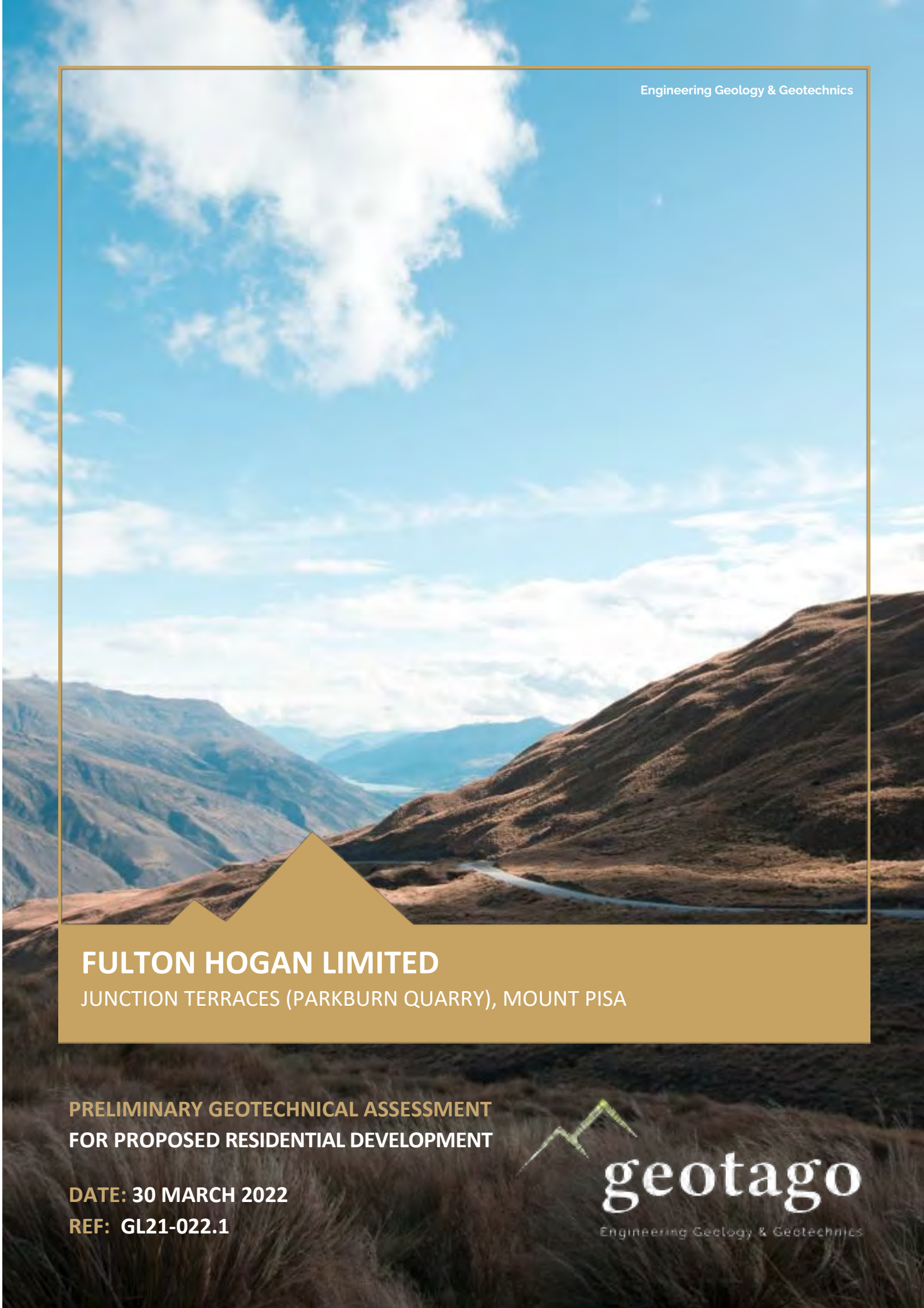

Engineering Geology & Geotechnics

FULTON HOGAN LIMITED

JUNCTION TERRACES (PARKBURN QUARRY), MOUNT PISA

PRELIMINARY GEOTECHNICAL ASSESSMENT
FOR PROPOSED RESIDENTIAL DEVELOPMENT

DATE: 30 MARCH 2022

REF: GL21-022.1

geotago

Engineering Geology & Geotechnics

Report Quality Control

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Approval

Reviewer	Title	Date Signed
Peter Forrest BSc PhD FGS CMEngNZ (PEngGeol)	Director Principal Engineering Geologist	30 March 2022

Signature of reviewer

Limitations

Geotago Ltd has undertaken this assessment in accordance with the brief as provided, based on the site and location as shown on Drawings 001 & 002. This report has been provided for the benefit of our client, and for the authoritative council to rely on for the purpose of processing the consent for the specific project described herein. No liability is accepted by this firm or any of its directors, servants or agents, in respect of its use by any other person, and any other person who relies upon information contained herein does so entirely at their own risk.

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1 Introduction

1.1 Project Brief

Geotago Ltd has been commissioned by Vivian & Espie on behalf of the client Fulton Hogan Limited to carry out a preliminary geotechnical assessment for the purposes of informing a masterplan for a proposed residential and commercial subdivision of the Parkburn Quarry area, Mt Pisa. The development will be known as Junction Terraces.

This report will form part of the documentation submitted to Central Otago District Council (CODC) in support of the submission in demonstrating that ground conditions are suitable for the site to be developed for the proposed activities and to support the Plan Change Process.

This report includes a summary of the investigations undertaken in order to provide pertinent information on the following:

- Site conditions
- Ground and groundwater conditions
- Natural hazards
- Geotechnical considerations for foundations, retention and earthworks in context of the proposed land uses
- Consideration of other geotechnical opportunities and constraints including assessment of the southern batter area with respect to future stabilisation and development.

The site location is presented in Drawing 001.

1.2 Proposed Development

The current conceptual masterplan indicates mainly residential development with existing and future business and industrial activity being maintained on the upper terrace area along the northern margin of the property. A wetland will be maintained and enhanced in the area around the mouth of the Park Burn where it enters Lake Dunstan.

A village hub containing retail, commercial and residential apartments will occupy the eastern margin of the wider property adjacent to Lake Dunstan, spanning across the ingress point from the Lake. The lower (excavated due to quarrying activities) southern portion of the property is proposed as waterfront/marina type accommodation, built on 'islands' or 'peninsulas' and surrounded by the natural waters from Lake Dunstan, with connectivity to the Lake itself.

The current masterplan option includes development of the southern margin of the property that has been reinstated with clean inert materials from the quarrying process, generating a buttress slope up against the former quarry wall. This area of development is presented in more detail as a separate report (GL21-022.2) detailing the feasibility of such an exercise, given the non-engineered nature of the reinstatement along the southern batter.

The remainder of the quarry area, which includes areas already excavated and areas of natural ground at original contour level, will be medium to high density residential, interspersed with wetlands and embankments and buffer planting.

The developed concept design and scheme layout of the Junction Terraces masterplan is presented in Appendix A.

2 Site Information

2.1 Site Description

Parkburn Quarry is located on the east of SH6 Luggate-Cromwell Road, situated between the highway and Lake Dunstan to the its immediate east. The address of the site is 922 Luggate Cromwell Road, Cromwell.

The residential subdivision of Pisa Moorings extends up to and forms the southern boundary of the quarry. To the north of the quarry are further quarry facilities owned and operated by other aggregate companies.

The legal description of the property is Secs 64-65 Pts 62-63 Blk IV Wakefield SD Sec 1 SO 365897.

The site is operational for the excavation of gravels and aggregates used mainly in the civil construction industry. The southern section has been excavated down to approximately 1m above the high level of Lake Dunstan (currently 193.5 to 194.5m AOD based on ORC data). The eastern section of the quarry was the original area of excavation and has been backfilled to near original topographical levels.

There remains open natural ground in the north and north western section of the wider property that has yet to be quarried.

2.2 Topography

The upper unquarried level of the property where the administration and other infrastructure is situated sits at approximately 210m AOD, falling to 205m AOD for the original landforms to the immediate south. The current operational area is at approximately 200m AOD, with the principle excavated land to the south (i.e. former quarry floor) at 195m (+/- 1m).

The 'Existing Quarry Condition' plan presented by Baxter Design in Appendix A provides a good approximation of the current ground levels.

2.3 Surface Water and Drainage

There is a single surface water course that runs through the site, namely Park Burn, the riparian corridor for which crosses the north east corner of the property in a NW-SE alignment, discharging into the adjacent lake Dunstan.

2.4 Site History and Aerial Photography

Aerial photographs available from the Google Earth Images and Retrolens.nz dating from 1954 to 2019 were studied to observe the site over time and assess the geomorphological setting.

