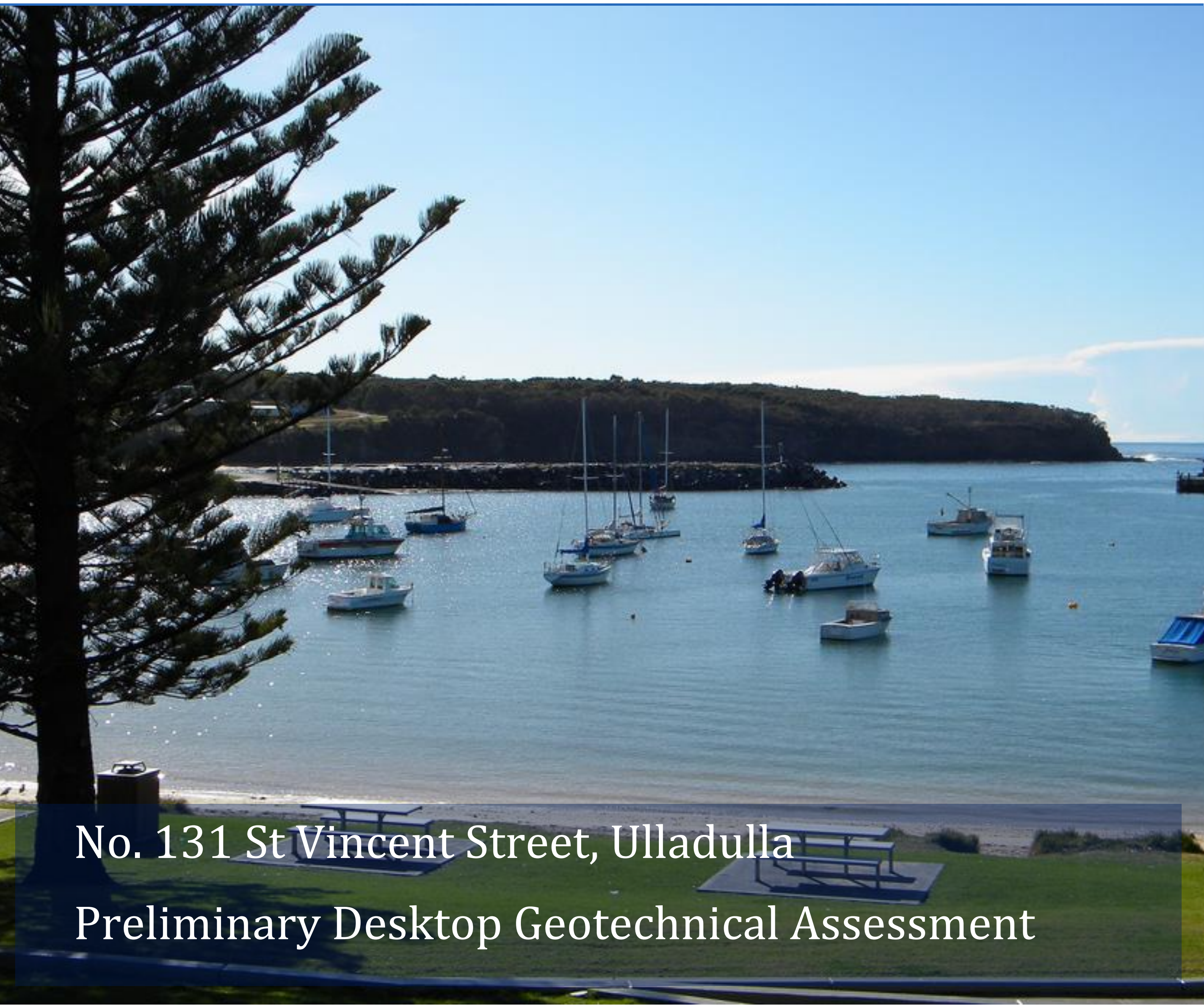

No. 131 St Vincent Street, Ulladulla

Preliminary Desktop Geotechnical Assessment

Prepared for:

Olivander Capital

Terra Insight Pty Ltd
ABN: 76 610 821 906
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U34 No 10 Sylvester Ave
Unanderra NSW 2526

Our Ref: TERRA23-288.Rep2.Rev0

13 October 2023

Prepared for:
Olivander Capital

Att: Mr Beasley

RE: No. 131 St Vincent Street, Ulladulla
Preliminary Desktop Geotechnical Assessment

Dear Chris,

Please find enclosed our Preliminary Desktop Geotechnical Assessment for the above site in relation to its proposed redevelopment. This report should be read in conjunction with the attached document 'About Your Report' in Appendix A. Should you need anything further please contact the undersigned.

For and on behalf of Terra Insight

Karen Gates
Principal Engineer/ Director
CPEng MIEaust MEIANZ BEng MEngSc(Geot) MEnvMgt MBA NPER CEng CEnvP

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1 Introduction

At the request of Olivander Capital (the client), Terra Insight Pty Ltd (Terra) has carried out a Preliminary Desktop Geotechnical assessment No. 131 St Vincent Street, Ulladulla, (hereafter referred to as the Site, shown on Figure 1). The assessment involved a desk top study of existing information available for the site and nearby sites.

It is understood that the client proposes to develop the Site into a mixed-use precinct, with medium-high density residential, affordable housing and commercial use (including a childcare centre). It is proposed to create a new laneway on the Site to improve traffic movements. Whilst not specified in the Planning Proposal, Terra understands that the existing warehouse will be demolished as part of this development and basement excavations will be required for sub-terranean carparking. The relevant planning proposal is included in Appendix B. It is noted that the site is mostly sealed with concrete pavements and in private ownership and consequently investigation of the site was not permitted.

The objectives of the assessment were to :

- Identify the subsurface conditions likely to be encountered on the site including a summary of the geotechnical properties of the ground relevant to the project;
- Identify the geotechnical risk that need to be managed including potential risks to the project and identification of potential mitigation options.
- Provide engineering advice to allow preliminary design of the proposed development including Interpretation of the implications of the ground conditions and the suitability of ground conditions to support the proposed development and assessment of groundwater depths and any impacts to groundwater as a result of excavation works for basement levels.

2 Desktop Study Findings

2.1 Site description

A summary of key Site details is provided in Table 2-1.

Table 2-1: Summary of Site identification, ownership and use information

Road Address	No. 131 St Vincent Street, Ulladulla	
Title Identifiers	Lot 1 Section 26 DP 759018	
Site Description	The Site has an approximate area of 1.1ha, and is located approximately 1km to the south west of the Ulladulla Harbour. It contains a bulky goods warehouse with a large, sealed carpark. Existing infrastructure on the Site includes a retail warehouse, with a timber and trade centre. There is also a nursery and landscaping department. Most of the Site's surface is capped by concrete as part of the carpark. This carpark is filled, with a retaining wall constructed on the south western corner.	
District Name	Ulladulla NSW, 2539	
Current Zoning	E4 General Industrial	
Proposed Site Use	Mixed use precinct with medium-high density residential, commercial premises, childcare and affordable housing. The Planning Proposal (PP) intends to increase the allowable building height from 11m to 30m, and to introduce a floor space ratio of 3.5:1.	
Proposed Zoning	MU1 Mixed Use	
Surrounding Land Use	North	R3 Medium Density Residential
	South	E4 General Industrial
	East	E3 Productivity Support

	West	E4 General Industrial
Council	Shoalhaven City Council	

2.2 General Geology

Online Geological Mapping accessed using Minview (refer Figure 1) indicates the Site is underlain by an alluvial gravel, sand and clay deposits unit, which is comprised of unconsolidated to poorly consolidated alluvial gravel, sand and clay deposits which are closely associated with basalts of similar age near Ulladulla.

