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Project 86043.05
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Geotechnical Monitoring Plan
Proposed A1 Building
Ivanhoe Place, Macquarie Park

1. Introduction

This Geotechnical Monitoring Plan (GMP) sets out the proposed geotechnical monitoring requirements during basement excavation works for the proposed A1 Building of the Ivanhoe Estate at Ivanhoe Place, Macquarie Park. This GMP has been prepared to address condition B46(b) of the Development Consent by the Minister for Planning and Public Spaces (Ref: SSD 8903 dated 2020), so that the Certifier can consider issuing a Crown Building Works Certificate (CBWC).

The proposed bulk excavation level (BEL) is about RL 50 m AHD, which will require a maximum depth of cut of about 17 m. The upper part of the excavation will be supported by a soldier pile retaining wall incorporating shotcrete infill panels, with a mixture of temporary ground anchors, buttresses and corner struts. The lower part of the excavation will generally be unsupported through sandstone bedrock.

A geotechnical investigation was previously carried out by Douglas Partners (DP) at the site for Stage 1 of this development (Ref: 86043.01.R.002.Rev0 dated 22 December 2017), which included three rock-cored boreholes to depths of between 18.1 m and 23.5 m. The deepest of the cored boreholes was drilled adjacent to Herring Road, which is classified as a State Road that is therefore managed by Roads and Maritime Services (RMS) of Transport for NSW (TfNSW). RMS (TfNSW) requirements for monitoring of the excavation (Ref: Technical Direction GTD 2020/01 of 2 July 2020) therefore apply with respect to the effect of the proposed excavation on the public road.

2. Objectives

The objectives of the GMP are to ensure that the proposed development on the site does not adversely affect neighbouring properties, including the structural integrity of neighbouring structures and infrastructure, the groundwater regime and the comfort of residents living adjacent to the proposed development with respect to vibrations.

The plan has been separated into the following three sections to monitor the following effects of the proposed development:

- **Geotechnical** – movement or settlement of temporary and permanent works and structures, excavation support, and adequacy of foundation materials;
- **Hydrogeological** – potential changes of the groundwater;
- **Vibration** – vibrations generated by excavation works.

The Principal Contractor for the proposed development is responsible for implementing the measures outlined in this plan. The contractor shall engage the services of suitably qualified and experienced professionals for the required monitoring activities.

3. Available Information

The GMP is based upon the following information:

- Structural Drawing No Series A1-ST-002 by Enstruct Group Pty Ltd dated 9 April 2021;
- Report on Geotechnical Investigation by DP (Ref: 86043.01.R.002.Rev0 dated 22 December 2017);
- Report on Groundwater Monitoring by DP (Ref: 86043.01.R.005.Rev0, dated 30 July 2018)
- Analysis Summary Report by DP (Ref: 86043.05.R.001.Rev1 dated 22 April 2021);
- Previous DP monitoring results of vibration levels generated by various items of excavation equipment operating within the Sydney region in sedimentary rocks of the Triassic Period.

4. Geotechnical Monitoring

The key geotechnical aspects which require monitoring on this project are as follows:

- stability of excavations;
- stability of adjacent existing buildings; and
- adequacy of the foundation materials to provide support to footings.

Geotechnical monitoring along the Herring Road site frontage is to be undertaken in accordance with RMS Technical Direction GTD 2020/01 dated 2 July 2020.

Prior to the start of demolition and excavation work on the site, it is recommended that dilapidation surveys be undertaken on the neighbouring buildings in order to document any existing defects so that any potential claims for damage, due to construction-related activities, can be accurately assessed. The stability of the adjacent structures is dependent on the stability of the proposed basement excavation.

For monitoring stability of both the excavation and the existing buildings, visual inspections by a suitably qualified and experienced geotechnical engineer or engineering geologist will be carried out at regular intervals, as construction progresses, together with regular instrumented survey of the excavation and the existing structures. Following the inspections and/or review of the survey data, installation of temporary or permanent rock face support, comprising rock bolts/anchors, may be required to stabilise potentially unstable blocks formed at the intersection of joints or of a joint with the excavation face.

The geotechnical engineer is to inspect the excavation of footings to confirm the bearing capacity of the rock.

4.1 Geotechnical Monitoring Procedure

The steps shown in Table 1 are recommended, with Hold Points identified where information should be provided to the structural or geotechnical engineers prior to continuing with the works.