The main points of interest from the review of historic aerial photography is summarised in Table 1 below. The 1984 and 2001 aerial photographs are reproduced in Appendix B, together with a current aerial view from circa 2018 taken from the NZ Geotechnical Database GIS system.

Table 1: Summary of Historical Photography

Date	Description
Pre 1984	Open fields/paddocks. Clutha River in its original alignment prior to the flooding to form Lake Dunstan.
1984	The road off the highway currently used for the Quarry access road is shown in the current configuration. The road served a single dwelling and associated outbuildings, beyond which appears to be orchards and farmland. Park Burn shown as a braided stream discharging into the Clutha River.

Date	Description
2001	Lake Dunstan is shown in its current configuration. The quarry is operational in the north east corner of the wider property.
2004	The quarry has extended within the north eastern corner of the current property.
2007	The quarry has extended into the southern portion of the site, with the main processing infrastructure in place within the central section of the operation.
2007 - 2022	Little change to the operational area. Backfilling has occurred throughout the period.

The quarry has been effectively worked and progressively backfilled in a clockwise direction, starting in the north east corner of the property and working round to the south west corner adjacent to SH6. The current active quarry wall has a west to east orientation and is being worked northwards.

2.5 Previous Site Investigations

The New Zealand Geotechnical Database (NZGD) has been reviewed for geotechnical investigation data within the vicinity of the project site. Three water well bores are recorded in the vicinity of the central processing plant area. The logs all indicate coarse sandy gravels as to be anticipated. Groundwater level was recorded in the 2014 bore record stating static water level was at 10.9m below ground level, but there is no reference to the topographical height of the borehole collar.

There are no other geotechnical reports available for review.

3 Site Investigation Details

3.1 Site Assessment

Geotago Ltd completed an engineering geological assessment of the subject property on 22 February 2022, which included a general site walkover and subsurface investigations. The geotechnical investigation comprised 12 test pits advanced to a maximum depth of 2.2m where they met with effective refusal due to either water ingress, pit collapse or dense material. No Scala penetrometer tests were completed on the grounds that the material being encountered was too coarse and dense to allow for meaningful use of the equipment.

The investigations were located across the quarry area to provide a wide distribution of test locations as shown on Drawing 002.

3.2 Investigation Logging

Soils recovered from the test pits have been logged and are presented in Appendix C. Logging of the soil encountered has been undertaken in accordance with NZ Geotechnical Society Guidelines for the Field Classification and Description of Soil and Rock for Engineering Purposes.

4 Subsurface Conditions

4.1 Geological Setting

The Geological Map of New Zealand, Sheet 18 (Wakatipu), at a scale of 1:250,000 maps the site as being underlain by Late Pleistocene outwash (river) deposits comprising generally unweathered to slightly weathered, loose, sandy to silty, well rounded gravel usually on large outwash plains.

4.2 Ground Conditions & Stratigraphy

The majority of the test pits were excavated either on the floor of the operational quarry or in areas that have been subsequently backfilled, therefore the most common geology encountered was either the natural outwash gravels or uncontrolled fill used in the backfilling operation. However, there were also occasional encounters with loess in the areas of where quarry activity has not yet taken place.

Full details of the observed subsurface stratigraphy can be found within the test pit logs contained in Appendix C.

A summary of the sub-surface conditions identified in the investigations undertaken is presented below in order of depth from the ground surface. The sub-surface conditions have been extrapolated between the investigations undertaken and other available information.

4.2.1 Topsoil

Topsoil was encountered in all test pits except TP101, TP103 and TP108. The soil comprises organic sandy SILT, brown, with roots to depths of approximately 0.2 m. Topsoil has been introduced in the area of TP102 where rehabilitation has been undertaken.

4.2.2 Loess

Loess soils comprising tightly light brown SILT were encountered below the topsoil in TP104, TP107 and TP112. The loess extended to a maximum depth of 1.2m in TP112, and at its least thickness in TP107 extending to 0.6m below ground level.

4.2.3 Uncontrolled Fill

Fill was encountered across the quarry in three main forms. In the first instance, crusher dust comprising tightly packed sand with gravels has been used as a finishing surface where the quarry is either backfilled or is at its finished level of excavation, but is being tracked by heavy vehicles. This was recorded in TPs 101, 102, 103 and 110.

The second form of fill comprises general fill that has been used to backfill previously quarried areas. The material is generally coarse granular material but contains extraneous materials such as timber, wood, concrete etc. Such fill was encountered in TP108 to 0.9m but is anticipated in other areas of the original quarry area in the north east corner of the site.

The third and most widely encountered fill is the waste 'Pea Gravel', comprising the 5-8mm range material that is too small to crush and too large to be included with the sand based products. The gravel is loose, free-running and collapses on excavation, making test pit progression difficult once encountered.

The pea gravel have been used to backfill the quarry area and former settlement ponds extensively, often extending to depths of 5 to 6m below the current ground level. The peas have also been used to form the southern batter slopes along the former quarry wall, where their depth may be as much as 11m in places.

4.2.4 Outwash Deposits

The natural gravel sequence below any loess and uncontrolled fill comprises sandy GRAVELS with cobbles and occasional boulders. The material is loose to tightly packed. The sand is generally coarse grained, with the gravels well graded and subangular to subrounded.

The following photograph was taken of the current working face and shows the typical vertical sequence of the outwash gravels.

Figure 1: Outwash Deposits Vertical Sequence

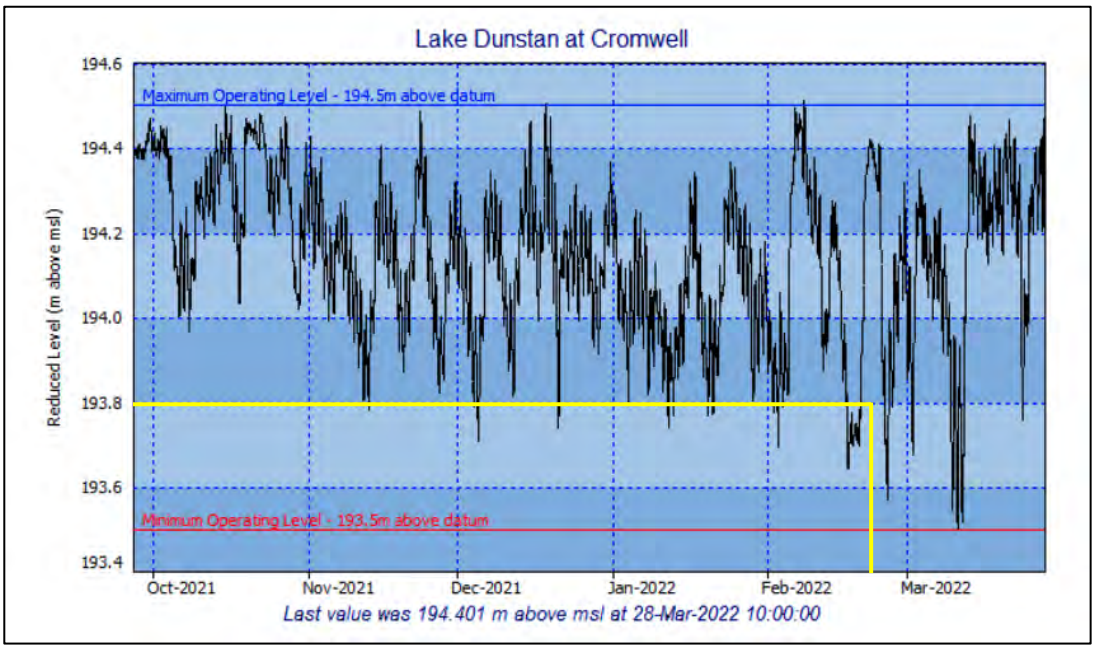
4.3 Groundwater

Groundwater was encountered in the first three test pits, completed on the basal floor of the quarry in the southern section of the property. TP101 recorded groundwater at 1.1m below ground level, with rapid ingress terminating the test pit. TP102 recorded the greatest depth to groundwater at 1.9m, with TP103 at 1.6m depth below ground level.

No further borehole information was available from the ORC borehole database beyond that described by the NZ Geotechnical Database.

Lake Dunstan is reported to have a normal operating range of 193.5 to 194.5 m AOD. Based on ORC data, at the time of the investigation in mid-February 2022, the Lake would have been at approximately 193.8m AOD s shown in the graph below (Figure 2) taken from the ORC website:

Figure 2: Hydraulic Levels of Lake Dunstan



The groundwater below the quarry is reasonably static and is the controlling factor in quarry depth, with excavation ceasing some 1m above groundwater. The groundwater is anticipated to be in hydraulic conductivity with the Lake, which is reported to have a daily fluctuation in the realms of 750mm.