2.3 Surface Topography

The developed portion of the Site is near level, comprising of the main warehouse on the west, a sealed carpark on the east, and a garden centre in the north western corner. Significant amounts of fill have been applied to level the Site. However, the natural slopes are visible on the eastern boundary and show that the Site may have originally possessed a slight to moderate slope down to the south. The developed portion of the Site is at approximately 43m AHD, whereas the footpath on the eastern boundary slopes from 45m AHD off the north eastern corner to 40m at the south eastern corner.

2.4 Acid Sulfate Soil Mapping

The NSW Planning Portal Spatial Viewer shows that the Site is classed as Class 5 ASS, meaning the Site is located within 500m of Classes 1-4 soils, however these higher-class ASS were not shown on the mapping.

ASS soils typically occur in low-lying coastal areas, typically at elevations below 5m AHD, in rare cases it can be observed up to 12m AHD. Given the mapping and the Site's elevation, further assessment for ASS is not deemed necessary.

2.5 Historical Aerial Imagery

Aerial imagery from 1959 to 2022 was sourced and has been summarised in Figure 2. In addition to aerial imagery, Google StreetView imagery was used to cover gaps in the timeline of the aerial imagery. Image 1 is from 2008 and shows the Site during the construction of the Bunnings Warehouse. Filling of the Site is clearly visible.

Image 1: Google StreetView Imagery dated January 2008, view looking west from St Vincent Street

Table 2.2 presents a summary of observations made from reviewing the collection of aerial imagery, including off-Site observations of the surrounding area.

Table 2-2: Observations during review of Historical Aerial Imagery

Time Period	On Site	Off Site
Prior to 1960	The Site appears undeveloped and vegetated.	Sites to the east and north east appear to be cleared. The site directly west is in similar condition to the Site; undeveloped and vegetated. St Vincent Street is not yet visible to the east of the Site, however the Princes Highway is visible further to the east.
1960 - 2000	The first building appears on the Site in 1967, in the north western corner, observably a small shed. In 1972, there appears to be numerous buildings on the Site, a larger shed on the eastern portion and some smaller infrastructure on the western side. In 1991, there appears to have been some filling on the southern portion of the Site, the soils are distinctly paler than those on the northern part which suggests they may have been imported. There is also some vegetative growth on the Site. Due to the low quality of the aerial imagery, it is difficult to determine whether the larger shed had been demolished by this time.	The Ulladulla Sewage Treatment plant is visible to the south west of the Site in 1979 imagery. The part of St Vincent Road directly east of the Site does not appear paved in this imagery. Several lots across St Vincent Street to the east have been developed, these appear to be commercial sites.
2000 - Present	In 2004 imagery, the Site appears abandoned. There is significant vegetative growth surrounding the former building footprints. Subsequent imagery from 2009 shows the completion of the Bunnings Warehouse, whose development covers the majority of the Site's surface.	A roundabout at the intersection of Deering and St Vincent Street appeared in 2004. 2009 imagery shows the development of the Dunn Lewis Centre, directly south of the Site. A roundabout at the intersection of Parson and St Vincent Street appeared in 2018.

2.6 Review of council records

A request for information pertaining the use of the Site was sent to Shoalhaven Council. Terra also conducted a search of Shoalhaven City Council development applications online. A summary of findings from council records is presented in Table 2.3.

Table 2-3: Summary of council records

Application Number	Description	Notes
ST67/0192	Septic tank permit, owned by Lambert ME	Demolished
BA67/0080 & BA67/0081	Fibro dwelling and fibro factory respectively, owned by Toland SG	Both demolished
BA69/0354	Weatherboard garage, owned by Lambert ME	Approved
BA71/0677	Factory additions, owned by Lambert ME	Approved
BA72/0037	Timber moulding factory, owned by Toland SG	Approved
1995/0082H	Local Government Act Formal Order – Land in Unhealthy Condition	-
2003/0043H	Local Government Act Formal Order – Land not kept in a safe and healthy condition	-
DA06/2580	Construction of new single story warehouse and showroom for sale of bulk goods retail (Bunnings) with carparking and advertising sign.	Approved 22/1/2007

Application Number	Description	Notes
DR08/1113	Sewer connection for new Bunnings Warehouse, approved	Completed 2/2/2008
DS08/1153	Construct timber pigeon hole rack within the timber yard. Amendment to signage details.	Approved 21/4/2008
DS08/1286	Use of a fire fighting tank in the south western corner. Elimination of fire exit door.	Approved 18/12/2008
DA09/1729	Installation of water tanks to collect water for irrigation of nursery and water for flushing toilets and deletion of two car spaces. An objection was received from a nearby resident due to the tank being unsightly.	Approved 21/7/2009
Multiple Applications (TFS16-2023)	Numerous applications for temporary food stalls, all of which were approved	Likely for the operation of Bunnings community BBQ stalls

2.7 Review of Existing Reports for the site

Several existing reports for the Site were as follows.

H. Troon Pty Ltd – Construction Stage Erosion Sediment Control Plan (September 2007)

This report describes the erosion control measures recommended during the construction of the Bunnings Warehouse. It mentions that the Site is undergoing cut and fill earthworks to achieve the required Site levels, and that a significant amount of fill material will need to be imported onto the Site from off-site sources. They note that they plan to use all excavated material won from the Site as fill material.

It was estimated the Site was 2.5m above basalt bedrock prior to filling. The amount of filling required was 600mm, to bring the Site to 3.5m above basalt. It is also noted that 250mm of fine rock was applied to the carpark area. Both the pad site and the carpark were compacted using drum rollers.

Coffey Geotechnics – Stage 2 Environmental Site Assessment (February 2007)

This report was subsequent to a Preliminary Environmental Site Assessment conducted in 2006 by Coffey Geotechnics, which identified three Areas of Environmental Concern (AEC) and identified fibrous asbestos within fill material and topsoils on the Site. We note that the report provided to Terra has been redacted and does not show quantitative laboratory data.

A Stage 2 report was commissioned to better assess the contamination on the Site, particularly the extent of asbestos contamination. As part of this report, twenty-two (22) test pits were excavated. The results of this report showed that the Site is impacted with asbestos, and three remedial options were provided:

- Excavation and offsite disposal
- Capping and encapsulation
- Restrict any development and administer the Site.

Terra understands that option 2 was undertaken. A review of this documents therefore indicates the potential for an encapsulated area containing asbestos affected material buried on the site.

It is likely that VENM clean material won from the Site was exported off-Site and the void then filled with the contaminated material. The exact location of this encapsulated contaminated fill should be marked on the site management plan. This was not provided by Council when a request was made for all Site-related data. Some historical data is located in off-site storage and Terra has requested from council the cost of retrieving this data for further review.

Coffey notes that there was a former kiln on the Site, which may have used a diesel or kerosene heater. The method of storage for this fuel could not be identified, however the testing did not indicate consistently elevated levels of TPH, and as such, it was deemed unlikely that any previous USTs on the Site has leaked, causing soil or groundwater contamination.

