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GEOTECHNICAL DESKTOP ASSESSMENT

BALLARAT WEST EMPLOYMENT ZONE

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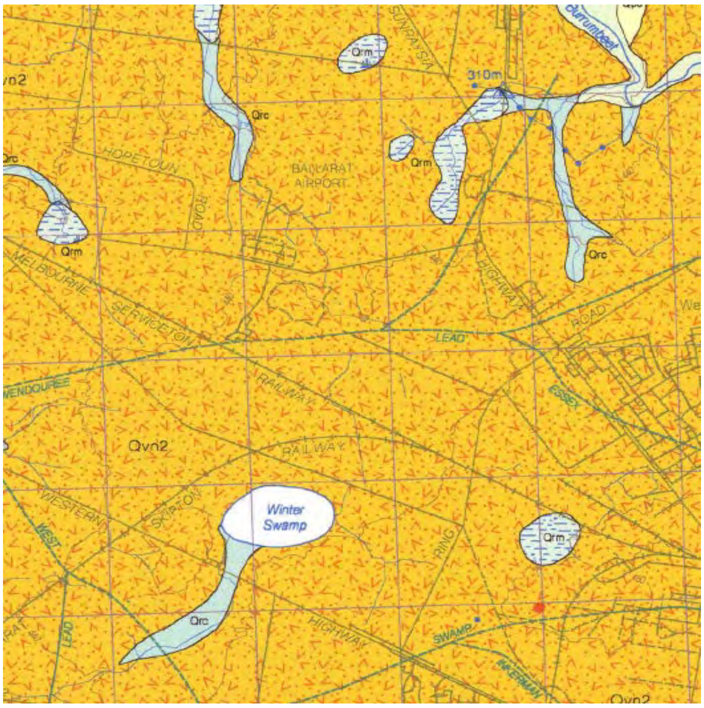

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REPORT

Golder Associates

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1.0 INTRODUCTION

VicTrack on behalf of Major Projects Victoria (MPV) and the City of Ballarat (CoB) has engaged Golder Associates Pty Ltd (Golder) to undertake a geotechnical desktop assessment for the proposed Ballarat West Employment Zone (BWEZ) development. We understand that MPV and CoB have commissioned the design and development of a master plan, business case and strategy for the BWEZ.

The scope of services to be provided by Golder was presented in our proposal P47612076-001-L-Rev0, dated 26 March 2014. Authorisation to proceed with the geotechnical desktop assessment was provided by VicTrack in an email dated 2 April 2014.

This report presents the findings of the geotechnical desktop assessment which includes an assessment of published geological information and a review of available geotechnical reports undertaken in the vicinity of the site, along with discussion relating to preliminary geotechnical design considerations.

Please note the desktop review does not include a review of any potential contamination issues associated with the site. A preliminary soil contamination assessment has been undertaken for the site by AECOM in September 2011. For the purpose of this report the AECOM report has been reviewed with respect to geotechnical considerations only.

2.0 THE SITE AND PROPOSED DEVELOPMENT

We understand that the BWEZ is a 623 hectare precinct to the west of Ring Road and Learmonth Road and adjacent to the Ballarat Airport in Ballarat West. The site has been earmarked as Ballarat's future employment area, and the purpose of the project is to unlock land for industry and to create significant employment opportunities for Ballarat's population.

We understand that the BWEZ Master Plan includes a mixture of land uses including: residential, commercial, road ways, freight hub and ancillary uses, environmental corridors, drainage corridors, and public open spaces.

The location of the site is shown in Figure 3 – Site Locality Plan, and the master plan is shown in Figure 5 – BWEZ Master Plan.

3.0 AIMS OF THE GEOTECHNICAL DESKTOP ASSESSMENT

The aims of the geotechnical desktop assessment were as follows:

- Review reports provided by VicTrack.
- Review publically available information and records of mine workings in the vicinity of the site.
- Review available geotechnical, geological and hydrogeological information from past projects completed by Golder near the site.
- Provide comments on the likely subsurface conditions including depth to groundwater.
- Review the proposed development plan and comment on the preliminary geotechnical design considerations with respect to the proposed Master Plan.

4.0 AVAILABLE GEOTECHNICAL INFORMATION

Our assessment of the likely subsurface conditions and the potential geotechnical opportunities and constraints included a review of information from the following sources.

Publically available information reviewed included:

- Geological Survey of Victoria, 1:63 360 Geological Map Series ‘Ballarat’, 1964;
- Geological Survey of Victoria, 1:50 000 Geological Map Series ‘Ballarat’, 1996;
- ‘Parish of Dowling Forest Counties of Ripon and Grenville’, (circa 1850) Geological Map;
- ‘Plan of the Ballarat and Sebastapol Gold Mines showing the various Claims and Leases’, (1870-1879);
- GeoVic online database - Department of State Development, Business and Innovation; and
- Visualising Victoria Groundwater (VVG) online database – Federation University Australia.

Golder projects reviewed included:

- Western Highway – Ballarat Section, Estimate of Unrippable Rock, dated December 1993
- Proposed Water Treatment Plan – North Ballarat, dated July 2006

Investigation reports made available by VicTrack for the purpose of this review included:

- Report by VicRoads, titled; “Western Highway Project, Western Link Road, Ballarat, Site Conditions Information, Part 1 of 2” dated February 2014.
- Report by VicRoads, titled: “Western Highway Project, Western Link Road, Ballarat, Site Conditions Information, Part 2 of 2” dated March 2013.
- Report by AECOM, titled: “Soil Contamination Assessment, Ballarat West Employment Zone Master Plan’, dated September 2011.

5.0 SUBSURFACE CONDITIONS

The following sections outline the inferred subsurface conditions likely to be encountered at the BWEZ site. Publically available information, information supplied by VicTrack and information from past Golder projects (described in Section 4.0) were used in our assessment of the subsurface conditions as described below.

5.1 Geology

Based on a review of the available published geological information, we consider the BWEZ has the potential to encounter the following sequence of geological units:

- A variable layer of topsoil and fill is expected to overlie the natural soils and basalt rock at the surface.
- Quaternary age swamp deposits comprising alluvium including gravel, sand and clay.
- Quaternary to Pliocene age ‘Newer Volcanics’ comprising residual clay over extremely, highly and moderately weathered basalt, scoria and tuff.

The 1:50 000 scale geological map indicates that the alluvial deposits are located in the northern and southern portions of the site, and are associated with water courses and swamps.