5 Natural Hazards

5.1 General

The Otago Regional Council Natural Hazards Portal has been reviewed for the purposes of identifying potential natural hazards that may impact the site. The information from the database is used together with our observations from the site investigation to inform the discussion below.

5.2 Alluvial Fan

The corridor containing the Park Burn is identified as an active floodwater dominated alluvial fan. However, the zone tapers out to a thin area restricted to the semi channelised burn as it discharges to the Lake. The remainder of the property is not zoned for any form of alluvial fan or alluvial landform.

The burn is in a very controlled environment and is contained as it passes through the quarry and wider site. It is not considered to pose a significant hazard to the site or to the proposed development.

5.3 Flooding

The site is not prone to flooding. Lake Dunstan is a highly controlled water body, whereby any increase in lake level due to increased precipitation and runoff from the surrounding area is quickly discharged over the spillways, maintain the effective working level of the lake.

5.4 Liquefaction

The project site is classified as Domain A. This classification suggests that the ground is predominantly underlain by rock or firm sediments, with a low to zero liquefaction potential. This is aligned with our site investigation data and the fact that the site is underlain to depth by relatively dense coarse sandy gravels and cobbles.

5.5 Slope Stability

The site is effectively on level ground and remote from natural steeper slopes that would be prone to landslide or instability.

5.6 Seismic

The soil classification for the site is Class D, relating to soft or deep sediments. This is considered an appropriate classification.

No active faults were mapped in the field, however, the active Pisa Fault Zone shown on the published Qm 18 is approximately 4.5km west from the site. The fault is considered low risk due to its recurrence level being greater than 10,000 years.

There is a significant seismic risk to the Central Otago region when the rupture of the alpine fault system occurs; recent probability predictions estimate a magnitude 7.5 or greater is highly likely within the next 45 years. Significant ground shaking is expected from this type of event.

Further discussion on seismic design and its potential influence on the development is presented in Section 7.9 to 7.11 inclusive.

6 Geological Ground Model & Residual Risk

6.1 Ground Model

The geological ground model for the site is based on the collated information presented in this report including the desk top information, intrusive investigation, anecdotal information and our interpretation of the data assembled to date with pertinent points summarised below:

- The site is currently an operation gravels and aggregates quarry, first operational from the 1990s. Prior to this, the area was open pasture and farmland.
- The site is located on level topography which does not display any slope instability features. In addition, the site is remote from steeper slopes and/or slopes prone to the development of slope instability features.
- The site is underlain by competent ground conditions consisting of loess (where not stripped for quarry operations) and natural sandy gravels with some cobbles and boulders to depth.
- Ground water was encountered in the test pits completed on the excavated quarry floor area, some 1-2m below the current floor level. The groundwater is anticipated to be in hydraulic conductivity with the adjacent Lake Dunstan, which has an operation level of 193.5 to 194.5m AOD.
- Park Burn runs through the eastern margin of the site as the only overland surface water course within the site itself.
- Groundwater is susceptible to seasonal variations and it is feasible that groundwater levels may rise, or seepage rates increase, over those observed following a period of prolonged rainfall and during the winter months, but will fundamentally be controlled by the operational level of Lake Dunstan.
- The site is located in the vicinity of the active Pisa Fault Zone and should be considered as seismically active in line with the wider Otago region. The soil classification for the site is Class D, relating to soft or deep sediments.
- The site is not considered be risk of liquefaction due the relatively dense, coarse sediments that underly the area to depth.

6.2 Current Site Model

With reference to Drawing 003, the current site / quarry area has been divided up schematically to represent the current land use and potential geotechnical constraints associated with the current and past uses.

The constraints are described below in Table 2:

Table 2: Site Areas & Potential Constraints

Site Area	Land Use	Potential Constraints
1	Administration, plant and equipment	Low risk area in terms of ground conditions. Area likely to be maintained as industrial / commercial use

Site Area	Land Use	Potential Constraints
2	Current settling pond	This will be backfilled at some point, with residual silt and fine sands having accumulated at the base of the pond. Backfilling likely to be with pea gravels in line with other backfilled areas. Poor ground conditions will likely result from backfilling.
3	Operational quarry area	Quarry activities have exposed natural gravel sequence. Low risk in terms of ground conditions. Groundwater is shallow.
4	Backfilled areas	Former quarry areas backfilled with uncontrolled but clean fill. This includes pea gravel to depths of up to 5m. Likely to be geotechnically constrained due to the free-running nature of the pea gravel.
5	Former settling ponds	Fill and sediment within the former pond areas are likely to be soft sand and silts, with a high moisture content and low bearing capacity. Remainder of fill will be pea gravels, with their inherent constraints.
6	Quarry floor	Current exposed natural gravels on the quarry floor where operations have ceased. Groundwater is shallow at this level, but the natural soils have few geotechnical constraints.
7	Southern Batter (Reinstated)	This area is the current southern batter and boundary to the site. The former quarry wall has effectively been buttressed with coarse quarry scrapings and pea gravel, mantled with site won topsoil and superficial soils from the quarry extension. The slope is approximately 1V:5H or 11-12 degrees. The fill is not engineered. Excavation of test pits in this area demonstrated the free running nature of the pea gravels. This would impact on any future earthworks in order to develop the slope area. It is understood that the backfilled area is at a maximum of some 11m.
8	Southern Batter (in process of reinstatement))	Pea gravels currently being deposited in this area as part of the quarry reinstatement as per Area 7. Some partial revegetation using quarry scrapings and topsoil for the quarry extension areas. The fill is non-engineered and will present similar constraints to those identified for Area 7.
9	Future quarry Extension	Natural ground yet to be quarried. The ground conditions present as the natural sequence of topsoil over loess over sandy gravels. Groundwater is at depth in these locations (i.e. >10m from current ground level).

6.3 Geotechnical Risk and Limitations

Geotechnical investigation and their interpretation are subject to limitations and inherent risk due to the spatial distribution of the investigation points relative to the property/site area and the residual uncertainties of the ground conditions that remains uninvestigated. Therefore the following should be noted:

- The investigation, ground model and site model are based on the current configuration of the operational quarry. With operations planned to continue for the foreseeable future, the position of the quarry wall, the areas of backfilling and natural ground will change in time, meaning that some of this report may become redundant.
- Ground conditions can vary between investigations undertaken and there is always some natural variability in ground conditions both laterally and vertically, particularly with recent deposits.

- Small-scale ground anomalies, particularly associated with human disturbance such as demolished buildings, buried services and landscaping works can often be missed by the investigations.
- Ground strength can change with variations in natural water/moisture content, soil type and ground loading. As such, our interpretation and assessments are cognisant that ground conditions may differ to those reported at the time of this investigation due to periods of wet weather and/or during the winter months.
- The impact of climate change and its influence on ground conditions from a geotechnical perspective is an area being currently researched. However, based on our current understanding effects will include changes in groundwater regimes, soil saturation and surface water characteristics all of which may have a future effect on any current site development.

7 Geotechnical Considerations

7.1 General

With reference to the proposed masterplan (Appendix A), the future development of the quarry will comprise a mix of residential, commercial, retail, industrial and recreational areas, including water front property. The latter will provide a significant proportion of the residential development, built on small peninsulas and adjacent embankments that will be built up from the current quarry floor.

The ground conditions and geotechnical design parameters will vary across the global site, the latter being influenced by the nature and position of the structures being built. However, at this stage of the project, some general geotechnical constraints and opportunities can be addressed in order to facilitate the feasibility assessment of the development.

The main geotechnical considerations are:

- Building platform stability
- Uncontrolled fill extents (area and depth)
- Earthworks and batter stability
- Slope stability of reinstated quarry batters
- Bearing capacity and foundations
- Geotechnical design parameters for retaining walls
- Seismic conditions and design parameters
- Groundwater

These are all addressed in the following sections. It is however accepted that more targeted site investigation will undoubtedly be required, particularly as the quarry continues to be worked, which may influence and change some of the assumptions and values given below.

7.2 Building Platform Stability

Based on our ground model developed for the site, we are of the opinion that the site is generally suitable for the proposed mixed residential development comprising two to three storey lightweight residential structures. The commercial, retail and industrial units as well as other structures and associated infrastructure can also be accommodated by the current ground conditions, albeit, more

robust foundation and earthworks solutions may be required to accommodate increased load profiles.

In the main, building platforms or build areas will be on level ground underlain by competent material, more likely or not comprising the dense sandy GRAVELS, or in some instances improved ground and or certified fill.

Building platform preparation on areas of natural ground will be nominal, with little required in terms of earthworks given the level nature of the majority of the site. Areas underlain by loess soils may require certification for bearing capacity (see Section 7.6).