A summary of testing results is as follows:

- Slightly elevated zinc and TPH (fraction C10-C36) levels were encountered. These were associated with weathering of the historical Site buildings and the Site usage, respectively.
- Buried waste was encountered and comprised of sandstone cobbles, tin sheeting, glass, steel cabling, timber fragments and ceramic roof tiles.
- Fill as deep as 0.55-1.1m was encountered, this deeper fill contained scrap metal, a tree stump and wood fragments/dust.
- A thin layer of sandy clay, charcoal and plant matter was encountered between 0.5-1.05m in one of the test pits

Generally, the waste material encountered appeared to be inert. Asbestos in soil samples was detected in multiple locations, with the deepest observation at 0.3m. Potentially asbestos-containing material was also observed at several locations. It was determined that the presence of asbestos was likely due to poor demolition practices of former Site owners, however there may have also been some illegal dumping.

No other obvious contamination (other than the presence of asbestos) was recorded. It was noted that should other contamination be identified, this may be managed during the construction stage of the Site development.

<u>H Troon Pty Ltd – Letter to Council (June 2008)</u>

This letter explains that the earthwork on the Site were balanced (equal volumes of cut to fill) with the fill being used and compacted behind retaining walls and under ramps. The letter includes a Hilf Density report, which logs the soils encountered at 300mm depth as Gravelly CLAY: low plasticity, orange-brown. The report does not include VENM certificates for any imported fill.

2.8 Review of existing reports for nearby sites

Terra has undertaken investigations for sites in Ulladualla. The nearest relevant site is 116-118 St Vincent Street. The findings are summarised in the following sections.

<u>116-118 St Vincent Street, Ulladulla</u>

The investigation comprised of nine (9) boreholes across the property. The holes were named BH01 to BH09. They were implemented using an excavator with an auger. A summary of the materials encountered is provided in the following tables. The site was grouped into two areas based on the similarity of subsurface conditions encountered on the property as follows:

- Area 1: the area at the western and southern side of the property, including boreholes BH01 to BH05;
- Area 2: the area on the eastern and northern part of the existing building, including boreholes BH06 to BH09;

The subsurface investigation found the site is underlain by fill underlain by tertiary aged residual soils and then weathered sandstone materials. Observations of the site also indicate that some sandstone rock was outcropping in some places. We note that the materials underlying 116 – 118 St Vincent Street are tertiary aged, poorly consolidated and generally exhibit soil like properties. Terra's visual assessment of the soils is that they are sandy cohesive soils with at least 35% fines. The sandstone rock is weak, of extremely low strength and highly weathered, slightly laterised in places and has soil like properties but exhibits some rock structure.

Tables 2.4 to 2.5 summarise the subsurface conditions encountered for Area 1 and Area 2 respectively.

Table 2-4: Summary of Subsurface Conditions 1 – 116-118 St Vincent Street

Subsurface conditions *(Soil name, plasticity or particle characteristics, colour, secondary components and minor components)*	Structure and other comments	Depth encountered in test pit/exposure (m)				
		BH01	BH02	BH03	BH04	BH05
Silty SAND: fine to medium sand, black orang brown, with fine to medium gravels, with foreign materials	Fill	0.0-0.3	0.0-0.1	0.0-0.1	NA	NA
Gravelly Sandy CLAY: low plasticity fines, brown, fine to coarse sand, fine to medium angular gravels	Fill	NA	NA	NA	0.0-0.3	NA
Clayey SAND: fine to coarse sand, light brown orange, low plasticity with inert foreign materials	Fill	0.3-0.7	0.1-0.5	0.1-0.3	NA	NA
Sandy CLAY: low to medium plasticity, orange-brown, fine to medium sand with fine angular gravels	Fill	NA	NA	NA	0.3-0.5	0.0-0.9
Sandy CLAY: medium plasticity, orange, fine to medium sand	Residual	0.7-1.3	0.5-1.3	0.3-1.5	0.5-1.3	NA
Silty CLAY: low to medium plasticity, orange grey with fines	Residual	1.3-1.5*	1.3-1.5*		NA	NA
Sandy CLAY: medium plasticity, pale cream orange, fine to coarse sand	Residual/ Extremely Weathered Material				1.3-1.5*	0.9-1.5*

Notes * - End of hole at target depth; ^{r} - Early refusal on rock, ^{vr} – virtual refusal, NE – not encountered

Table 2-5:Summary of Subsurface Conditions 2 – 116-118 St Vincent Street

Subsurface conditions *(Soil name, plasticity or particle characteristics, colour, secondary components and minor components)*	Structure and other comments	Depth encountered in test pit/exposure (m)			
		BH06	BH07	BH08	BH09
Silty SAND: fine to coarse sand, black orange brown with foreign material	Fill	0.0-0.2	0.0-0.2	NA	NA
Gravelly SAND: fine to coarse sand, brown, fine to medium angular gravels, with foreign materials	Fill	NA	NA	0.0-0.3	NA
SAND: fine to coarse sand, light brown, with inert foreign materials	Fill	NA	NA	NA	0.0-0.3
Sandy CLAY/ Clayey SAND: medium plasticity, light brown, fine to medium sand	Fill	0.2-0.6	0.2-0.5	0.3-0.7	NA
Sandy CLAY: medium to high plasticity, orange, fine to coarse sand, trace fine gravel	Residual	0.6-1.6	0.5-1.3	0.7-1.5*	0.3-1.3
Sandy Gravelly CLAY: low to medium plasticity, pale orange, fine to coarse sand, fine angular gravels	Residual/ Extremely Weathered Material	1.6-3.0*	1.3-1.5*		NA
Silty CLAY: low to medium plasticity, pale orange	Residual/ Extremely Weathered Material				1.3-3.0*

Notes * - End of hole at target depth; ^{r} - Early refusal on rock, ^{vr} – virtual refusal, , NE – not encountered

As no groundwater was encountered, no groundwater sampling was able to be undertaken. Two groundwater wells were installed on the site with the base of the well founded at 3m depth in weathered material. These wells were installed to allow future groundwater sampling and monitoring as part of the preliminary assessment. Consequently, no water samples to allow groundwater assessment for contaminant were able to be obtained.

Ulladulla High School 2006 and 2009 Investigations

Two Geotechnical investigation reports for Ulladulla High School were available on the NSW government website 'DiGs'. The High School is located to then north of the site and is situated at similar elevations within the same geological unit. The Geotechnical investigations numerous boreholes and included soil laboratory testing.

The subsurface conditions are summarised in Table 2-6 and slow seepages were typically observed along the interface of the residual soils and weathered rock.