Refer to Figure 4 – Geological Map, showing the 1:50 000 scale geological map overlain on the site.

5.2 Inferred subsurface conditions

Based on published geological information and the results of nearby geotechnical investigations, the proposed BWEZ site is expected to be underlain by the following units:

Unit 1 – Topsoil/Fill

A layer of topsoil between approximately 100 mm to 300 mm was encountered in some of the VicRoads boreholes and test pits in the vicinity of the site. The topsoil material typically comprised silt, sand and clay with grass roots observed within the unit. The topsoil is expected to be encountered within the BWEZ site.

Fill material is likely to be present at the site and is expected to be of variable composition and nature. The maximum thickness of the fill will depend on the extent of previous excavations and/or backfilling works at the site. From aerial photography it is inferred that much of the site was previously used for agricultural purposes and additional fill material or near surface disturbed ground may be present at the site associated with previous farming activity. There may also be fill associated with existing or former pavements throughout the site, in particular pavements associated with the airport runway at the north of the site. Evidence of areas of deep fill or areas of landfill were not apparent in the information reviewed.

Unit 2 – Alluvium

The geological map indicates the presence of alluvium in northern and southern parts of the site (refer Figure 4, shown as geological units Qrm and Qrc). The alluvium is expected to comprise silts, clays and sands and is likely to be associated with the Winter Swamp (located outside the BWEZ) to the south and existing water courses to the north (located within the BWEZ). The thickness of the alluvium is difficult to estimate without site specific geotechnical information. Other minor water courses are indicated to be present at the site (refer Figure 4). These minor water courses may be associated with localised, typically near-surface, alluvial deposits.

Unit 3 – Residual basaltic clay

Residual basaltic clay is expected to underlie the fill or alluvium (if present). Residual basaltic clay is derived from the complete weathering of the underlying Quaternary age Newer Volcanics basalt. The thickness of this unit is expected to be variable depending on the weathering profile, the VicRoads report indicates a thickness of between 0 m and 5 m.

The residual basaltic clay encountered in the VicRoads investigation comprised clay and silty clay with a firm to stiff consistency, some basaltic sand and gravel was observed within the unit. The clays are typically high plasticity and are classed as highly reactive. Residual basaltic clays may also contain high strength basalt boulders and cobbles within the soil matrix.

Unit 4 - Weathered basalt

The residual soils are expected to be underlain by basalt rock. Typically, the basalt rock is variably weathered and fractured with the potential for significant clay seams present in joints and fractures within the rock mass. The strength of the weathered basalt is likely to increase with decreased weathering and an increase in the spacing of defects within the rock mass. Significant variation is to be expected in the surface profile of the basalt rock.

We note that the VicRoads report encountered a number of surface outcrops of basalt which may also be present at the site. Based on the weathered basalt encountered in the VicRoads investigation, the depth to the surface of this unit could range between about 0 m to 4 m below the existing ground surface. The basalt is likely to range from extremely weathered when first encountered to slightly weathered and from low to very high strength.

5.3 Groundwater

Standpipes were installed in four boreholes (approximately 4.5 m to 10 m deep) drilled as part of the VicRoads investigation. Groundwater was not encountered in any of the standpipes. Perched water may be present within the near surface fill or alluvial sediments, and localised perched groundwater from rainfall and/or runoff may be present at the site at wetter times of the year.

Information presented in the Visualising Victoria's Groundwater (VVG) online database includes groundwater observations for nearby boreholes and broad scale interpolation of depth to groundwater. Information presented in the VVG database indicates a depth to groundwater across the site from about 5 m to 10 m.

5.4 Historic mining activity

The majority of the historic mining activity in the Ballarat area is indicated to have been generally located to the south east of the site, however, there is some evidence of mining activity in the vicinity of the site.

The 1:50 000 and 1:63 360 scale geological maps indicate the presence of 'deep leads' underlying the basalt beneath the site. It should be noted that the locations of these leads are indicated to be approximate only. Deep leads are former water courses that were covered by basalt lava flows in which alluvial gold was deposited and sometimes mined.

In addition, the 'Parish of Dowling Forest Counties of Ripon and Grenville' map indicates the presence of a disused mine shaft to the south east of the site which is approximately 460 ft. deep, and bores to the north east of the site as a result of the gold rush era (i.e. 1800s) mining activity. The information reviewed did not indicate the presence of mine shafts on the site of the proposed BWEZ.

6.0 PRELIMINARY GEOTECHNICAL DESIGN CONSIDERATIONS

The preliminary geotechnical design considerations relevant to the expected subsurface conditions at the site and expected development are discussed below and summarised in Table 1. The comments and preliminary recommendations presented in the following sections are presented for preliminary planning purposes only. Detailed geotechnical investigation and site specific assessment will be required prior to commencing any detailed design at the site.

6.1 Reactive soils and preliminary site classification

The residual basaltic clays described in the VicRoads report are likely to be of high plasticity. High plasticity clays are subject to large volume changes when subject to natural variations in moisture content and are hence classified as reactive soils. Buildings/pavements founding on reactive soils can undergo relatively large surface movements (i.e. compared with structures/pavements founding on materials such as rock or clays of low reactivity) if correct design and construction procedures aren't followed.

The Australian Standard for residential slabs and footings (AS 2870-2009) classifies sites with a soil depth profile greater than 1.5 m and located on clay derived from alkaline volcanics (e.g. basalt) as either an H2 (highly reactive) or E class (extremely reactive) site. The reactivity of soils refers to shrinking and swelling of the soil with changes in moisture content. The changes in moisture content can be driven by acute factors, such as the planting or removal of trees and the installation of underground services or seasonal factors and rainfall patterns.

Table 2.3 of AS 2870-2009 notes that such sites have a predicted characteristic surface movement of greater than 60 mm under normal seasonal conditions. This is consistent with our experience working with residual basaltic clay in Ballarat and in Victoria. Surface movement of this magnitude may lead to structures supported on clay soils to experience differential movement in excess of 55 mm (AS 2870-2009 Table 2.2) and may lead to observable tilting of structures unless engineering measures are in place to manage the movement.

AS2870 should be referred to for the design of structures such as lightly loaded residential buildings at the site.