Development where certified fill underlies the building area will again require nominal earthworks, as the ground conditions will have been engineered to accommodate the proposed development.

The areas where building platforms are developed over uncontrolled fill or rehabilitated quarry batters, will require most attention. Foundations can be designed to carry loads to stable ground below any uncontrolled fill, such as areas 4, 5, 6 & 7 of Drawing 003, but such solutions may be more financially viable for the larger commercial type structure. Alternatively ground improvement will be required.

Development of the peninsular and islands for the waterway residential areas will be engineered and take into account freeboard, high groundwater and erosion of the perimeters.

7.3 Uncontrolled Fill Extent

The site investigation has highlighted that where the quarry has been backfilled and previous ground levels effectively reinstated, uncontrolled fill has been used. This fill is generally quarry generated waste materials such as pea gravel, quarry scrapings and to a lesser extent imported fill of various origins.

The lateral and vertical extent of these areas will require further investigation in order to delineate their spatial distribution. Area 4 of Drawing 003 may also include fill containing organic (vegetation) material, as well as hard fill such as concrete, metal and other construction and roading materials.

Area 5 may pose the most significant challenge and will require further investigation to understand exactly the depth and nature of the fill. These former settling ponds are likely to have saturated fine grained materials at the base of the backfilled area, overlain by the ubiquitous pea gravel. The depth of the ponds is likely to be in the region of 5m.

The areas and slopes of batter reinstatement along the former quarry wall (currently areas 6 & 7 of Drawing 003) are predominantly constructed from the waste pea gravel. Test pitting through this material (presented in a parallel report GL21-022.2) has demonstrated that the fill is particularly unstable on excavation, the gravels running freely from any free face. Given the former height of the quarry wall, the upper reaches of the 1 in 5 slope may well be in the region of 11m from current finished ground level to the former quarry floor.

As the quarry develops, pea gravel waste will continue to be deposited in a similar manner to the current operation, forming backfill to shallow slopes that buttress the quarry walls. This process may sterilize large areas of the future development footprint, should the pea gravel prove to be a significant constraint to being engineered or built on.

7.4 Earthworks and Batter Angles

Earthworks and drainage should be undertaken in accordance with NZS4404 Land Development and Subdivision Engineering, NZS4431 Code of Practice for Earth Fill for Residential Development and any District and Regional Plan provisions on residential development.

Recommended temporary and permanent batter angles for cut slopes up to a maximum of 3.0m in both wet and dry conditions are presented below in Table 3. The batters provided should be adhered to where more than one soil type is present within the slope or defaulted to the shallower angle where appropriate.

Slopes that are required to be steeper than those described below should be structurally retained or subject to specific geotechnical design.

Table 3: Batter Angles for Soil Slopes

Material Type	Recommended Maximum Batter Angles for Temporary Cut Slopes Formed in Soils		Recommended Maximum Batter Angles for Permanent Cut Slopes Formed in Dry (Drained) Soils
	Wet ground	Dry Ground	
Topsoil	2H:1V	1H:2V	2H:1V (grassed/planted
Loess	1H:1V	1H:2V	2H:1V
Outwash Deposits	1H:2V	1H:3V	1H:2V
Uncontrolled Fill	1H:1V	1H:2V	2H:1V (unretained, drained)
Pea gravels	5H:1V*	5H:1V	5H:1V
Engineered Fill	1H:2V	1H:2.5V	2H:1V

All slopes should be periodically monitored during construction for signs of instability and excessive erosion, and, where necessary, corrective measures should be implemented to the satisfaction of a Geotechnical Engineer or Engineering Geologist. Should construction and earthworks be undertaken during the winter period, the frequency of the inspections should increase, with site inspections being made after any significant weather event.

As recommended in Table 3 above, unretained engineered fill slopes should be formed at 2H:1V (or flatter) providing they are well drained and compacted to the appropriate specification based on NZS4431. If steeper grades are required, the fill will require geogrid reinforcement to form slopes up to 45° but subject to specific engineering design from a chartered professional engineer.

7.5 Slope Stability of Reinstated Quarry Batters

This is subject to a separate report referenced GL21-022.2 and should be read in conjunction with this report.

The current slope angle of the reinstated batters is approximately 1V to 5H, which based on site observation is a stable angle for the pea gravel that makes up the vast majority of the slope material.

The pea gravel is typically 5 to 8mm in size, being subangular to subrounded in shape. It has very low interlocking capacity between grains and no cohesion as all fines have been removed as part of the screening and washing process.

As described previously, the material does not hold up when excavated, with its free face collapsing to its natural angle of repose. This will make excavation and earthworks within this material very difficult. Its poor performance in terms of sloping batter means that extensive retaining, ground improvement or deep foundations will be required in these areas.

7.6 Bearing Capacity and Foundations.

The bearing capacity has been determined from our interpretation of the engineering description of the soil conditions and observations from the test pits on the soil behaviour. The values presented take into consideration natural variability of ground strength between investigations undertaken and potential strength reduction associated with saturated soil conditions.

7.6.1 Residential Development

The loess materials are unlikely to consistently meet the criteria of NZS3604 Good Ground for residential development and as such will provide a reduced geotechnical Ultimate Bearing Capacity of 200 to 240kPa on average. However, loess deeper within the soil profile not subjected to surface weathering and erosion may well generate sufficient strength to be classified as Good Ground with an Ultimate Bearing Capacity of 300kPa subject to site specific testing.

The sandy gravel outwash materials will consistently meet the criteria of NZS3604 Good Ground and as such will provide a geotechnical Ultimate Bearing Capacity of at least 300kPa.

It is anticipated that engineered fill placed in accordance with NZS4431 will achieve 300kPa geotechnical Ultimate Bearing Capacity in accordance with NZS3604 Section 3 testing requirements.

For the natural soils on site, together with areas of certified engineered fill, with the appropriate standards adhered to, foundations suitable for residential development are typical NZS3604 types or alternatively could be in the form of a waffle slab-on-ground.

Settlement is expected to be within limits set by NZS3604:2011 for the above allowable bearing capacity stresses.

The uncontrolled fill, including the pea gravel, are not considered suitable for foundations in its current state and will require specific engineering design (SED).

7.6.2 Commercial and Industrial Buildings

Design details will be required before foundation design for larger commercial and industrial style budlings can be determined. However, they are likely to comprise typical steel portal frame type construction and or concrete tilt panel type builds with concrete ground slabs and floors. Foundations for such buildings will need specific engineering design to accommodate the associated loads.

As such, piled foundations may be appropriate, particularly in areas where uncontrolled and or pea gravel type fill is prevalent, as this would be a commensurate foundation design, extending through the fill to competent ground without the need for extensive cut and fill operations.

7.7 Expansive Soils

There is no specific engineered foundation design required to resist shrink/swell associated with the non-expansive soils encountered on site.

7.8 Retaining Walls

Engineered retaining walls will be required on site under the following circumstances:

- where the retention height is greater than 1.5m.
- where retaining wall supports any surcharged loads such as sloping ground and structure/traffic loads.
- where retaining wall failure will affect the stability and integrity of adjacent structures and neighbouring properties.

All retaining walls should be constructed with appropriate toe drainage and backfilled to their full height with lightly compacted free draining granular material or other appropriate drainage solution. Toe drainage should be discharged at a point that will not impact or influence the construction works on site or alternatively be connected to the reticulated stormwater system.

Table 4 provides geotechnical parameters for the engineered retaining wall design as required:

Table 4: Retaining Wall Design Parameters

Unit	Cohesion (c′)	Friction Angle (ϕ′)	Ultimate Bearing Capacity (kPa)	Unit Weight (γ)
Loess	1	24°	200-300kPa	18kN/m^3
Outwash Deposits	0	28-32°	300kPa	18kN/m^3
Pea Gravels	0	10-12°	<150kPa	16kN/m^3

7.9 Seismic Conditions and Design Parameters

For detailed design purposes it is recommended the magnitude of seismic acceleration be estimated in accordance with the recommendations provided in NZS 1170.5:2004 assuming Class D subsoil conditions exists across the site.

Liquefaction is not considered to be a significant risk in terms of consolidation settlement in the upper levels of the future development due to the depth to groundwater and the relative density of the course materials.

For the lower level waterfront properties built on natural granular soils or engineered platforms, liquefaction will remain low risk because of the dense granular soils that are essentially free draining. However, lateral spreading associated with the horizontal load across free faces such as the edge of the proposed peninsulas will require site specific investigation and design.

Areas where liquefaction may be of concern include the former settling ponds. Fine grained saturated material may be present at the base of these structures, that would be prone to consolidation settlement on seismic loading.