Table 2-6: Summary of Subsurface conditions – Ulladulla High School Investigations

Subsurface conditions *(Soil name, plasticity or particle characteristics, colour, secondary components and minor components)*	Structure and other comments	Stiffness/ Density	Thickness and Depths of layers
Silty SAND, Silty CLAY, Silty Sandy CLAY	Fill Soils	-	0.65-1.8 thickness
Clayey SILT, Silty Sandy CLAY: dark grey to yellow brown	Topsoils	-	0.4-0.6 (thickness)
Silty CLAY, Clayey SILT, Sandy Silty CLAY: low to high, predominantly medium plasticity and high plasticity silts, light grey, red brown, purple, yellow brown	Residual Soils grading into weathered materials	Stiff to Very Stiff with depth	Below topsoils and fill
SILTSTONE to Silty SANDSTONE – extremely weathered, behaves like hard silt/clay, light grey	Extremely Weathered Materials	Very Stiff to Hard	1.3-4.5 (6.6m max depth)

Laboratory testing of the residual soils indicated the following range for Atterberg Limits, Linear Shrinkages and Shrink Swell Indices:

- Liquid Limit 35-58 %
- Plastic Limit 20 %
- Plasticity Index 19-38 %
- Linear Shrinkage 8.0-15.5 %
- Shrink Swell 0.8-1.7 %

Soil Aggressivity testing was also undertaken and indicated the following ranges:

- pH 4.9-7.0 pH typically around 5.0 pH
- Chloride <10-190 ppm
- Sulfates <10-390 ppm
- EC 0.04-0.05 mS/cm

Ulladulla Man Shed located at Camden St

The field Investigation involved:

- Excavation of six test pits at the site using a mini-excavator. Two previous boreholes undertaken within the MUMS site by GHD. The test pits were named TP01 to TP06.
- Refusal was encountered in four of the 6 test pits undertaken on the site. Refusal occurred in weathered sandstone rock.

The subsurface conditions underlying the site were found to comprise the following:

- Topsoil/Fill; typically, silty sand to sandy silt and sandy gravel (road base); underlain by
- Residual soil comprising silty clay to sandy clay, orange brown with some grey mottling, fine to coarse sand; underlain by
- Weathered materials: siltstone, grey with orange mottling, extremely to highly weathered, extremely low to very low strength.

Groundwater seepage was not observed in any test pit. Soils were typically found in a dry to moist condition.

Table 2.7 provides a summary of the subsurface conditions encountered in the test locations.

Table 2-7: Summary of subsurface conditions – Camden Street

Test pit Number	Depth range over which material was encountered within the Boreholes (m) BGSL		
	Material Description		
	Topsoil/Fill	Residual soil	Weathered material
TP01	0.0-0.5	0.5-0.7	0.7-1.2 R
TP02	0.0.-0.3	0.3-0.8	0.8-1.0 R
TP03	0.0-0.5	0.5-0.7	0.7-0.9 R
TP04	0.0.-0.3*	NE	NE
TP05	0.0.-0.3	0.3-0.5	0.5-0.7 R
TP06	0.0-0.3*	NE	NE

Note – * - End of test pit at target depth. NE – not encountered, R – early refusal

3 Preliminary Geotechnical Assessment Recommendations

3.1 Geotechnical site model

The site likely to be underlain fill and then residual soil which grades into weathered rock at variable depths across the site. We expect the depth of fill to be about 0.6m to 3.0m depth. Prior to filling, it was estimated the Site was 2.5m above basalt bedrock prior to filling.

The amount of filling required was 600mm, to bring the Site to 3.5m above basalt. It is also noted that 250mm of fine rock was applied to the carpark area. Both the pad site and the carpark were compacted using drum rollers.

Depth to weathered rock is therefore expected to be between 3 and 6m. An area of encapsulated asbestos affected material is likely to be present on the site.

The composition of the natural soils below the topsoil and fill is likely to comprise of:

- **Residual Soil:** comprising of Silty CLAY, Sandy Silty CLAY and Clayey SILT, medium plasticity, light grey, red/purple and yellow brown, typically stiff to very stiff, very acidic to neutral pH values, low sulphates and low chloride.
- **Extremely Weathered Material:** comprised of siltstones or sandstones potentially basalts, extremely weathered with soil like properties to significant depths, behaves as a hard clay/silt.

Perched groundwater may be encountered at the interface of the fill and residual soil and residual soil and weathered rock. Generally, investigations in the area did not encounter a permanent groundwater table within 3m depth. Minor seepages only were observed.

Preliminary design parameters for the materials encountered on the site are provided in the following table.

Table 3-1: Soil Parameters for preliminary design purposes

Material	Bulk Unit Weight (kN/m^3)	Undrained Shear strength (kPa)	Long Term Elastic Modulus E_u (MPa)	Short Term Elastic Modulus E_u (MPa)	Drained Parameters		
					Cohesion c′ (kPa)	Friction Angle Φ′ (degrees)	Poisson's Ratio
Granular Fills	18	N/A	2-5	5-8	0	25	0.4
Unit 1 Clayey Residual soils and fills stiff to 3m to 6m depth	18	50-150	8-12	10-20	1-3	22	0.4
Unit 2 Weathered materials >3m to 6m depth	20	150-250	20-30	15-25	3-5	24	0.3

3.2 Project Opportunities and Risk management

The site is well suited to the proposed development from a geotechnical perspective. The following table outlines the potential geotechnical risks (positive and negative) identified for the project and makes recommendations for their management.

Table 3-2: Risk assessment and mitigation

Number	Risk	Mitigation/Management
1	Excavated material: The site has been substantially filled and there is an encapsulated area of asbestos affected material.	Spoil is likely to be classified as GSW (potentially recyclable) and will not be able to be spoiled as VENM. Some material may need to be disposed of as asbestos affected material to landfill or encapsulated deeper on the site.
2	Excavations for basements : Excavations for basements will mostly be in fill and are unlikely to encounter large volumes of groundwater. The excavations will need temporary support where located near existing structures near the site	Shoring walls or contiguous piled walls may be required to support excavations. Seepages should be manageable with sumps and pumps.
3	Foundation conditions: post excavation, the footings are likely to encounter residual soil and then weathered materials with latite at depths between 3 and 6m across the site	Suitable foundation conditions for the building exist at relatively shallow depth below the site post excavation (eg within 1 to 3m). The building basement slab may be partly founded on rock and partly supported by piers to rock. Deeper excavations (below 2-4m depth below single basement slab) may encounter hard rock requiring sawing.

3.3 Footings

3.3.1 Site classification to AS2870

It is noted that AS2870 provides guidance on reactive soil movements for two storey or smaller residential structures for the purposes of footing design. However, the guidance within this standard is often referred to when understanding reactive soil movements and their impact on footings.

A site classification of P is deemed applicable for the site based on the following:

- The presence of deep filling on the site and an encapsulated area; and
- The presence of an existing structure, which when removed, will result in changes to the moisture regime in the soils underlying the site.

The footings will need to be designed by a competent structural engineer to suit the site conditions. Based on the preliminary information available within this report, it is expected that reactive movements will be in the order of 20 to 40mm. Where excavated for basements, these movements are likely to reduce to below 20mm.

Designs and design methods presented in AS 2870-2011 are based on the performance requirement that significant damage can be avoided provided that site conditions are properly maintained. The above site classification assumes that the performance requirements as set out in Appendix B of AS 2870 are acceptable and that site foundation maintenance is undertaken, by both the builder at the time of the construction and the owner throughout the life of the proposed development, to avoid extremes of wetting and drying.

Details on appropriate site and foundation maintenance practices are presented in Appendix B of AS 2870-2011 and in CSIRO Information Sheet BTF 18, Foundation Maintenance and Footing Performance: A Homeowner's Guide (refer Appendix C). The following is recommended based on these guidelines:

- The planting of fast growing trees or trees with aggressive root systems close to the proposed building should be avoided.
- Irrigation of landscaped areas should be carefully managed to provide relatively uniform soil moisture content in landscaped areas around the building.
- Surface water should be drained from the site to minimise ponding around the building walls and floor areas. Surface drains should be maintained free of blockages.
- Appropriate drainage is provided around buildings to prevent scouring. The ground around the building platform should slope away at 1 in 20 for 2m with surface waters collected via surface drains and disposed of safely away from slopes and retaining structures.

