plan.

All geotechnical investigations, earthworks and specific geotechnical design should be completed / reviewed by a Chartered Professional, or suitably-qualified Engineer (Geotechnical). The following list of recommendations includes all geotechnical hazards noted from the information available and presented within this report, however other hazards and recommendations/remedial solutions may be present.

Surficial soft subgrade, expansive soils and organics present should be removed from relevant areas prior to development. Removal of this material, will among other benefits, increase the bearing capacity of the subsoils and reduce the risk of settlement beneath properties. It is considered likely that the material could be reworked to form part of the topsoil required for sections or reserve areas.

Protect disturbed ground during and post-development. This will prevent surface scour and erosion of material, in addition to reducing silt runoff from the site. It is recommended that this could be controlled by re-vegetation of disturbed ground, utilising species that naturally grow in dune systems and are low growing, have broad root systems and high evapotranspiration rates.

It is considered that the area should be developable utilising conventional earthwork techniques. However specific testing of the area should be conducted to confirm this.

Dynamic compaction of material may be required to provide adequate compaction on site. This, in conjunction with the other recommendation within this report, may reduce the potential for liquefaction to affect the area.

Volume reduction as a result of compaction is anticipated to be large, in some cases compacted material may be less than half of its in-situ volume.

It is considered that the low undulating dunes across the area could be flattened to provide fill material. It may become apparent that additional fill material may be required to develop the area. This should be controlled, engineered fill as recommended by the designing civil/geotechnical engineer.

Where large dunes are present any development should include specific geotechnical investigation, slope stability analysis and utilise suitable ground retention/retaining structures or batters/terracing. These should be designed/reviewed by a Chartered Professional Engineer (Geotechnical).

6. Limitations

This report has been prepared by GHD for Whanganui District Council and may only be used and relied on by Whanganui District Council for the purpose agreed between GHD and the Whanganui District Council as set out throughout this report.

GHD otherwise disclaims responsibility to any person other than Whanganui District Council arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

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The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this report.

Site conditions (including the presence of hazardous substances and/or site contamination) may change after the date of this Report. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

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Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
0	B Curley	Bruce Simms		Sarah Jenkin		

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