For the purposes of seismic design, the design earthquake scenarios are summarised in Table 5 below. The figures presented are derived from New Zealand Geotechnical Society Module 1, Appendix A1, with Cromwell as the point of location nearest to the project site and are valid for all Soil Classes.

The two design earthquake scenarios are derived from NZS 1170 – Structural Design Actions. These scenarios represent the following design performance requirements:

- Serviceability Limit State (SLS) – to avoid damage that would prevent the structure from being used as originally intended, without repair, and;
- Ultimate Limit State (ULS) – to avoid collapse of the structural system.

Table 5: Design Earthquake Scenarios

	Serviceability Limit State (SLS)	Ultimate Limit State (ULS)
Annual Exceedance Probability (AEP)	1/25	1/500
Earthquake Magnitude Value (M)	6.2	6.2
Peak Ground Acceleration (a_{max} (g))	0.08	0.34

7.10 GNS Active Faults Characteristics (March 2019)

This comprehensive report published in March 2019 has re-examined the distribution and nature of the faults within the Lakes and Central Districts of Otago. This has been facilitated through the technological improvement of remote sensor mapping, increased field studies and improved interpretation of field data.

The Pisa Fault Zone is in close proximity to the site. Table 5.2 of the GNS report provides the following characteristics of the Pisa Fault Zone:

- A fault zone with deformed geologically young sediments and landforms
- Is classified as being definite to possibly active fault, based on various sections and extensions of the fault and its recharacterization (i.e. the Cluden and Bannockburn Faults as strands to the Pisa Fault Zone).
- Has an assigned net slip rate of 0.1mm/yr.
- Has a calculated recurrence level of 30,000 yrs.
- Is classified with a Recurrence Interval of VI – the lowest category for active faults.

The active faults in the immediate vicinity of the upper Clutha valley (downstream of the Wanaka-Hawea basin), are assessed as low-activity faults, with recurrence intervals of more than 10,000 years. The reinterpretation that the Pisa Fault Zone extends south along the foot of the Carrick Range as a 'possible' active fault, and inclusion of the Bannockburn Fault strand in the fault zone, places Bannockburn in the potential frame of fault rupture and related hazards. However, risks are low because of the indicated very long recurrence interval for ground-rupturing earthquakes on the Pisa Fault Zone.

7.11 Development of Land Proximal to Active Faults

The MfE has published the guidance document 'Planning for Development of Land On or Close To Active Faults: A Guideline to Assist Resource Management Planners in New Zealand'. The document provides guidance on the identification of active faults, their relative level of risk they pose to development and the planning framework needed to manage such risk. The document also outlines a risk based approach to resource consent consideration.

With reference to Table 9.2 of the MfE guidelines and application of the characteristics of the Pisa Fault Zone (as shown highlighted below), Geotago assesses that the proximity of the Pisa Fault Zone does not prohibit the development nor restrict the type of structure to be built to any particular Importance Level.

Table 9.2: Relationship between fault recurrence interval and Building Importance Category

Recurrence interval class	Fault recurrence interval	Building importance category (BIC) limitations* (allowable buildings)	
		Previously subdivided or developed sites	"Greenfield" sites
I	≤2000 years	BIC 1	BIC 1
II	>2000 years to ≤3500 years	BIC 1 and 2a	
III	>3500 years to ≤5000 years	BIC 1, 2a and 2b	BIC 1 and 2a
IV	>5000 years to ≤10,000 years	BIC 1, 2a, 2b and 3	BIC 1, 2a, and 2b
V	>10,000 years to ≤20,000 years		BIC 1, 2a, 2b and 3
VI	>20,000 years to ≤125,000 years	BI Category 1, 2a, 2b, 3 and 4	

Note: Faults with average recurrence intervals >125,000 years are not considered active.

7.12 Groundwater

As previously stated, groundwater is likely in hydraulic conductivity with the adjacent Lake Dunstan, and as such its level will fluctuate in association with the controlled level of the lake.

Groundwater is unlikely therefore to fluctuate to such an extent and rise to levels that would pose a risk to the foundations or building platforms of the waterfront properties.

8 Conclusions & Recommendations

8.1 General

This preliminary geotechnical assessment is intended to provide information on the ground conditions and geotechnical constraints and opportunities to facilitate the development of the conceptual design of the Junction Terrace masterplan. At this stage of the project, the investigation and data collection is broad, and should not be construed as the final set of design parameters or recommendations but a baseline of information from which further targeted investigation and analyses will follow as the project matures.

8.2 Conclusions

- Parkburn Quarry has been subject to a conceptual masterplan for its redevelopment to provide significant residential, commercial, retail and industrial land use to the district.
- The operational quarry has progressively extracted sands and gravels for the civil construction industry, with former quarried areas being backfilled with waste materials from the processing operation (general fill and 'pea gravels').
- Natural ground comprises loess soils over outwash deposits of sands and gravels with cobbles and boulders.
- Groundwater is in hydraulic conductivity with Lake Dunstan, which has an operational lake level of 193.5 to 194.5m AOD. The current quarry floor is at approximately 195-196m AOD.
- There are no natural hazards that will impact on the site or its development, with the minor exception of potential liquefaction in areas of the former settling ponds and the small risk of lateral spreading of the embankments associated with the waterfront properties/areas.
- Ground conditions are generally conducive to the development, with traditional shallow foundations for residential build where natural ground is exposed. Specific engineering design (SED) will be required for the waterfront properties, and the larger commercial, industrial and retail type structures, particularly where these coincide with areas of historical fill.
- The reinstated slopes that buttress the former quarry walls, where pea gravel has been used as bulk fill, will prove problematic in terms of stability and suitability for development. Ground improvement and or deep foundations will be likely in these areas, which may dictate the type and nature of the development in these zones.
- There are no seismic conditions or constraints that negate the development of any building, regardless of its Building Importance Category.

8.3 Recommendations

- The findings of this report should be presented to the stakeholders and design team members to inform the iterative design process as the masterplan develops.

- Consideration must be given to the buttress slopes to the former quarry walls being backfilled with pea gravel. The problematic ground conditions as a result of using this waste material needs to be investigated to determine:

    i. The depth and extent / footprint of the slopes

    ii. If retaining walls can be employed at the base or lower sections of the slopes to form stable ground / terraces

    iii. If piles can be driven to provide foundation solutions

    These areas may be key to the actual development layout, particularly as the material continues to be used as uncontrolled fill around the site.

- Deep geotechnical investigations in the areas of general fill, particularly around the areas of the former settling ponds will be required. Consolidation and settlement calculations will be required to determine if the fill can classified as suitably compacted to accommodate shallow foundations.

- Liquefaction assessment will be required if these deeper investigations prove fine grained saturated material at the base of the infill.

- Assessment of the island/peninsula design will be required to determine if lateral spreading will be an issue.