- Roof run-off should be collected and piped to the storage tanks or discharged a safe distance away from building foundations.

3.3.2 Footing Design parameters

All footings for the same structure should be founded on strata of similar stiffness and reactivity to minimise the risk of differential movements, with articulation provided where appropriate. Footings are expected to comprise either:

- A ground slab with perimeter edge beams and internal beams; or
- A stiffened raft / raft supported by edge beams and piers.

Slabs /rafts founded on natural stiff residual soils or weathered materials underlying the site may be proportioned on an allowable bearing pressure of 100kPa and 250kPa respectively. High level footings located on controlled fill can be designed based on an allowable bearing of 100kPa.

If foundations for proposed structures are located within the zone of influence of any service trenching, the structure should be supported by pier footings. The depth of the pier footing should be extended below the zone of influence ignoring shaft adhesion. A structural engineer should be consulted for detailing.

If bored piers (deep footings) are adopted they can be founded into the rock which underlies the site. Piers designed to bear on the proximal end of rock at depths between 3 to 6m can be designed based on a nominal ultimate end bearing pressure of 1.8MPa and ultimate shaft adhesion of 50kPa. A geotechnical strength reduction factor of 0.45 shall be applied to the ultimate end bearing for the bored pier.

Skin friction must not be relied on within the fill and alluvial soils or within the zone of seasonal moisture content variation (e.g. the top 1.0 m depth from the surface). We note that the ultimate end bearing provided is dependent on a clean base of bored hole. Inspection of high level or pier footings excavations should be undertaken to confirm the founding conditions and the base should be cleared of fall-in prior to the formation of the footing.

Foundation design shall be checked for uplift restraint. Where this cannot be provided by dead weight effects, consideration may be given to the use of hold-down passive anchors grouted into the rock to augment uplift restraint.

Table 3.3 on the following page provides relevant design parameters for footings for the site.

3.3.3 Durability

Many factors can affect the corrosion potential of soil including soil moisture content, resistivity, permeability and pH, as well as chloride and sulfate concentration.

Chloride and sulfate ion concentrations and pH appear to play secondary roles in affecting corrosion potential. High chloride levels tend to reduce soil resistivity and break down otherwise protective surface deposits, which can result in corrosion of buried metallic improvements or reinforced concrete structures. Sulfate ions in the soil can lower the soil resistivity and can be highly aggressive to Portland Cement Concrete (PCC) by combining chemically with certain constituents of the concrete, principally tricalcium aluminate. This reaction is accompanied by expansion and eventual disruption of the concrete matrix. Soils containing high sulfate content could also cause corrosion of the reinforcing steel in concrete. The level of sulfates detected in samples from nearby the site are negligible. The pH of the soils is within the highly acidic to moderately acidic range.

Table 6.4.2(C) of the Australian Standard AS2159-2009 Piling – Design and installation defines the exposure conditions for the design of concrete piles based on the level of sulfates and pH of the soil. This indicates based on the laboratory results and the low permeability nature of soils on site an exposure classification of mild.

Table 6.5.2(C) of the Australian Standard AS2159-2009 Piling – Design and installation defines the exposure conditions for the design of steel piles based on the level of chlorides, pH, and resistivity. This indicates based on the laboratory results, an exposure classification of non-aggressive

Table 3-3: Preliminary Foundation Design Parameters

Material	Undrained Shear Strength (kPa)	Allowable Beraring Capacity (kPa)	Youngs Modulus (MPa)	Bulk Unit Weight (kN/m^3)	Geotechnical strength reduction factor	Ultimate End bearing (MPa)	Ultimate Shaft Adhesion (kPA)
Topsoil/ uncontrolled fill	25	NA	4	8	0.45	Ignore	Ignore
Controlled fill	50	100	8	16	0.45	Ignore	Ignore
Residual Soil - Firm to stiff Clay below 1 to 3m depth	50-100	150	12	16	0.45	0.9	40
XW Rock (Siltstone/sandstone) below 3 to 6m depth	-	250	30	20	0.45	1.8	50

Notes: NE – not encountered

3.4 Retaining Walls

It is understood a basement beneath the building is proposed. This will require excavations and retaining walls. The excavations may need temporary support if located near existing structures on the site or adjacent sites. Further advice is provided in Section 3.4.

Structural design of retaining structures must be sufficient to limit lateral ground movement in the soil at this site. A triangular pressure distribution could be adopted for the design of permanent retaining walls, which cantilever in the lateral direction by a single point restraint. The earth pressures on the active side of the wall may be calculated for a particular depth using the following equation:

$$Pa = K\ (\ Ps\ +\ \gamma_b.H\ )$$

where: Pa = Lateral earth pressure on the active side of the wall (kPa)

γ_b = Bulk unit weight (kN/m3)
K = Earth pressure coefficient which depends upon material type; whether movement needs to be limited; whether temporary or permanent.
Ps = Design surcharge pressure (kPa)
H = Height/depth below top of excavation (m)

The assumed lateral pressure distributions may need to be modified to account for material layering, surcharge loads, any concentrated pad or strip footing loadings, or hydrostatic pressure due to build-up of water behind the wall. These parameters in table 3.4 are based on the estimated soil parameters for materials as provided in Table 3.1. The following table provides design values for a retaining wall with sloping ground behind.

Table 3-4: Earth Pressure co-efficient

Material	Lateral Earth Pressure Coefficient, K	Passive Pressure Coefficient, Kp	Bulk Unit Weight, γ_b (kN/m^3)
Unit 2	0.60	2.3	18
Unit 3	0.50	3.0	20
Unit 1 and Granular fill	0.30	NA	20

These parameters assume that the soil remains in the state observed during fieldwork at the site and that drainage conditions behind the retaining walls are satisfactory. Allowances for blockage of drainage systems during the design life may be required in the final design. We recommended that footings of any proposed retaining walls are founded into weathered rock by at least 500mm. Design however needs to recognise the eccentricity of retaining wall footing loads.

Retaining walls will rely on subsurface drains, complemented with surface water drainage measures. Even with subsoil drains installed, allowance should be made in the design for the likelihood of subsoil drain failure. For this purpose, a hydrostatic pressure build-up equivalent to a third of the wall height is recommended. If the wall is constructed as part of basement (eg a tanked wall), the design will need to consider full height hydrostatic pressure building up behind the wall. Drainage detailing of the wall should aim to separate surface and subsoil water. To achieve this, it is usual practice to cap the subsoil drainage system with impervious materials. As with all subsoil drains, the principal requirements for effectiveness are:

- Positive outlets for the collector pipes at no more than 20 metres apart.
- The use of durable, clean drainage aggregate. Durability must meet the requirements of AS 2758.1, Clause 9.3.2 for exposure classification A1.
- Filter protection to drainage pipes and aggregate.

Flush out points must be provided on subsoil lines. Basement walls must be effectively tanked.

3.5 Earthworks

3.5.1 Site preparation

Ground preparation should allow for the stripping of topsoil and uncontrolled fill (if encountered) from structural footprints. Stripped soil would not be suitable for structural fill and must be processed to exclude cobbles and foreign material (where present) and then used for landscape applications if determined to be suitable for this purpose. Surplus excavated materials may need to be exported or disposed of off the site.