6.2 Foundation options

The footing solution for a particular structure will depend on the type of structure, the loads imposed on the footings by the structure, the subsurface ground conditions and the allowable total and differential settlement for the structure. Based on our understanding of the geological conditions of the site, the following comments are provided for the range of footing solutions which typically would be considered for a development of this type. Based on the geological map indications, residual basaltic clay or weathered basalt are expected to comprise the founding materials over most of the site. Based on the BWEZ Master Plan areas of alluvium typically coincide with areas identified for open space and environmental corridors. Other areas lying close to swamps (e.g. at the south of the site and north of Winter Swamp) have been identified for further investigation and drainage study before confirming the proposed future use.

6.2.1 Shallow foundations – strip and pad footings

We expect a variable layer of fill and topsoil to be present across the site overlying alluvium and/or residual basaltic clay. We do not recommend that shallow footings be founded within the uncontrolled fill, topsoil or alluvial materials. Shallow footings should be founded within the natural basaltic clay or the weathered basalt. Some excavation works would be required to remove the materials overlying the founding materials.

The following preliminary comments are relevant to the design and construction of shallow footings:

- For footings founded on residual basaltic clay, it is recommended that a minimum founding depth of 1.0 m below the finished surface level be adopted.
- Care should be taken to protect the base of the footing excavations in the residual basaltic clay by the placement of blinding concrete following excavation as the soils have the potential to soften if they are allowed to become wet.
- The ground surface around the footings should be sloped away from the footing to divert surface runoff away from the footing.
- For footings founded on the weathered basalt rock, some over excavation is expected/required due to the variable nature and profile of the rock surface and the possible presence of basalt cobbles and boulders.
- Hand cleaning techniques may be required in order to expose a clean rock surface at the base of the footing excavation. After the assessment and verification of the surface material, any over excavated sections should be backfilled with blinding concrete up to the base of the footing.
- A geotechnical engineer should assess all prepared footing excavations prior to blinding.

The following photograph (Figure 1) highlights a number of the above construction issues, showing a footing excavation in weathered Newer Volcanics basalt.

Figure 1: Example of excavation for spread footing supported on basalt

6.2.2 Deep foundations – piled foundations

Based on the subsurface conditions for the site, we consider piled foundations would be a suitable foundation solution for more heavily loaded structures at the site. Typically three pile types are used in Melbourne and Victoria, these are continuous flight auger (CFA) piles, driven piles and bored piles. Based on the expected subsurface conditions at the site and the expected shallow depth to rock, CFA or driven piles are not commonly adopted as foundation solutions in the basalt rock.

We expect that bored piles founding on or in the weathered basalt will be a suitable option for the proposed development in areas of the site where the thickness of the residual clays preclude the construction of spread footings founding on the weathered basalt. Bored piles derive their load capacity in the weathered basalt by a combination of end bearing and shaft friction. The required penetration of the bored piles into the founding material will depend on the pile size and load and the properties and thickness of the founding material.

The following preliminary comments are relevant to the design and construction of piled foundations:

- We recommend all pile sockets to be not less than two pile diameters long with the top of socket taken as the depth at which highly weathered or less weathered rock is encountered.
- The design settlement of bored piles founded in weathered basalt is typically about 1% of the pile diameter. Differential settlement between adjacent piles is typically about half of the design settlement.
- We recommend that a geotechnical engineer be in attendance on site at the time of the drilling of each socket, to confirm that the design conditions are being met and to assess the required socket lengths.

6.3 Building floor slabs

Given the highly reactive nature of the residual basaltic clay soils at the site, it is important that the moisture condition of the natural clay not be excessively wet or excessively dry at the time of floor slab construction. The long term performance of floor slabs founded on basaltic clay is dependent on the subgrade moisture condition at the time of casting the floor slab and also any future changes in the moisture content of soils at the slab edges.

Typical floor slab construction types include stiffened rafts and infill slab construction. Both are discussed in the following sections.

6.3.1 Stiffened raft

Stiffened raft floor slabs are expected to be a suitable slab on ground construction type on the residual basaltic clays. This type of construction will assist in resisting ground movement associated with changes in soil moisture content of the highly reactive founding clay material. We would recommend that where this type of construction is use it be formed over the entire building footprint.

The following preliminary comments are relevant to the design and construction of stiffened rafts:

- We recommend that perimeter edge beams be extended at least 1.2 m into the residual soil or onto the weathered rock to assist in providing a barrier to changes in moisture content at the edge of the construction area.
- Additionally we recommend that perimeter paving at the edge of the building be constructed to grade away a minimum distance of 1.5 m from the edge of the building. The grading and paving will assist in maintaining stable moisture conditions for the soils in close proximity to the footings at the edge of the building.

The adoption of a stiffened raft with stiffness greater than that adopted for a Class H residential raft slab will assist in resisting ground movements associated with changes in soil moisture content. However, given the variable thickness of the highly reactive clays beneath the site, long term differential movements over the area of the building are still likely to occur.

6.3.2 Infill slab

Another approach commonly adopted for large floor span areas consists of a thin infill slab between isolated footings at column locations. For this construction type we do not recommend that the infill slab be constructed directly on the residual basaltic clays. The high reactivity of the clays will cause problems with movement of the slab.

Typically we would recommend that the residual soils be excavated to a suitable depth and replaced with an imported fill material to minimise the risks associated with shrinking and swelling of the residual basaltic clays. The thickness of clay to be removed is dependent on the in situ moisture condition of the clay, the overall thickness of the clay stratum and the thickness of the slab and the movements it can accommodate.

6.4 Excavation conditions

From our understanding of the likely development, some excavation will be required as part of site grading and levelling works, construction of footings, basements, and service trench excavations. Provided below are preliminary comments in relation to the excavation conditions for materials we anticipate will be encountered at this site.

6.4.1 Fill, alluvium and residual basaltic clay

Fill, alluvium and residual basaltic clay are expected to overlie the majority of the BWEZ site. We consider the fill (excluding any large obstructions or remnant footings), alluvium and residual basaltic clay could be excavated using conventional small to medium sized mechanical earthmoving equipment. The depth of the soil profile beneath the site is difficult to estimate without intrusive investigation works, although it is likely to vary between about 0 m and 5 m. Where fill, alluvium and residual basaltic clays are excavated, the effects of drying out or of moisture entering fissured clays can lead to the collapse of excavations. The likelihood of excavation collapse due to the presence of fissures can be reduced by:

- Provision of temporary excavation support;
- Battering of excavation walls;
- Limiting the vertical height of excavations;

- Minimising the length of time that excavations are left open; and
- Preventing the ingress of water into excavations or ponding of water at the crest of batters.