Drawings

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FULTON HOGAN

PARKBURN QUARRY, MOUNT PISA

SITE LOCATION PLAN

SCALE: NOT TO SCALE

REF:	DATE:
GL21-022.1 DRW001	23 FEBRUARY 2022

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FULTON HOGAN

PARKBURN QUARRY, MOUNT PISA

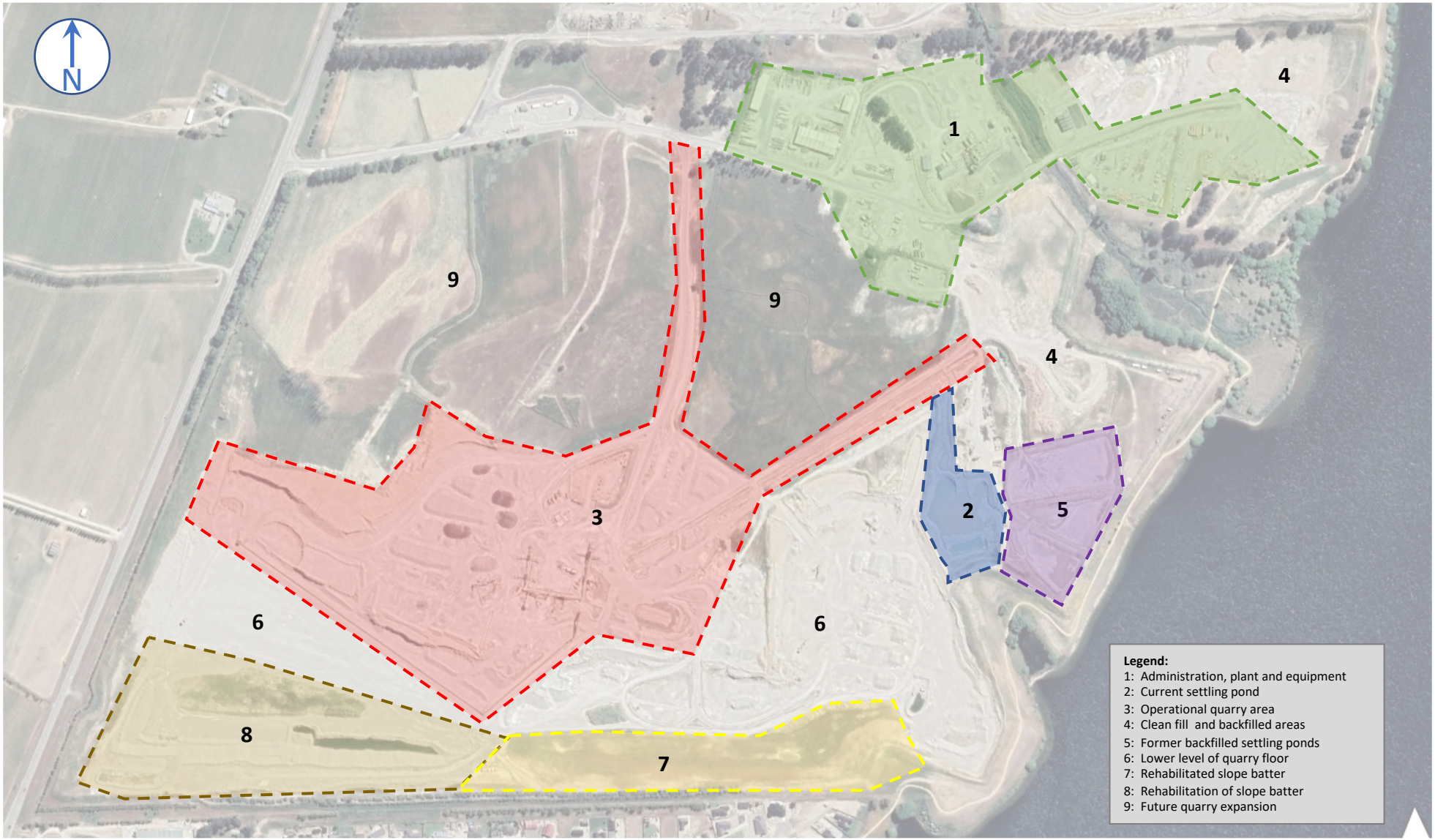
SITE INVESTIGATION PLAN

SCALE: 1:7000 APPROX

0m 280m

REF: 21-022.1 DRW002

DATE: 23 FEBRUARY 2022



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FULTON HOGAN

PARKBURN QUARRY, MOUNT PISA

SITE MODEL

SCALE: 1:7000 APPROX

0m 280m

REF: 21-022.1 DRW003

DATE: 23 FEBRUARY 2022

Appendix A – Scheme Layout (Excerpts)