3.5.2 Fill

Fill materials to be placed on the site are likely to comprise pavement materials, general fill to elevate the site or structural fill below building footings. Structural and general fill should be compacted in layers not exceeding 200mm thick compacted thickness. Fill and pavement materials should be placed and compacted to the required density ratios as outlined in Table 3.5.

Table 3-5: Fill placement density requirements

Description	Density Ratio Requirements
Pavement – Base	Minimum 98% Modified
Pavement - Sub-base	Minimum 95% Modified
Subgrade (top 300mm)	Minimum 100% Standard
Structural Fill zone (within 200mm of footings)	Minimum 100% Standard
General Fill Zone (deeper than 300mm below top of subgrade)	Minimum 98% Standard

Testing of controlled fill should be in accordance with the following:

- Density and compaction testing should be undertaken on all fill placed in road formations (pavement subgrades, subbase and base layers) and building footprints. For roadworks (other than general filling), geotechnical supervision to Level 2 is recommended as defined in AS3798.
- Where the fill material has a grading with more than 20% coarser than 37.5mm, a method specification for placement and assessment should apply. Where the fill has less than 20% of particles coarser than 37.5mm it can be tested for in situ density by nuclear gauge.
- Density and compaction testing of the fill should be carried out on each 200mm thick layer of the compacted fill. Proof rolling of each layer should also be carried out using a smooth drum roller of at least 12 tonne mass;
- Density testing of fill should be carried out at the rate of three tests per visit or one test every 2000m2, whichever is the greater. If full time geotechnical supervision of the fill occurs, then a minimum three tests per day should be sufficient;

3.5.3 Ease of excavation

This ease with which materials can be excavated onsite has been assessed using the Kirsten eight-point classification system provided in Table 3.5. The topsoil, fill, and residual materials encountered are expected to meet a Kirsten Classification of Class 1 to 3 and should be readily excavated using conventional earthmoving equipment such as hydraulic excavators, backhoes, and dozers to depths of 3m. Extremely weathered rock of extremely low strength should be readily excavated with easy to hard ripping consistent with Class 4 to 5 materials. Less weathered basalt potentially likely to be encountered at depths below 4 to 6m may require sawing to facilitate removal.

Table 3-6: Kirsten's eight-point excavation classification system

Class	Material Type	Description of Excavatability
1	Soil / Detritus	Hand spade (Dozer D3)
2		Hand pick and spade
3		Power tools
4	Rock	Easy ripping (Dozer D7)
5		Hard ripping (Dozer D8)
6		Very hard ripping (Dozer D9)
7		Extremely hard ripping / blasting (Dozer D10)
8		Blasting

3.5.4 Temporary and Permanent Slopes

Permanent cut slope faces less than 600mm in height shall be battered at not greater than 1V:2.5H or retained. Permanent cut slopes greater than 0.6m in height shall be supported by engineered retaining walls. Retaining walls should be designed by a competent engineer and shall be supported on strip footings with piers to weathered rock encountered at depths of at least 3.0m below the current surface levels at the time of the investigation.

Temporary cut slope faces less than 1.0m in height shall be battered at not greater than 1V:1H. Temporary cut slopes greater than 1.0m will need to consider proximity of the existing dwellings upgradient and weather conditions forecasted whilst the cut is to remain open. They may require temporary support if likely to remain open greater than 1 to 2 weeks or rain is forecasted.

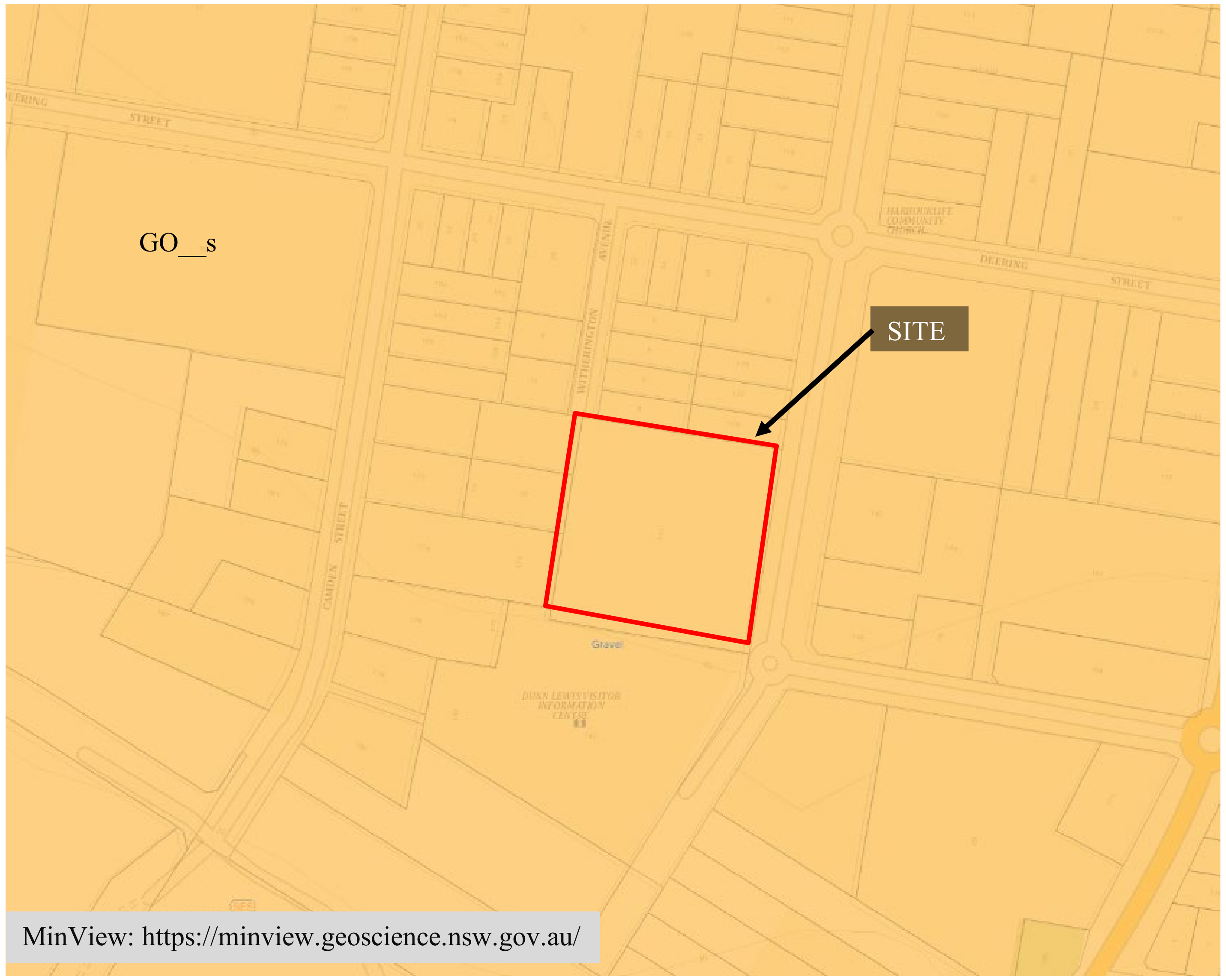
A temporary works plan should be documented by the earthworks contractor (endorsed by Geotechnical Engineer) which includes inspection of the slope daily with the provision for any excavation to be supported or back filled if movement is observed or rain is forecasted. Construction should be planned to avoid significant excavation in extended period of wet weather. An excavation of up to 3.0m depth will be required for the proposed basements. Ground support will be required prior to excavation. This is likely to require shoring piles or similar.