A detailed stability check should be performed on all temporary and permanent batters exceeding 2 m in total height.

6.4.2 Weathered basalt

Excavation of the weathered basalt may require the use of large mechanical equipment, potentially with hydraulic breakers should high strength basalt be encountered. The ease by which rock can be excavated is likely to be dependent upon the distribution and orientation of discontinuities within the rock. The use of hydraulic breakers and large mechanical equipment has the potential to increase the cost and time associated with excavation in this material.

For piled excavations extending into the basalt rock, it is expected that heavy duty piling rigs would be required. Pile drilling tools capable of excavating very high to extremely high strength rock such as coring barrels, chisels and grinders may be required. Additionally, tools for cleaning the excavation base will be required.

6.5 Pavement design

The alluvial deposits are not anticipated to be suitable for construction of pavements. For pavements constructed on basaltic clay subgrades, it is not only the strength or durability of the pavement which determines the service life of these roads, but also the shrink/swell movements that occur in reactive clay soils as a result of moisture variations. Moisture variations may be due to seasonal influences, leaking services or moisture removal by tree roots. The resulting movements can ultimately cause permanent deformation in flexible pavements and severe cracking of the bituminous surfacing, which requires regular maintenance to limit further deformation.

To maximise the service life of pavements in this area we recommend the following measures be adopted:

- Pavements are designed with generous crossfalls or grades so that they are freely draining even after undergoing some permanent deformation.
- Careful attention is given to design and construction of subsoil and surface drainage to minimise the ingress of surface water into the subgrade clays.
- Drains are checked and cleared regularly.
- Cracks in pavements are quickly repaired.
- Planting be restricted to raised garden beds and to small plants with shallow root systems.

For basaltic clay subgrades, special preparation procedures should be followed for the construction of new pavements. We recommend that subgrade preparation and the fill placement and compaction be continuously supervised and the compacted relative density be checked by field density testing. Tests should be performed in accordance with the test methods specified in the Australian Standard AS 1289 “Method of Testing Soils for Engineering Purposes”. The Australian Standard AS 3798 “Guidelines on Earthworks for Commercial and Residential Developments” provides recommendations on the interpretation and application of relevant test methods specified in AS 1289 and we recommend these be adopted. AS 3798 should also be referred to for guidance on specifying, executing and controlling of earthworks testing for the development.

6.5.1 Reuse of residual basaltic clay as select fill

The residual basaltic clays encountered at the site are likely to be of high plasticity, highly reactive and are susceptible to changes in volume associated with changes in moisture content. Given the highly reactive nature of these soils we do not typically recommend them for use as select fill material.

Basaltic clays would typically not meet criteria for use as select fill. The highly reactive nature of the basaltic clays can lead to difficulties during earthworks including:

- Moisture conditioning of the material (i.e. difficulties in achieving a uniform moisture content within the material required for compaction).
- Poor workability (i.e. difficult to place and compact) during wet weather.
- Inability to meet stringent proof-roll criteria.
- Potential loss of strength after placement if subjected to moisture ingress.

The use of basaltic clays as subgrade fill for pavements or floor slabs requires careful attention to the moisture condition during construction. It is important that the condition of the clay not be excessively wet or dry at the time of pavement or floor slab construction. The long term performance of pavements and floor slabs founded on basaltic clay is dependent on the subgrade moisture condition at the time of construction and also any future changes in the moisture content of soils at the slab or pavement edges.

Stabilisation of the basaltic clays may be considered if they are to be used as select engineered fill. It may be possible to improve the basaltic clay by stabilisation using lime. In our experience, a mixture of the residual basaltic clays with the addition of about 3% lime (by dry mass) would be required to stabilise the residual clay materials. We note that the success of this treatment would be heavily dependent on the strength and moisture condition of the clay at the time of treatment. The presence of basalt cobbles and boulders may cause difficulties with stabilisation.

If lime treatment of earthworks materials was adopted for this project we consider it may be prudent to undertake a field mixing trial to assess the viability of this option. The methods and procedures adopted for lime stabilisation and the associated mixing, curing and compaction of the treated soils should be undertaken by a specialist stabilisation contractor.

6.6 Other considerations for building on reactive soil sites

6.6.1 Site surface conditions

It is expected that topsoil would be typically observed at the surface of the site, however, some surface outcrops of basalt may be encountered at the surface also. Beneath the topsoil, alluvium and/or a variable layer of residual basaltic clay is expected. The nature of the residual basaltic clay means that it is susceptible to changes in volume associated with changes in moisture content. Accordingly, the ground can become soft during periods of high rain fall and in areas where water has accumulated/ponded and saturated the near surface soils. As a result, the ground surface may become difficult to traffic, particularly for heavy machinery and mobile plant in these areas. The following photograph shows typical surface conditions in moisture-softened areas of residual basaltic clay (Figure 2).

The potential for soft surface conditions is an important consideration during the design and construction process, as it may present signification cost and time (schedule) implications. Some mitigation measures include: scheduling works in the dryer months (where possible), and preparing the surface (e.g. by installation of a working platform) adequately so that it is suitable for use by heavy machinery and mobile plant. It is also important to design site drainage to limit the accumulation of storm water on site, to reduce the softening of the residual basaltic clay.

Figure 2: Softened residual basaltic clays

In this material and where piling rigs, mobile cranes and mobile plant are to be used, we recommend that working platforms be constructed. For the construction of these working platforms, we recommend that the topsoil and very soft to soft residual basaltic clay be stripped off, or engineered fill material be placed. The exposed subgrade should be assessed by a geotechnical engineer for use as a subgrade for a working platform. The required thickness of the working platform will be dependent on the imposed pressure beneath the tracks or bog-mats and the nature of the exposed subgrade materials.

Following appointment of piling and mobile crane contractors and provision of the track or outrigger loads for mobile plant, we are able to provide advice on procedures for the preparation and placement of working platforms and the minimum thickness of any platform that may be required.

The tracking of mobile plant and equipment across the site will cause some disturbance to the surface of the crushed rock working platform and this would need to be properly managed and the working area maintained for the duration of the works.

6.6.2 Underground service trenches

Service trenches sometimes provide a conduit for water to infiltrate beneath floor slabs and pavements. To reduce the risk of this occurring for buildings and pavements founded on the residual basaltic clays, we recommend all new service trenches under building floor slabs and pavements be backfilled with selected fill of low permeability or in preference to this, be located outside of the building footprint where possible. The use of sand bedding or similar is not recommended.