Fulton Hogan

EXISTING QUARRY CONDITION
SCALE 1:5000 @A3

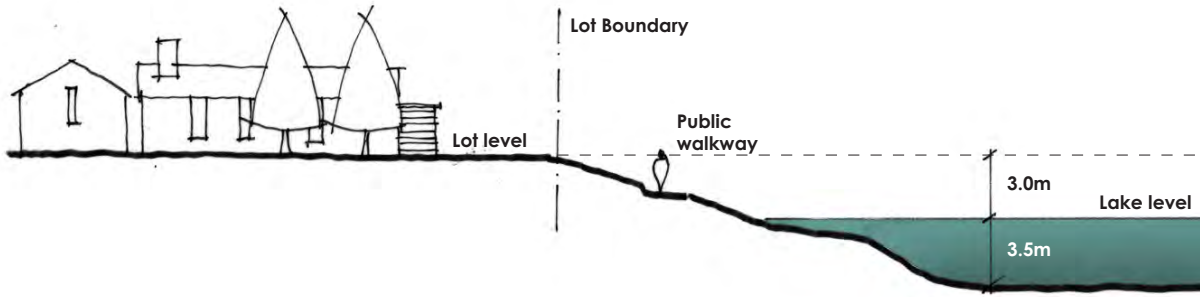
baxter design

Fulton Hogan

MASTERPLAN
1:5000 @A3

Note: Plan indicative only

baxter design

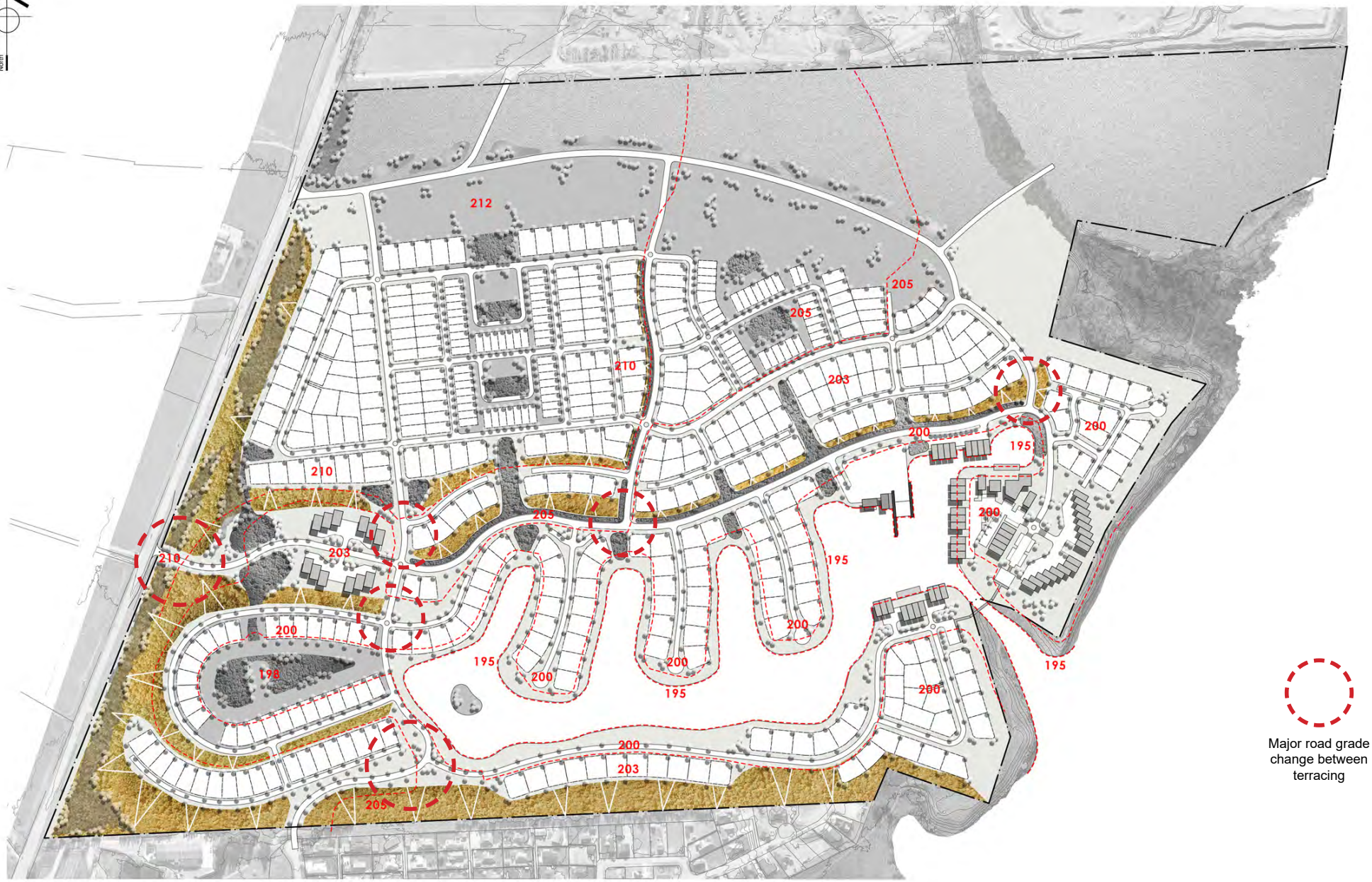


Fulton Hogan

WATERWAY LOTS - SKETCH SECTION

baxter design

Note: Plan indicative only

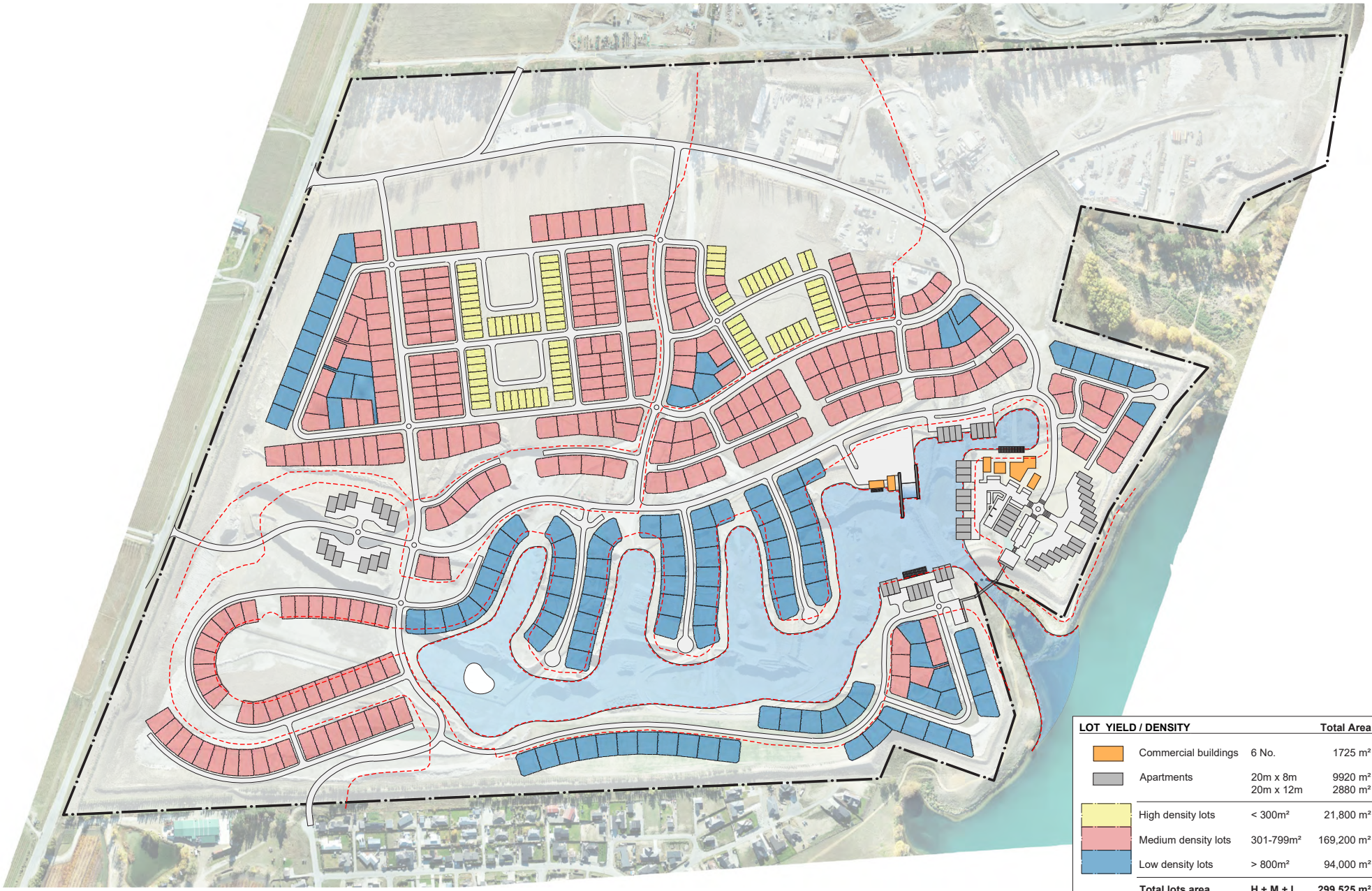


Fulton Hogan

CONCEPT LEVELS

baxter design

Note: Plan indicative only



LOT YIELD / DENSITY			Total Area	Quantity
	Commercial buildings	6 No.	1725 m²	
	Apartments	20m x 8m	9920 m²	62
		20m x 12m	2880 m²	12
	High density lots	< 300m²	21,800 m²	85
	Medium density lots	301-799m²	169,200 m²	272
	Low density lots	> 800m²	94,000 m²	112
	Total lots area	**H + M + L**	**299,525 m²**	**543**

Fulton Hogan

DEVELOPMENT PATTERNS & LOT YIELD

baxter design

Note: Plan indicative only

Appendix B – Aerial Photographs

1984 Aerial Photograph

2001 Aerial Photograph

2018 Aerial Photograph

Appendix C - Engineering Logs

Test Pit Log

Project:	Parkburn Masterplan	Project Number:	GL21-022
Site Location:	Parkburn Quarry, Mount Pisa	Client:	Fulton Hogan
Test Pit Number:	TP101		Sheet 1 of 1

Depth (m)	Water Level	Geological Unit	Sample	Soil Rock Description	Legend	Depth
		FILL		Sand with gravels, light brown. Tightly packed, dry. Sand coarse grained, gravels fine grained subangular to subrounded (CRUSHER DUST)		
0.5		OUTWASH DEPOSITS		Sandy GRAVEL with cobbles and occasional small boulder, greyish brown. Loose to tightly packed, dry. Sand coarse grained, gravels well graded subangular to subrounded. Cobble subrounded. Strong water ingress from 1.0m depth.		0.5
1.0	▽					1.0
1.5				End of pit due to water table.		1.5
2.0						2.0
2.5						2.5
3.0						3.0
3.5						3.0

Date Excavated: 22 February 2022	Equipment: 35T tracked excavator with 1200mm tooth bucket
Logged By: PF	Contractor: Fulton Hogan

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Notes:

Test Pit Log

Project:	Parkburn Masterplan	Project Number:	GL21-022
Site Location:	Parkburn Quarry, Mount Pisa	Client:	Fulton Hogan
Test Pit Number:	TP102		Sheet 1 of 1

Depth (m)	Water Level	Geological Unit	Sample	Soil Rock Description	Legend	Depth
		TOPSOIL		Sandy SILT, with organic content, roots and rootlets.		
0.5		FILL		Sand with gravels, light brown. Tightly packed, dry. Sand coarse grained, gravels fine grained subangular to subrounded (CRUSHER DUST)		0.5
1.0		OUTWASH DEPOSITS		Sandy GRAVEL with cobbles and occasional small boulder, greyish brown. Loose to tightly packed, dry. Sand coarse grained, gravels well graded subangular to subrounded. Cobble subrounded. Storng water ingress at 1.8m.		1.0
1.5						1.5
	▽					
2.0				End of pit due to water table		2.0
2.5						2.5
3.0						3.0
3.5						3.5

Date Excavated: 22 February 2022	Equipment: 35T tracked excavator with 1200mm tooth bucket
Logged By: PF	Contractor: Fulton Hogan

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Test Pit Log

Project:	Parkburn Masterplan	Project Number:	GL21-022
Site Location:	Parkburn Quarry, Mount Pisa	Client:	Fulton Hogan
Test Pit Number:	TP103		Sheet 1 of 1

Depth (m)	Water Level	Geological Unit	Sample	Soil Rock Description	Legend	Depth
		FILL		Sand with gravels, light brown. Tightly packed, dry. Sand coarse grained, gravels fine grained subangular to subrounded (CRUSHER DUST)		
0.5		OUTWASH DEPOSITS		Sandy GRAVEL with cobbles and occasional small boulder, greyish brown. Loose to tightly packed, dry. Sand coarse grained, gravels well graded subangular to subrounded. Cobble subrounded. Water ingress at 1.6m.		0.5
1.0						1.0
1.5	▽					1.5
2.0				End of pit due to water table		2.0
2.5						2.5
3.0						3.0
3.5						3.5

Date Excavated: 22 February 2022	Equipment: 35T tracked excavator with 1200mm tooth bucket
Logged By: PF	Contractor: Fulton Hogan

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Test Pit Log

Project:	Parkburn Masterplan	Project Number:	GL21-022
Site Location:	Parkburn Quarry, Mount Pisa	Client:	Fulton Hogan
Test Pit Number:	TP104		Sheet 1 of 1

Depth (m)	Water Level	Geological Unit	Sample	Soil Rock Description	Legend	Depth
		TOPSOIL		Sandy SILT, with organic content, roots and rootlets.		
0.5		LOESS		SILT, light brown. Tightly packed, dry.		0.5
1.0		OUTWASH DEPOSITS		Sandy GRAVEL with cobbles and occasional small boulder, greyish brown. Loose to tightly packed, dry. Sand coarse grained, gravels well graded subangular to subrounded. Cobble subrounded.		1.0
1.5						1.5
2.0						2.0
2.5				End of pit - Stable		2.5
3.0						3.0
3.5						3.5

Date Excavated: 22 February 2022	Equipment: 35T tracked excavator with 1200mm tooth bucket
Logged By: PF	Contractor: Fulton Hogan

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Test Pit Log

Project:	Parkburn Masterplan	Project Number:	GL21-022
Site Location:	Parkburn Quarry, Mount Pisa	Client:	Fulton Hogan
Test Pit Number:	TP105		Sheet 1 of 1