Table 1: Summary of Geotechnical Monitoring Activities

Step	Description	Hold Point
Prior to Commencement of Works		
1	The Principal Contractor and any relevant subcontractors should familiarise themselves with the structural engineer's drawings, the geotechnical reports and this monitoring plan.	
2	Undertake dilapidation (building/structure condition) reports for neighbouring buildings and road infrastructure.	
Shoring Installation		
1	Final design drawings will nominate minimum pile socket lengths and/or minimum toe depths. Establish site survey and datum to allow accurate measurement of pile depth.	
2	Inspection of the shoring system (including plunge columns) to confirm works have been carried out in accordance with the geotechnical aspects of the design drawings. It is recommended that about 10% of the piles should be inspected with at least the first two to three piles witnessed in their entirety.	
3	Progressively install monitoring targets near the top and bottom of each shoring wall and at 10 m lateral spacing and at the 1/4, middle and 3/4 points along the vertical rock face. Install survey targets on the nearest structure. Carry out a baseline survey of all monitoring targets (two independent sets to confirm measurement consistency) immediately after the target installation.	Hold Point
4	Install two inclinometers along the Herring Road frontage, either in selected shoring piles or behind the shoring wall, but in either case the inclinometers are to be taken to a depth of 3 m below the BEL and should both be located within the middle-third of the lateral alignment of the cut face. Take baseline readings of both inclinometers (comprising two independent sets to confirm measurement consistency) before commencement of any excavation works.	Hold Point

Step	Description	Hold Point
During Excavation		
1	At weekly intervals - Registered surveyor to measure lateral and vertical movements of the survey targets along the walls of adjacent buildings. Results should be notified to the structural and geotechnical engineers, as indicated in Table 2. If either lateral or vertical movements exceed the 'alarm' trigger levels at the top of the shoring wall, then excavation should stop, and the information should be provided to the geotechnical and structural engineers for their advice.	Hold Point
2	Builder to carry out daily visual inspections of the shoring and buildings to check for any signs of ground movement/instability.	
3	Undertake one set of inclinometer readings for each inclinometer at the following intervals: • after excavation to the first row of anchors or struts (before anchor/struts installation); • after excavation to subsequent rows of anchors or struts (before anchor/struts installation); • after excavation to the pile toe (where above bulk excavation level) • at bulk excavation level then fortnightly thereafter for two months, then monthly thereafter; • once basement slabs have been constructed and anchors/struts are de-commissioned; and • one month following completion of basement structure or after three consecutive measurements not less than a week apart showing no further movement, whichever is the later.	Hold Point
4	Readings of survey targets shall be undertaken at weekly intervals, including any new targets that have been progressively installed as excavation proceeds. The relative movement between the survey markers at the same plan locations shall also be reported.	Hold Point
5	Inspection of anchor/strut installation by an experienced geotechnical engineer or engineering geologist to confirm anchors/struts have been installed as per the design drawings.	Hold Point
6	Inspection of anchor stressing (proof-testing and lock-off) by an experienced geotechnical engineer or engineering geologist to confirm anchors have been tested and stressed as per the design drawings.	Hold Point
7	At maximum 1.5 m depth intervals - Progressive inspection of any unsupported cut faces by an experienced geotechnical professional to identify any adversely inclined structures (e.g. joints) or previously undetected conditions and features, which may require additional support. If the geotechnical engineer or engineering geologist considers that additional stabilisation measures are required then these measures should be implemented to the satisfaction of the geotechnical engineer prior to continuing with the excavation.	Hold Point
8	Inspection of the end bearing conditions of the shoring piles after the pile toes are exposed, no later than 0.5 m excavation below the pile toe levels.	Hold Point
9	Additional stabilisation measures may be required and implemented to the satisfaction of the geotechnical engineer prior to continuing with the excavation. This may include adoption of special excavation methods (e.g. smaller drops before inspection, or excavation in panels) prior to excavation below the toe of the shoring pile wall.	Hold Point

Step	Description	Hold Point
After Excavation		
1	Inspection of the base of the excavation at bulk excavation level by geotechnical engineer to assess the geotechnical conditions.	Hold Point
2	Inspection of all shallow footing excavations below the bulk excavation level by an experienced geotechnical engineer or engineering geologist to confirm that the bearing capacity meets the requirements of the design, including spoon testing of the footings (requiring 50 mm diameter core holes to be drilled by the contractor through the base of the footings 24 hours ahead of inspections to 1.5 x the footing width), to check defect spacing and confirm the rock classification. The frequency of spoon testing will be dependent on the design bearing pressure adopted.	Hold Point
2	At weekly intervals - Registered surveyor to measure lateral and vertical movements of the survey targets along the walls of adjacent buildings for at least 2 weeks.	
3	Undertake one set of inclinometer readings for each inclinometer at the following intervals: • once basement slabs have been constructed and anchors / struts are de-commissioned; and • one month following completion of basement structure or after three consecutive measurements not less than a week apart showing no further movement, whichever is the later.	
4	Inspection of anchor de-stressing by experienced geotechnical engineer or engineering geologist to confirm that the anchors have been de-stressed and disconnected from the structure	Hold Point