6.6.3 Landscaping

Landscaping of the site should be carried out recognising the highly reactive nature of the Unit 2 clays. Planting of trees and large shrubs adjacent to the buildings within a distance of 1 to 1.5 times their mature height, should be avoided. Otherwise, the drying effect of moisture extraction by the plant roots may result in shrinkage of the clay soils and adversely affect buildings. These recommendations also apply for landscaping adjacent to road pavements. For further recommendations relevant to construction and architectural requirements for reactive clay sites refer to Appendix B of AS 2870.2-1996.

6.7 Mining activities in the area

Section 5.4 reviewed mining records and geological maps in the vicinity of the BWEZ site and found some evidence of shafts and mining activity in the vicinity of the site, but it appears that the majority of the mining was undertaken to the south east of the site. Geological maps indicated the presence of alluvial deep leads below the site, which, if present would be located beneath the basalt and are not expected to impact the proposed development. Published geological information indicates the thickness of basalt across the site to typically be greater than 20 m.

6.8 Areas of deep filling

The construction of, or removal of structures and dams at the site has the potential to affect the engineering performance of the soil profile over discrete areas. Soil containing uncontrolled building debris is generally not a suitable material on which to support structures or roadways due to the unpredictable and potentially variable response to loading.

Where man-made dams or natural water reservoirs have been backfilled (if any), zones of increased moisture or soft compressible soils may still be present. Uncontrolled fill material should be removed and replaced with controlled engineered fill. Non-engineered soils may provide an unpredictable response to future loading and should be treated with care.

Soft soils are likely to be present in areas of increased moisture content. Areas surrounding the Winter Swamp and natural waterways may have a naturally higher moisture content.

6.9 Earthquake design

The methods of assessing earthquake risk classification and consequential design implications are outlined in Australian Standards AS 1170.4 – 2007, 'Structural Design Actions Part 4: Earthquake actions in Australia'. The standard uses a number of factors in assessing an earthquake design category for a particular structure at a given site.

The stratigraphy at this site is expected to comprise fill and topsoil, residual basaltic clay and/or alluvium over weathered rock. Based on our understanding of the materials encountered at nearby sites a site Sub-Soil Class of B_e – Rock may be applicable if the thickness of fill, alluvial and residual basaltic clay soils overlying the weathered basalt rock is no more than 3 m. Should the thickness of the Unit 1, 2 and 3 soils exceed 3 m the site Sub-Soil Class C_e should be adopted.

The hazard factor (Z) depends on the geographic location of the site. The hazard factor (Z) for Ballarat presented in Table 3.2 of AS 1170.4-2007 is 0.08.

6.10 Summary of preliminary geotechnical design considerations

Based on our understanding of the BWEZ site, the preliminary geotechnical design considerations for the site are summarised below in Table 1. These preliminary geotechnical design considerations are preliminary in nature and will need to be confirmed and expanded upon once more information is available about the proposed development and once an intrusive geotechnical investigation has been undertaken.

Table 1: Preliminary geotechnical design considerations

Issue	Implication(s)	Mitigation measures
REACTIVE SOILS	■ Additional design considerations required for buildings and pavements founding on the residual basaltic clays. ■ Likely site classification of either H2 (highly reactive) or E class (extremely reactive) site with high corresponding surface movements (settlement). ■ Potential for high differential movement of structures supported on residual basaltic clays, which may result in tilting and cracking of structures and pavements.	■ Undertake an in situ geotechnical investigation to assess the subsurface conditions across the site, including the depth to rock, and the strength and weathering characteristics of the rock across the site. ■ Structures should be designed to accommodate the expected level of characteristic movement of the residual basaltic clay or be founded on the underlying basalt rock. ■ Design structures in accordance with AS 2870-2009 –Residential Slabs and Footings. ■ Design site drainage/stormwater to reduce potential for accumulation/ponding and infiltration of water into the underlying residual basaltic clay. ■ Construction surface preparation
FOUNDATION OPTIONS Shallow foundations	■ Depth to basalt rock is likely to be variable, and the extent of foundation excavations could vary significantly over the site. ■ Shallow footings should be founded on residual basaltic clay or weathered basalt rock, not on fill or alluvial material. ■ For footings founded on the weathered basalt rock, some over excavation is expected/required due to the variable nature and profile of the rock surface and the possible presence of basalt cobbles and boulders. ■ Consideration should be given to the construction methods to ensure that footing excavations founding in residual basaltic clay are protected from moisture content variations.	■ Undertake an in situ geotechnical investigation to assess the subsurface conditions at structure locations, including the depth to rock, and the strength and weathering characteristics of the rock across the site. ■ Refer to section 6.2.1 for preliminary comments on the design and construction of shallow footings.
FOUNDATION OPTIONS Piled foundations	■ Depth to basalt rock is likely to be variable, and the suitability of piled foundations is dependent on this. ■ Difficult/slow drilling conditions in high strength basalt rock.	■ Assess the expected depth to rock at locations of proposed structures by undertaking an intrusive geotechnical investigation.
BUILDING FLOOR SLABS Stiffened raft	■ The construction of floor slabs on reactive soils (residual basaltic clay) requires careful control of the subgrade moisture condition to prevent cracking and damage to buildings.	■ Follow specific design and construction procedures for stiffened rafts on reactive soils. ■ Refer to section 6.3.1 for some preliminary comments.
BUILDING FLOOR SLABS Infill slab	■ Infill slabs should not be constructed directly onto the residual basalt clay, and may not be a suitable option for this site. ■ Imported materials may be required to replace the residual basaltic clays excavated from beneath the infill slab and the additional costs associate with this. Alternatively, stabilisation of the basaltic clay could be considered.	■ Assess the subsurface conditions at the proposed building locations by undertaking a detailed geotechnical investigation, to determine the viability of the use of infill slabs.
EXCAVATIONS Fill, alluvium, residual basaltic clay	■ Excavations in these materials are likely to be performed with small to medium sized earthwork equipment.	■ Undertake an in situ geotechnical investigation to assess the subsurface conditions at locations of proposed excavations and the excavatability of the material expected to be encountered on site.
EXCAVATIONS High strength basalt rock	■ Increased cost and time associated with the excavation of basalt rock, due to the requirement to use bigger/more powerful equipment and a slower excavation rate.	■ Undertake an in situ geotechnical investigation to assess the subsurface conditions at locations of proposed excavations, including the depth to rock, and the strength and weathering characteristics of the rock across the site, and to understand the excavatability of the material expected to be encountered on site. ■ Plan development to limit the excavation in rock.