Depth (m)	Water Level	Geological Unit	Sample	Soil Rock Description	Legend	Depth
		TOPSOIL		Sandy SILT, with organic content, roots and rootlets.		
0.5		OUTWASH DEPOSITS		Sandy GRAVEL with cobbles and occasional small boulder, greyish brown. Loose to tightly packed, dry. Sand coarse grained, gravels well graded subangular to subrounded. Cobble subrounded.		0.5
1.0						1.0
1.5						1.5
2.0						2.0
2.5				End of pit - stable		2.5
3.0						3.0
3.5						3.5

Date Excavated: 22 February 2022	Equipment: 35T tracked excavator with 1200mm tooth bucket
Logged By: PF	Contractor: Fulton Hogan

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Test Pit Log

Project:	Parkburn Masterplan	Project Number:	GL21-022
Site Location:	Parkburn Quarry, Mount Pisa	Client:	Fulton Hogan
Test Pit Number:	TP106		Sheet 1 of 1

Depth (m)	Water Level	Geological Unit	Sample	Soil Rock Description	Legend	Depth
		TOPSOIL		Sandy SILT, with organic content, roots and rootlets.		
0.5		OUTWASH DEPOSITS		Sandy GRAVEL with cobbles and occasional small boulder, greyish brown. Loose to tightly packed, dry. Sand coarse grained, gravels well graded subangular to subrounded. Cobble subrounded.		0.5
1.0						1.0
1.5						1.5
2.0						2.0
2.5				End of pit - stable		2.5
3.0						3.0
3.5						3.5

Date Excavated: 22 February 2022	Equipment: 35T tracked excavator with 1200mm tooth bucket
Logged By: PF	Contractor: Fulton Hogan

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Project:	Parkburn Masterplan	Project Number:	GL21-022
Site Location:	Parkburn Quarry, Mount Pisa	Client:	Fulton Hogan
Test Pit Number:	TP107		Sheet 1 of 1

Depth (m)	Water Level	Geological Unit	Sample	Soil Rock Description	Legend	Depth
		TOPSOIL		Sandy SILT, with organic content, roots and rootlets.		
0.5		LOESS		SILT, light brown. Tightly packed, dry.		0.5
1.0		OUTWASH DEPOSITS		Sandy GRAVEL with cobbles and occasional small boulder, greyish brown. Loose to tightly packed, dry. Sand coarse grained, gravels well graded subangular to subrounded. Cobble subrounded.		1.0
1.5						1.5
2.0						2.0
2.5				End of pit - stable		2.5
3.0						3.0
3.5						3.5

Date Excavated: 22 February 2022	Equipment: 35T tracked excavator with 1200mm tooth bucket
Logged By: PF	Contractor: Fulton Hogan

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Test Pit Log

Project:	Parkburn Masterplan	Project Number:	GL21-022
Site Location:	Parkburn Quarry, Mount Pisa	Client:	Fulton Hogan
Test Pit Number:	TP108		Sheet 1 of 1

Depth (m)	Water Level	Geological Unit	Sample	Soil Rock Description	Legend	Depth
0.5		UNCONTROLLED FILL		Sandy silty GRAVELS with cobbles and occasional extraneous materials (wood, plastic, concrete). Grey brown. Tightly packed, dry.		0.5
1.0				Sandy silt with roots, rootlets and decaying plant matter		
1.5				Sandy GRAVEL, light browish grey. Very loosely packed, dry. Gravels 5-8mm in diameter. ('PEAS')		1.0 1.5
2.0						2.0
2.5				End of pit - collapsing in due to pea gravel		2.5
3.0						3.0
3.5						3.5

Date Excavated: 22 February 2022	Equipment: 35T tracked excavator with 1200mm tooth bucket
Logged By: PF	Contractor: Fulton Hogan

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Test Pit Log

Project:	Parkburn Masterplan	Project Number:	GL21-022
Site Location:	Parkburn Quarry, Mount Pisa	Client:	Fulton Hogan
Test Pit Number:	TP109		Sheet 1 of 1

Depth (m)	Water Level	Geological Unit	Sample	Soil Rock Description	Legend	Depth
		TOPSOIL		Sandy SILT, with organic content, roots and rootlets.		
0.5		UNCONTROLLED FILL		Sandy GRAVEL, light browish grey. Very loosely packed, dry. Gravels 5-8mm in diameter. ('PEAS')		0.5
1.0						1.0
1.5						1.5
2.0						2.0
2.5				End of pit - collapsing in the pea gravel		2.5
3.0						3.0
3.5						3.5

Date Excavated: 22 February 2022	Equipment: 35T tracked excavator with 1200mm tooth bucket
Logged By: PF	Contractor: Fulton Hogan

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Test Pit Log

Project:	Parkburn Masterplan	Project Number:	GL21-022
Site Location:	Parkburn Quarry, Mount Pisa	Client:	Fulton Hogan
Test Pit Number:	TP110		Sheet 1 of 1

Depth (m)	Water Level	Geological Unit	Sample	Soil Rock Description	Legend	Depth
		TOPSOIL		SILT, light brown. Tightly packed, dry.		
0.5		UNCONTROLLED FILL		Sand with gravels, light brown. Tightly packed, dry. Sand coarse grained, gravels fine grained subangular to subrounded (CRUSHER DUST)		0.5
				Sandy GRAVEL, light browish grey. Very loosely packed, dry. Gravels 5-8mm in diameter. ('PEAS')		
1.0						1.0
1.5						1.5
2.0						2.0
				End of pit - collapsing in pea gravels		
2.5						2.5
3.0						3.0
3.5						3.5

Date Excavated: 22 February 2022	Equipment: 35T tracked excavator with 1200mm tooth bucket
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Test Pit Log

Project:	Parkburn Masterplan	Project Number:	GL21-022
Site Location:	Parkburn Quarry, Mount Pisa	Client:	Fulton Hogan
Test Pit Number:	TP111		Sheet 1 of 1

Depth (m)	Water Level	Geological Unit	Sample	Soil Rock Description	Legend	Depth
		TOPSOIL		Sandy SILT, with organic content, roots and rootlets.		
0.5		LOESS		SILT, light brown. Tightly packed, dry.		0.5
1.0		OUTWASH DEPOSITS		Sandy GRAVEL with cobbles and occasional small boulder, greyish brown. Loose to tightly packed, dry. Sand coarse grained, gravels well graded subangular to subrounded. Cobble subrounded.		1.0
1.5						1.5
2.0						2.0
				End of pit - stable		
2.5						2.5
3.0						3.0
3.5						3.5

Date Excavated: 22 February 2022	Equipment: 35T tracked excavator with 1200mm tooth bucket
Logged By: PF	Contractor: Fulton Hogan

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Test Pit Log

Project:	Parkburn Masterplan	Project Number:	GL21-022
Site Location:	Parkburn Quarry, Mount Pisa	Client:	Fulton Hogan
Test Pit Number:	TP112		Sheet 1 of 1

Depth (m)	Water Level	Geological Unit	Sample	Soil Rock Description	Legend	Depth
		TOPSOIL		Sandy SILT, with organic content, roots and rootlets.		
0.5		LOESS		SILT, light brown. Tightly packed, dry.		0.5
1.0						1.0
1.5		OUTWASH DEPOSITS		Sandy GRAVEL with cobbles and occasional small boulder, greyish brown. Loose to tightly packed, dry. Sand coarse grained, gravels well graded subangular to subrounded. Cobble subrounded.		1.5
2.0						2.0
2.5				End of pit - stable		2.5
3.0						3.0
3.5						3.5

Date Excavated: 22 February 2022	Equipment: 35T tracked excavator with 1200mm tooth bucket
Logged By: PF	Contractor: Fulton Hogan

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Appendix D - Site Photographs

Test Pit 101 - Pit 	Test Pit 101 - Arisings 
Test Pit 102 – Pit 	Test Pit 102 - Arisings 
Test Pit 103 - Pit 	Test Pit 103 - Arisings 

Test Pit 104 - Pit 	Test Pit 104 - Arisings 
Test Pit 105 - Pit 	Test Pit 105 - Arisings 
Test Pit 106 - Pit 	Test Pit 106 - Arisings 

Test Pit 107 – Pit	Test Pit 107 - Arisings
	
Test Pit 108 - Pit	Test Pit 108 - Arisings
	
Test Pit 109 - Pit	Test Pit 109 - Arisings
	

Test Pit 110 – Pit 	Test Pit 110 - Arisings 
Test Pit 111 - Pit 	Test Pit 111 - Arisings 
Test Pit 112 - Pit 	Test Pit 112 - Arisings