4.2 Movement Trigger Levels

The movement trigger levels for the shoring walls at different locations are based on the predicted wall deflections by DP (Report Ref: 86043.05.R.001.Rev1, dated 22 April 2021) due to both the earth pressure induced movements in soils and weathered rocks, as well as the in-situ stress relief movements in strong rock. The threshold levels adopted are provided in Table 2.

Table 2: Movement Trigger Levels for Shoring Walls

Threshold Level	% of Agreed Limit	Magnitude of Deflection			Required Action
		SR1	SR2, SR10, SR12SR	SR3, SR4, SR5	
Alert Level	Up to 80%	<16mm	<12mm	<24mm	Notification of structural and geotechnical engineer. Excavation can continue.
Action Level	81% to 100%	16-20mm	12-15mm	24-30mm	Notification of structural and geotechnical engineer, and TfNSW within 24 hours. Review monitoring data and increase monitoring frequency to an agreed level. Excavation can continue.
Alarm Level	Over 100%	>20mm	>15mm	>30mm	Excavation to stop and agreed contingency measures to be implemented, as advised by structural and geotechnical engineer.

TfNSW must be informed immediately when 'alarm' trigger levels for shoring wall movement are exceeded on the Herring Road frontage.

4.3 Contingency Plans

If the subsurface conditions encountered during the excavation are different to those indicated in the geotechnical report, both the geotechnical and structural engineers must be immediately informed. The geotechnical and structural engineers should then inspect the site and re-design the foundations, excavation support (i.e. shoring) or another feature, if required.

Contingency measures for shoring wall movements will depend on the nature of the trigger level exceedance. Measures could include backfilling against the shoring wall, installation of additional anchors, and installation of internal props/bracing.

Note that all monitoring devices should always be kept in operating condition. Construction works shall be suspended where more than 30% of the devices are not operational.

5. Groundwater

Based on the available information the permanent groundwater table is below approximately RL 50.0 m AHD. Therefore, for compliance with the consent conditions, monitoring of groundwater levels outside of the basement excavation, weekly measurement of groundwater and discharge water quality and weekly measurements of pumped volumes shall be recorded once bulk excavation proceeds below RL 50.5 m AHD.

Vertical strip/core drains should be installed behind the shoring wall to collect all seepage that may occur from discontinuities and bedding planes in the rock mass and to direct the seepage to the subfloor drainage system, from where it can be removed using “sump-and-pump” methods.

Table 3: Summary of Groundwater Monitoring Activities

Step	Description	Hold Point
Prior to Bulk Excavation below RL 50.5 m AHD		
1	Installation of two groundwater monitoring wells outside of the basement by the geotechnical engineer, for measurement of water levels and at least one week of readings taken.	Hold Point
After Bulk Excavation below RL 50.5 m AHD		
1	Daily measurement of water levels at the monitoring bores during construction by the geotechnical engineer. Measurements may be undertaken daily by datalogger, and reported at weekly or monthly intervals, if there is no significant change in the weekly measurements of pumped groundwater/seepage volumes, unexplained by rainfall events, as excavation proceeds.	
2	Weekly measurement of groundwater and discharge water quality during construction by the environmental engineer/scientist	
3	Weekly measurements of pumped groundwater/seepage volumes during construction by Principal Contractor.	

5.1 Contingency Plans

If the results of groundwater quality measurements indicate an impact on existing groundwater conditions, or on disposal requirements for the pumped water, a plan must be developed to mitigate any impacts on existing groundwater conditions, and to provide treatment to meet the appropriate groundwater disposal requirements.

Previous groundwater monitoring indicates a natural groundwater fluctuation of approximately 0.7 m in this area. Groundwater levels that fall by more than 0.4 m below initial groundwater levels should trigger a hydrogeological assessment of the records of pumped groundwater volumes, records of pumped groundwater/seepage volumes and weather/climatic factors. A plan may need to be developed to reduce groundwater take if the groundwater fall is considered to be due to the excavation.