PAVEMENT DESIGN	■ Pavements constructed on residual basaltic clay subgrades require additional design consideration due to the shrink/swell behaviour of the clay as a result of moisture variations. ■ The alluvial deposits are not anticipated to be suitable for construction of pavements.	■ Understand the extent and thickness of the alluvial deposits and residual basaltic clay and the shrink/swell behaviour of the clay by undertaking a detailed geotechnical investigation and geotechnical laboratory testing of suitable samples from across the site. ■ During construction, follow special preparation procedures for pavements with residual basaltic clay subgrades. Refer to AS 3798 and AS 1289 for further details. ■ Refer to section 6.5 for further details.
REUSE OF RESIDUAL BASALTIC CLAY AS SELECT FILL MATERIAL	■ Residual basaltic clays are not typically recommended for use as select fill material, and may require stabilisation to be suitable.	■ Assess options for stabilisation of residual basaltic clay for use as subgrade material (e.g. using lime). ■ Refer to section 6.5.1 for further details.
SITE SURFACE CONDITIONS	■ Soft ground conditions should be expected in the residual basaltic clays during wetter months and in areas where water accumulates /ponds, making the site difficult to traffic. ■ Surface preparation measures may be required to enable heavy machinery and mobile plant to work at the site in these conditions.	■ Schedule works during the dryer months (where possible). ■ Design site drainage to limit the accumulation of storm water on site. ■ Prepare working platforms for heavy machinery and mobile plant (refer to section 6.6.1 for further details).
UNDERGROUND SERVICE TRENCHES	■ Underground service trenches can provide a conduit for water to infiltrate beneath floor slabs and pavements and cause damage. ■ Difficult excavation if wet soil or hard rock is encountered.	■ Backfill service trenches with selected low permeability fill or located these trenches outside the building footprint. ■ Design trench depth and alignments to avoid wet ground or way from shallow rock.
LANDSCAPING	■ Landscaping near buildings may result in drying of the underlying residual basalt clay as a result of moisture extraction. This may cause the clay to shrink which may adversely affect the buildings/pavements.	■ Plant trees and shrubs a distance of 1 to 1.5 times their mature height away from buildings and pavements. ■ For further recommendations refer to Appendix B of AS 2870.2-1996.
AREAS OF DEEP FILLING	■ Areas of deep fill are generally not suitable material on which to support structures or roads due to the unpredictable and potentially variable response to loading.	■ Identify areas of deep filling across the site by undertaking an in situ geotechnical investigation at proposed structure locations.
MINING ACTIVITIES	■ Potential for existing mine shafts and mining areas to be located in the vicinity of the proposed development which may impact on the location of the structures.	■ Review mining records and geological maps. Refer section 5.4 for further details. The review indicates a low risk of historic mine workings impacting on the proposed development areas.

7.0 FUTURE GEOTECHNICAL INVESTIGATIONS

This geotechnical desktop review is preliminary in nature and is intended for the purpose of project planning and is not intended to replace the need for a site specific intrusive geotechnical investigation.

We recommend that an intrusive geotechnical investigation be undertaken at the site prior to detailed design, to supplement and confirm the information gathered in the desktop assessment. Typically an intrusive geotechnical investigation of this scale would include the drilling of a number of boreholes and the excavation of test pits to better investigate and characterise the soil and rock profile at multiple locations across the site, particularly at proposed structure and pavement locations. Golder would be pleased to provide VicTrack with more information on our capabilities in this area as well as a realistic estimate of the future works required.

8.0 LIMITATIONS

Your attention is drawn to the document - “Limitations”, which is included in Appendix B of this report. The statements presented in this document are intended to advise you of what your realistic expectations of this report should be. The document is not intended to reduce the level of responsibility accepted by Golder Associates, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in so doing.

We would be pleased to answer any questions the reader may have regarding these Limitations.

Report Signature Page

GOLDER ASSOCIATES PTY LTD

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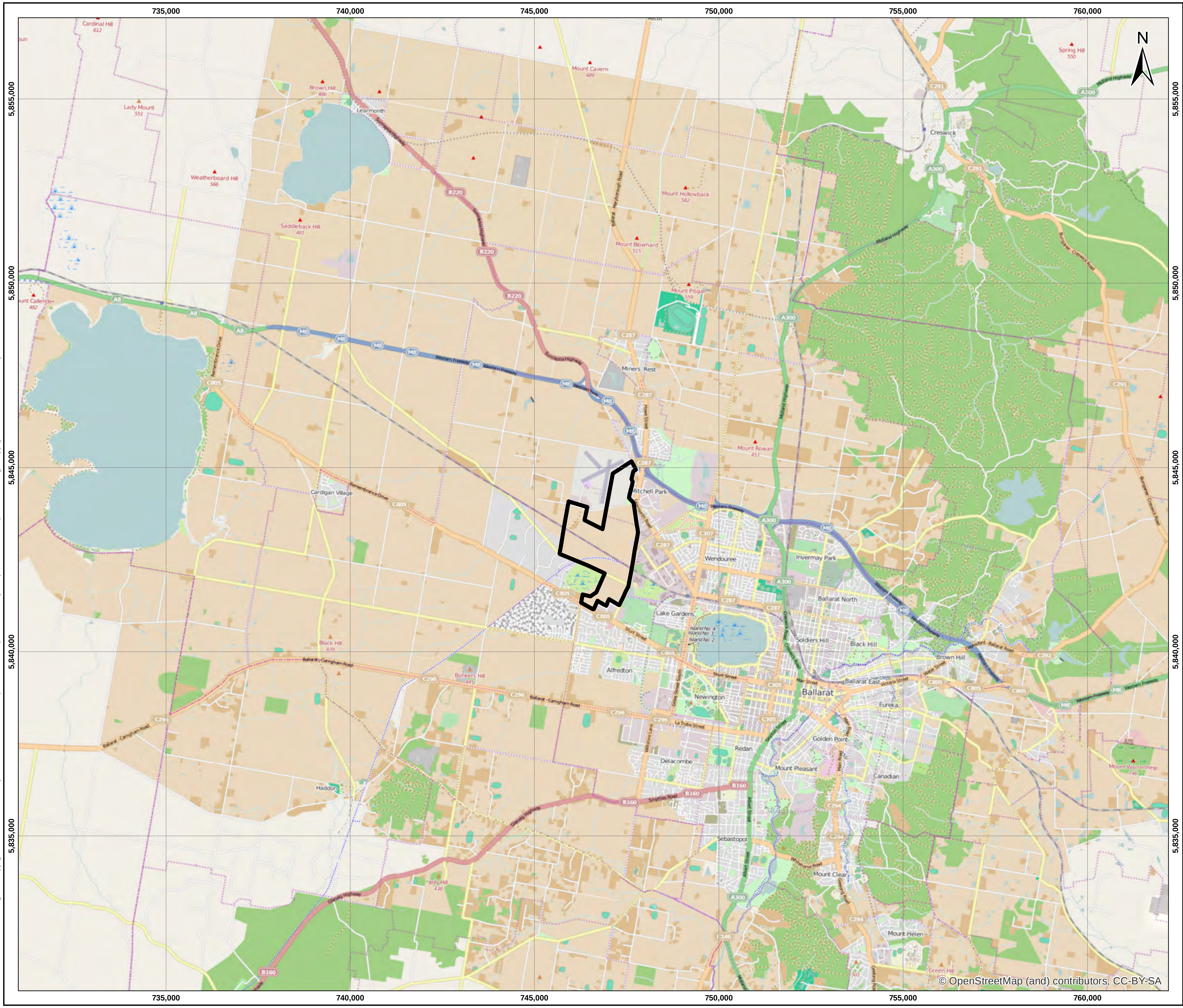
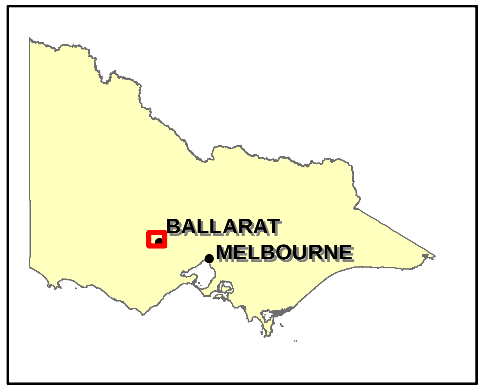