4 Recommendations for further investigation

This report provides preliminary advice based on geotechnical information obtained for the site and nearby sites. To confirm the subsurface conditions, geotechnical investigation for the site should include a combination of the following:

- Deep boreholes taken to depths of at least 8 m and cored into the rock to determine the degree of weathering and strength of the rock for basement design purposes;
- Shallow boreholes to access the natural of the near surface soils in terms of ractivity for shallow footing design and to obtain CBR samples for pavement design. This will generally be around 3 m deep and can be combined with environmental investigations to access the likely waste classification of the existing fill materials on site and their suitability for recycling.

Figures



Site Geology

Symbol	Group	Subgroup	Unit	Lithology
GO__s	-	-	Alluvial gravel, sand and clay deposits	Unconsolidated to poorly consolidated alluvial gravel, sand and clay deposits which are closely associated with basalts of similar age near Ulladulla.

Site Location

revision	description	drawn	approved	date
	Site location and geology	JH	KEG	8/09/2023

N

TERRA INSIGHT

scale	NTS
original size	A3

client:	**Olivander Capital**
project:	**131 Saint Vincent Street, Ulladulla Preliminary Site Investigation Lot 1 Section 26 DP 759018**
title:	**Site Location and Geology**
project no: **TERRA23-288**	figure no: **FIGURE 1**

Historical Imagery

revision	description	drawn	approved	date
	Historical Aerial Imagery	JH	KEG	8/09/2023

N

TERRA INSIGHT

scale	NTS
original size	A3

client:	**Olivander Capital**
project:	**131 Saint Vincent Street, Ulladulla** **Preliminary Site Investigation** **Lot 1 Section 26 DP 759018**
title:	**Historical Aerial Imagery**
project no: **TERRA23-288**	figure no: **FIGURE 2**

Historical Imagery

revision	description	drawn	approved	date
	Historical Aerial Imagery	JH	KEG	8/09/2023

N

TERRA INSIGHT

scale	NTS
original size	A3

client:	Olivander Capital
project:	**131 Saint Vincent Street, Ulladulla** **Preliminary Site Investigation** **Lot 1 Section 26 DP 759018**
title:	**Historical Aerial Imagery**
project no: **TERRA23-288**	figure no: **FIGURE 2**

Appendix A: Your Report

TERRA INSIGHT

Your Report

These notes have been prepared to help you understand the advice provided in Your Report and its limitations.

Your Report is based on what you tell us

Your Report has been developed based on the information you have provided such as the scope and size of your project. It applies only to the site investigated. If there are changes to the proposed works, then the advice provided within Your Report may need to be reviewed

Your Report is written with your needs in mind

The advice provided within Your Report is also not relevant to another purpose other than that originally specified at the time the report was issued. Please seek advice from Terra Insight before you share Your Report with another third party – except for the purpose for which the report was written.

Terra Insight assumes no responsibility and will not be liable to any other person or organisation for, or in relation to, any matter dealt with or conclusions expressed in the report, or for any loss or damage suffered by any other person or organisation arising from matters dealt with or conclusions expressed in Your Report.

Your Report is based on what we observed

The advice provided within Your Report assumes that the site conditions, revealed through selective point sampling (undertaken in accordance with normal practices and standards) at a particular point in time, are indicative of the actual conditions on your site. However, the nature of the materials underlying your site is affected by natural processes and the activity of man. Under no circumstances can it be considered that these findings represent the actual state at all points. The subsurface conditions may vary significantly on the other parts of the site, particularly where no nearby sampling and testing work has been carried out.

As a result conditions on your site can change with time; they can also vary spatially. As a result, the actual conditions encountered may differ from those detailed within Your Report. Although nothing can be done to change the actual site conditions which exist, steps can be taken to gain a better understanding of the subsurface conditions underlying your site and reduce the potential for unexpected conditions to be encountered

The advice within Your Report also relies on interpretation of factual information based on judgement and opinion and has a level of uncertainty attached to it. Only Terra Insight is fully familiar with the background information needed to assess whether or not the report's recommendations are valid and whether or not changes should be considered as the project develops. If the details of your project have changed, the site conditions have changed or a significant amount of time as elapsed since our report was written, the advice provided within Your Report may need to be reviewed.

Your Report has been written by a Professional

The report has been prepared using accepted procedures and practices of the consulting profession at the time it was prepared, and the opinions, recommendations and conclusions set out in the report are made in accordance with generally accepted principles and practices of that profession.

Your Report is better when it is kept together

Your Report presents all the findings of the site assessment and should not be copied in part or altered in any way. Keeping Your Report intact reduces the potential for yourself or other design professionals to misinterpret the report.

Your Geo-Environmental Report

If Your Report is for geotechnical purposes only, it will not relate any findings, conclusions, or recommendations about the potential for hazardous materials to exist at the site unless you have specifically asked us to do so. If your report is written for Geo-Environmental purposes the following should be noted in addition to the above:

- Advancements in professional practice regarding contaminated land and changes in applicable statues and/or guidelines may affect the validity of this report. Consequently, the currency of conclusions and recommendations in Your Report should be verified if you propose to use this report more than 6 months after its date of issue;
- Your Report is based on information gained from environmental conditions (including assessment of some or all of soil, groundwater, vapour and surface water) and supplemented by reported data of the local area and professional experience. The assessment has been scoped with consideration to industry standards, regulations, guidelines and your specific requirements, which includes budget and timing;
- The characterisation of site conditions is an interpretation of information collected during assessment, in accordance with industry practice. Any interpretation in Your Report is not a complete description of all material on or in the vicinity of the site, due to the inherent variation in spatial and temporal patterns of contaminant presence and impact in the natural environment.
- We may have relied on data and other information provided by you and other qualified individuals in preparing Your Report. We have not verified the accuracy or completeness of such data or information except as otherwise stated in Your Report. For these reasons Your Report must be regarded as interpretative, in accordance with industry standards and practice, rather than being a definitive record.
- For each purpose, a tailored approach to the assessment of potential soil and groundwater contamination is required. In most cases, a key objective is to identify, and if possible quantify, risks that both recognised and potential contamination posed in the context of the agreed purpose. If the proposed use of the site changes, the assessment may no longer be valid and will need to be reviewed.

* For further information on this aspect reference should be made to "Guidelines for the Provision of Geotechnical information in Construction Contracts" published by the Institution of Engineers Australia, National headquarters, Canberra, 1987.

Appendix B: Proposed Development

Appendix C: CSIRO

Foundation Maintenance and Footing Performance: A Homeowner's Guide

CSIRO

BTF 18 replaces Information Sheet 10/91

Buildings can and often do move. This movement can be up, down, lateral or rotational. The fundamental cause of movement in buildings can usually be related to one or more problems in the foundation soil. It is important for the homeowner to identify the soil type in order to ascertain the measures that should be put in place in order to ensure that problems in the foundation soil can be prevented, thus protecting against building movement.

This Building Technology File is designed to identify causes of soil-related building movement, and to suggest methods of prevention of resultant cracking in buildings.