If the groundwater monitoring wells are damaged or destroyed during the excavation works below RL 50.5 m AHD, then the monitoring well must be replaced prior to additional excavation. Provided that the detailed excavation has been completed for at least one month, then replacement of the monitoring well shall be undertaken unless the data already collected indicates no significant groundwater impact.

6. Vibration Monitoring

6.1 Acceptable Limits

A review of the site features indicated that the existing buildings on the adjacent properties are not "sensitive structures". Therefore an allowable vibration limit of 8 mm/s Vector Sum Peak Particle Velocity (VSPPV) at the foundation level is suggested. The proposed allowable vibration limit at the foundation level of adjacent buildings is also adequate to reduce the risk of structural damage to buildings and road assets on the adjacent properties, including buried services. However, vibration sensitivity of the services should be confirmed with the asset owners prior to excavation. The limit may need to be adjusted to reflect the asset requirements, response of neighbouring structures during excavation and vibration dosage once the neighbouring building is occupied.

This takes into account both structural damage and human comfort criteria given in relevant Standards (e.g. ISOAS 2670, EPA guidelines, German DIN4150 Standard and Australian Standard AS 2187-2 (2006)).

A vibration trial may be required to size equipment at the commencement of excavation into rock. The trial may indicate that minimum offset distances are required for the preferred plant, or that alternative excavation methods are required.

6.2 Monitoring Procedures

For this site it is recommended that the vibration monitoring is undertaken by carrying out an initial trial of excavation equipment; and if the trial indicates that the vibration limits could be exceeded then installing a permanent monitoring system which will allow 'self-management' of vibrations by the contractor.

Geophones should be installed on or near the base of the walls of the neighbouring buildings. The geophones should be firmly attached to the building's structure or footings and should be connected to a data monitor, which is capable of measuring vibrations to 0.5 mm/sec PPVi or less. The monitor shall be set up to record all vibrations which exceed 5 mm/sec. A warning light or sound signal shall be attached to the monitor, which is configured with an alarm threshold of 8 mm/sec PPVi to warn the excavation contractor of vibration exceedances.

Table 3 shows the steps recommended, with Hold Points identified, where information should be provided to the structural or geotechnical engineers prior to continuing with the works.

Table 4: Summary of Vibration Monitoring Activities.

Step	Description	Hold Point
Prior to Commencement of Bulk Excavation Works		
1	Undertake a vibration trial using the largest machine of each equipment category (e.g. rock breaker, bulldozer with ripping tyne, rock saw) to be used in order to determine the minimum buffer distances to neighbouring structures for each equipment type. Geotechnical engineer to advise on whether proposed equipment is likely to exceed allowable vibration levels and whether continuous monitoring is required.	Hold Point
2	If the vibration trial indicates that vibration limits may be exceeded by the proposed works then geophones and monitors are to be installed and configured to undertake continuous unattended monitoring of vibrations. Install geophone at the base of the neighbouring structure closest to the excavation works. Connect geophone to data monitor and install a flashing light or sound warning signal. Set warning light to trigger at 8 mm/s VSPPV	
During Excavations		
1	If continuous monitoring is required (see Step 1) – data from the monitor is to be uploaded weekly, with direct feedback to site personnel of the number of recorded events exceeding the Allowed Limit. Reports should include a tabulation of times and levels of any events exceeding a recording threshold of 8 mm/s VSPPV, for correlation with site activity records. The weekly vibration monitoring reports should be forwarded to the geotechnical engineer for review.	
2	If the number of exceedances on any day is more than 10 then the excavation works shall stop, and the geotechnical engineer shall be notified. The geotechnical engineer will investigate the causes of the exceedances and provide advice on measures to avoid further vibration exceedances	Hold Point

6.3 Contingency Plans

If the vibration trials indicate that continuous monitoring is required, then the monitor shall be configured such that either an SMS message is sent automatically to nominated mobile phones (including the monitoring entity and the site manager), or a flashing light or sound signal is triggered when the vibrations at the base of the neighbouring structure exceed 8 mm/s VSPPV. If the SMS message is sent or the warning signal is triggered, then the machinery operator should reduce the force generated by his equipment or move further away from the neighbouring structure.

Occasional exceedances may be allowed, however, if an exceedance occurs, an inspection should be made of the potentially affected building and excavation should only resume if no vibration-induced damage can be seen.

If the warning light is being triggered frequently (e.g. >10 times/day), excavation works are to stop, the geotechnical engineer is to be notified and a site visit carried out by the geotechnical engineer to investigate the cause of the exceedances. A change in excavation method may be recommended as a result of the inspection, or on the basis of recorded vibration data.