BALLARAT WEST EMPLOYMENT ZONE DEVELOPMENT

VIC TRACK

SITE LOCALITY PLAN



LEGEND

Site Boundary

NOTES

1. Background image sourced from Open Street Map licensed under the Open Data Commons Open Database License.

0 500 1,000 2,000 3,000 4,000 5,000 metres

SCALE (at A3) 1:100,000

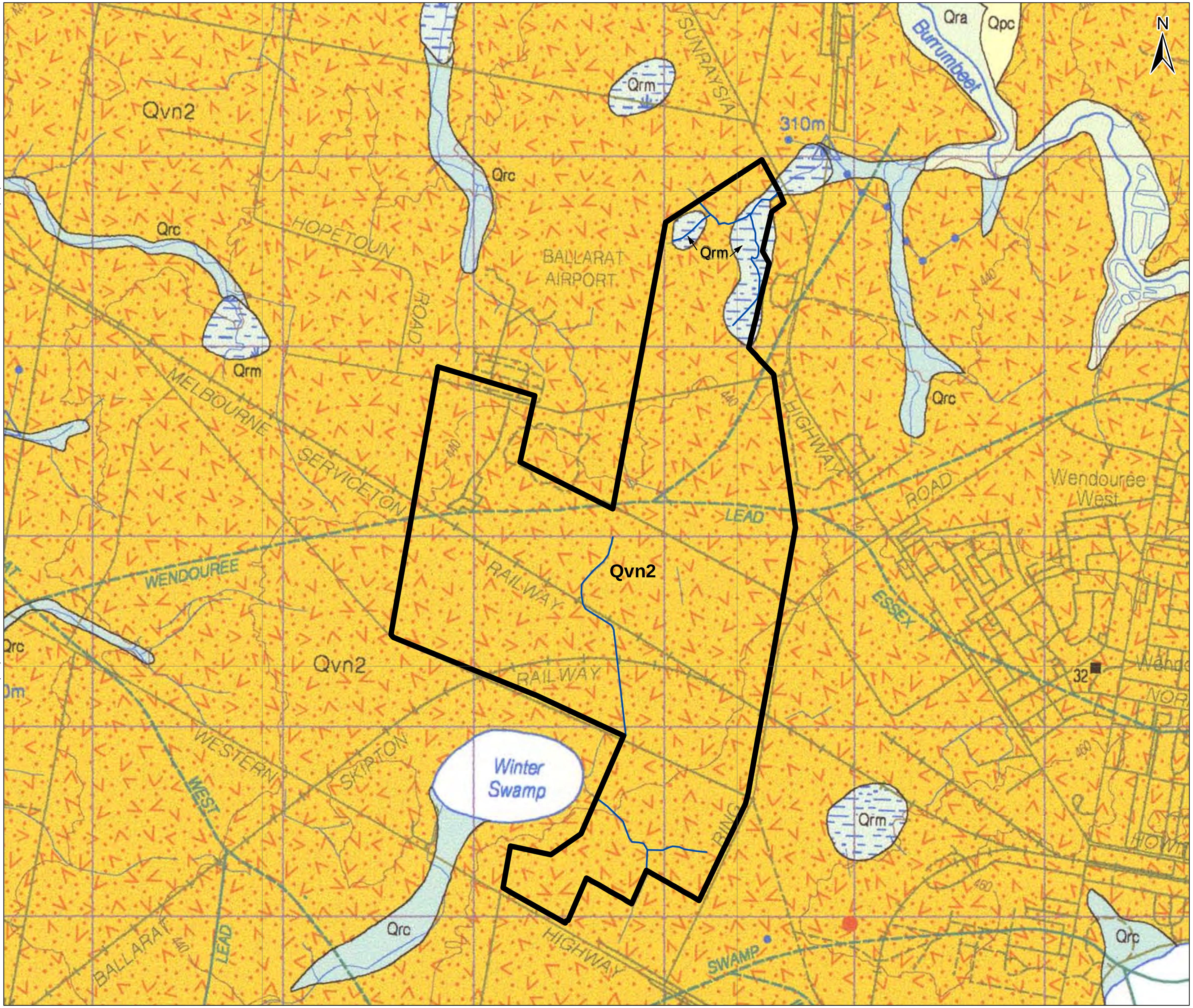
DATUM GDA 94, PROJECTION MGA Zone 54

PROJECT:	147612036
DATE:	17 APR 2014
DRAWN:	JPH
CHECKED:	SCR

FIGURE 3

Golder Associates

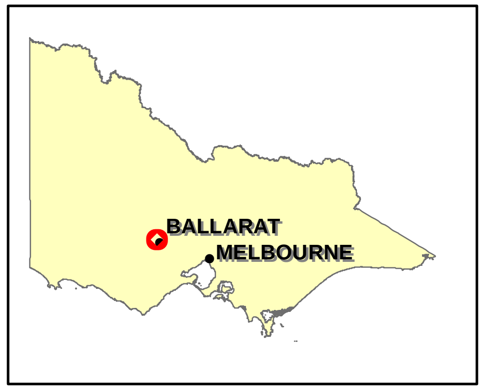
File Location: J:\Geo\2014\147612036 - MPV, Geotech Desktop Assessment, Ballarat West\Technical Doc\GIS\Project\Deliverable\147612036-001-R-F0003-Rev0.mxd



BALLARAT WEST EMPLOYMENT ZONE DEVELOPMENT

VIC TRACK

GEOLOGICAL MAP



LEGEND

Site Boundary

Watercourse

Alluvial deep leads (approx. position)

Qvn2 Newer Volcanics Basalt
Qrm Swamp deposits (Alluvium)
Qrc Colluvial deposits (Alluvium)

NOTES

1. Geological map obtained from 1:50000 Geological Map Series from the Geological Survey of Victoria, Report 101.

0 100 200 400 600 800 1,000 metres

SCALE (at A3) 1:20,000

DATUM GDA 94, PROJECTION MGA Zone 54

PROJECT:	147612036
DATE:	06 MAY 2014
DRAWN:	JPH
CHECKED:	SCR

FIGURE 4

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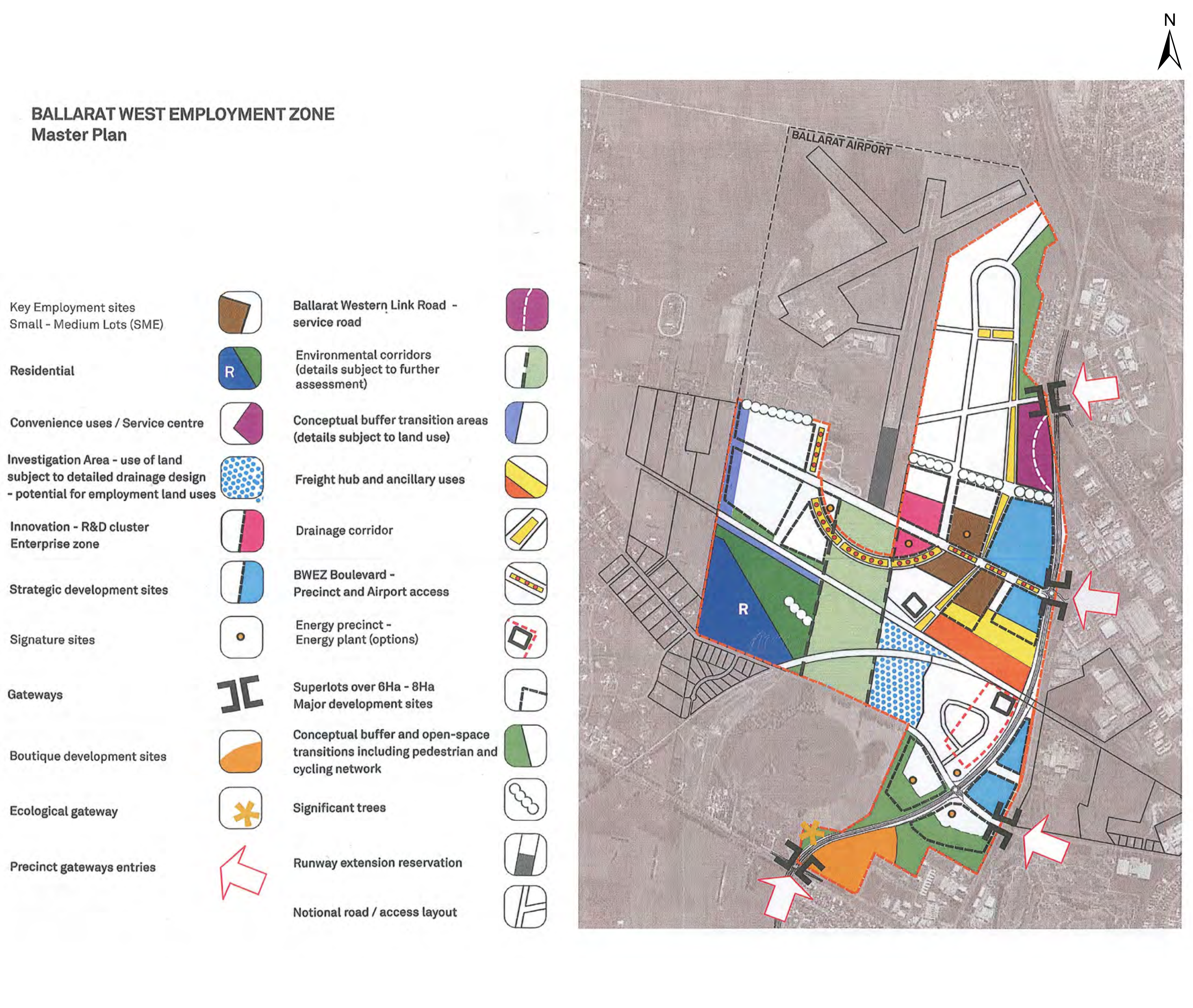

BALLARAT WEST EMPLOYMENT ZONE DEVELOPMENT

VIC TRACK

BALLARAT WEST EMPLOYMENT ZONE MASTER PLAN

NOT TO SCALE

NOTES

1. Master Plan obtained from VicTrack File: D/14/8254

DATUM GDA 94, PROJECTION MGA Zone 55

PROJECT: **147612036**
DATE: **17 APR 2014**
DRAWN: **JPH / TPC**
CHECKED: **SCR**

FIGURE 5

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APPENDIX A

Limitations (LEG 04, RL1)

Limitations

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GAP Form No. LEG04 RL1

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