7. Limitations

Douglas Partners (DP) has prepared this Geotechnical Monitoring Plan (GMP) for this project at Herring Road, Macquarie Park in accordance with DP's proposal dated 10 May 2021 and acceptance received from Tim Saviane of Mainland Civil Pty Ltd dated 10 May 2021. The work was carried out under DP's Conditions of Engagement. This GMP is provided for the exclusive use of Mainland Civil Pty Ltd for this project only and for the purposes as described in the report. It should not be used by or be relied upon for other projects or purposes on the same or another site or by a third party. Any party so relying upon this GMP beyond its exclusive use and purpose as stated above, and without the express written consent of DP, does so entirely at its own risk and without recourse to DP for any loss or damage. In preparing this GMP DP has necessarily relied upon information provided by the client and/or their agents.

The assessment of atypical safety hazards arising from this advice is restricted to the geotechnical groundwater components set out in this report and based on known project conditions and stated design advice and assumptions. While some recommendations for safe controls may be provided, detailed 'safety in design' assessment is outside the current scope of this report and requires additional project data and assessment.

This GMP must be read in conjunction with all of the attached and should be kept in its entirety without separation of individual pages or sections. DP cannot be held responsible for interpretations or conclusions made by others unless they are supported by an expressed statement, interpretation, outcome or conclusion stated in this GMP.

This GMP, or sections from this GMP, should not be used as part of a specification for a project, without review and agreement by DP. This is because this report has been written as advice and opinion rather than instructions for construction.

Please contact the undersigned if you have any questions on this matter.

Yours faithfully
Douglas Partners Pty Ltd

Atha Kapitanof
Associate

Reviewed by

Bruce McPherson
Principal

Attachments: About this Report

About this Report

Douglas Partners

Introduction

These notes have been provided to amplify DP's report in regard to classification methods, field procedures and the comments section. Not all are necessarily relevant to all reports.

DP's reports are based on information gained from limited subsurface excavations and sampling, supplemented by knowledge of local geology and experience. For this reason, they must be regarded as interpretive rather than factual documents, limited to some extent by the scope of information on which they rely.

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Borehole and Test Pit Logs

The borehole and test pit logs presented in this report are an engineering and/or geological interpretation of the subsurface conditions, and their reliability will depend to some extent on frequency of sampling and the method of drilling or excavation. Ideally, continuous undisturbed sampling or core drilling will provide the most reliable assessment, but this is not always practicable or possible to justify on economic grounds. In any case the boreholes and test pits represent only a very small sample of the total subsurface profile.

Interpretation of the information and its application to design and construction should therefore take into account the spacing of boreholes or pits, the frequency of sampling, and the possibility of other than 'straight line' variations between the test locations.

Groundwater

Where groundwater levels are measured in boreholes there are several potential problems, namely:

- In low permeability soils groundwater may enter the hole very slowly or perhaps not at all during the time the hole is left open;
- A localised, perched water table may lead to an erroneous indication of the true water table;
- Water table levels will vary from time to time with seasons or recent weather changes. They may not be the same at the time of construction as are indicated in the report; and
- The use of water or mud as a drilling fluid will mask any groundwater inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water measurements are to be made.

More reliable measurements can be made by installing standpipes which are read at intervals over several days, or perhaps weeks for low permeability soils. Piezometers, sealed in a particular stratum, may be advisable in low permeability soils or where there may be interference from a perched water table.

Reports

The report has been prepared by qualified personnel, is based on the information obtained from field and laboratory testing, and has been undertaken to current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal, the information and interpretation may not be relevant if the design proposal is changed. If this happens, DP will be pleased to review the report and the sufficiency of the investigation work.

Every care is taken with the report as it relates to interpretation of subsurface conditions, discussion of geotechnical and environmental aspects, and recommendations or suggestions for design and construction. However, DP cannot always anticipate or assume responsibility for:

- Unexpected variations in ground conditions. The potential for this will depend partly on borehole or pit spacing and sampling frequency;
- Changes in policy or interpretations of policy by statutory authorities; or
- The actions of contractors responding to commercial pressures.

If these occur, DP will be pleased to assist with investigations or advice to resolve the matter.

About this Report

Site Anomalies

In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, DP requests that it be immediately notified. Most problems are much more readily resolved when conditions are exposed rather than at some later stage, well after the event.

Information for Contractual Purposes

Where information obtained from this report is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a specially edited document. DP would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Site Inspection

The company will always be pleased to provide engineering inspection services for geotechnical and environmental aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site.