Soil Types

The types of soils usually present under the topsoil in land zoned for residential buildings can be split into two approximate groups – granular and clay. Quite often, foundation soil is a mixture of both types. The general problems associated with soils having granular content are usually caused by erosion. Clay soils are subject to saturation and swell/shrink problems.

Classifications for a given area can generally be obtained by application to the local authority, but these are sometimes unreliable and if there is doubt, a geotechnical report should be commissioned. As most buildings suffering movement problems are founded on clay soils, there is an emphasis on classification of soils according to the amount of swell and shrinkage they experience with variations of water content. The table below is Table 2.1 from AS 2870, the Residential Slab and Footing Code.

Causes of Movement

Settlement due to construction

There are two types of settlement that occur as a result of construction:

- Immediate settlement occurs when a building is first placed on its foundation soil, as a result of compaction of the soil under the weight of the structure. The cohesive quality of clay soil mitigates against this, but granular (particularly sandy) soil is susceptible.
- Consolidation settlement is a feature of clay soil and may take place because of the expulsion of moisture from the soil or because of the soil's lack of resistance to local compressive or shear stresses. This will usually take place during the first few months after construction, but has been known to take many years in exceptional cases.

These problems are the province of the builder and should be taken into consideration as part of the preparation of the site for construction. Building Technology File 19 (BTF 19) deals with these problems.

Erosion

All soils are prone to erosion, but sandy soil is particularly susceptible to being washed away. Even clay with a sand component of say 10% or more can suffer from erosion.

Saturation

This is particularly a problem in clay soils. Saturation creates a bog-like suspension of the soil that causes it to lose virtually all of its bearing capacity. To a lesser degree, sand is affected by saturation because saturated sand may undergo a reduction in volume – particularly imported sand fill for bedding and blinding layers. However, this usually occurs as immediate settlement and should normally be the province of the builder.

Seasonal swelling and shrinkage of soil

All clays react to the presence of water by slowly absorbing it, making the soil increase in volume (see table below). The degree of increase varies considerably between different clays, as does the degree of decrease during the subsequent drying out caused by fair weather periods. Because of the low absorption and expulsion rate, this phenomenon will not usually be noticeable unless there are prolonged rainy or dry periods, usually of weeks or months, depending on the land and soil characteristics.

The swelling of soil creates an upward force on the footings of the building, and shrinkage creates subsidence that takes away the support needed by the footing to retain equilibrium.

Shear failure

This phenomenon occurs when the foundation soil does not have sufficient strength to support the weight of the footing. There are two major post-construction causes:

- Significant load increase.
- Reduction of lateral support of the soil under the footing due to erosion or excavation.
- In clay soil, shear failure can be caused by saturation of the soil adjacent to or under the footing.

GENERAL DEFINITIONS OF SITE CLASSES

Class	Foundation
A	Most sand and rock sites with little or no ground movement from moisture changes
S	Slightly reactive clay sites with only slight ground movement from moisture changes
M	Moderately reactive clay or silt sites, which can experience moderate ground movement from moisture changes
H	Highly reactive clay sites, which can experience high ground movement from moisture changes
E	Extremely reactive sites, which can experience extreme ground movement from moisture changes
A to P	Filled sites
P	Sites which include soft soils, such as soft clay or silt or loose sands; landslip; mine subsidence; collapsing soils; soils subject to erosion; reactive sites subject to abnormal moisture conditions or sites which cannot be classified otherwise

Tree root growth
Trees and shrubs that are allowed to grow in the vicinity of footings can cause foundation soil movement in two ways:

- Roots that grow under footings may increase in cross-sectional size, exerting upward pressure on footings.
- Roots in the vicinity of footings will absorb much of the moisture in the foundation soil, causing shrinkage or subsidence.

Unevenness of Movement

The types of ground movement described above usually occur unevenly throughout the building's foundation soil. Settlement due to construction tends to be uneven because of:

- Differing compaction of foundation soil prior to construction.
- Differing moisture content of foundation soil prior to construction.

Movement due to non-construction causes is usually more uneven still. Erosion can undermine a footing that traverses the flow or can create the conditions for shear failure by eroding soil adjacent to a footing that runs in the same direction as the flow.

Saturation of clay foundation soil may occur where subfloor walls create a dam that makes water pond. It can also occur wherever there is a source of water near footings in clay soil. This leads to a severe reduction in the strength of the soil which may create local shear failure.

Seasonal swelling and shrinkage of clay soil affects the perimeter of the building first, then gradually spreads to the interior. The swelling process will usually begin at the uphill extreme of the building, or on the weather side where the land is flat. Swelling gradually reaches the interior soil as absorption continues. Shrinkage usually begins where the sun's heat is greatest.

Effects of Uneven Soil Movement on Structures

Erosion and saturation
Erosion removes the support from under footings, tending to create subsidence of the part of the structure under which it occurs. Brickwork walls will resist the stress created by this removal of support by bridging the gap or cantilevering until the bricks or the mortar bedding fail. Older masonry has little resistance. Evidence of failure varies according to circumstances and symptoms may include:

- Step cracking in the mortar beds in the body of the wall or above/below openings such as doors or windows.
- Vertical cracking in the bricks (usually but not necessarily in line with the vertical beds or perpends).

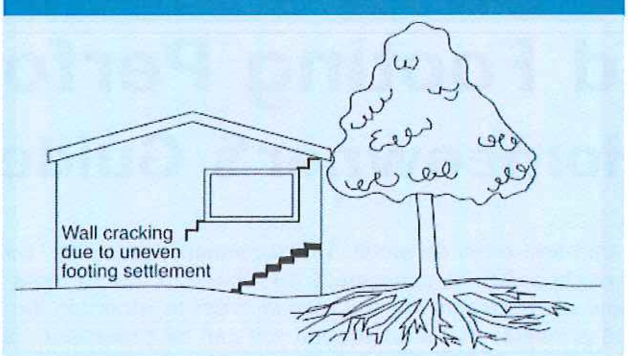
Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

Seasonal swelling/shrinkage in clay
Swelling foundation soil due to rainy periods first lifts the most exposed extremities of the footing system, then the remainder of the perimeter footings while gradually permeating inside the building footprint to lift internal footings. This swelling first tends to create a dish effect, because the external footings are pushed higher than the internal ones.

The first noticeable symptom may be that the floor appears slightly dished. This is often accompanied by some doors binding on the floor or the door head, together with some cracking of cornice mitres. In buildings with timber flooring supported by bearers and joists, the floor can be bouncy. Externally there may be visible dishing of the hip or ridge lines.

As the moisture absorption process completes its journey to the innermost areas of the building, the internal footings will rise. If the spread of moisture is roughly even, it may be that the symptoms will temporarily disappear, but it is more likely that swelling will be uneven, creating a difference rather than a disappearance in symptoms. In buildings with timber flooring supported by bearers and joists, the isolated piers will rise more easily than the strip footings or piers under walls, creating noticeable doming of flooring.

Trees can cause shrinkage and damage



As the weather pattern changes and the soil begins to dry out, the external footings will be first affected, beginning with the locations where the sun's effect is strongest. This has the effect of lowering the external footings. The doming is accentuated and cracking reduces or disappears where it occurred because of dishing, but other cracks open up. The roof lines may become convex.

Doming and dishing are also affected by weather in other ways. In areas where warm, wet summers and cooler dry winters prevail, water migration tends to be toward the interior and doming will be accentuated, whereas where summers are dry and winters are cold and wet, migration tends to be toward the exterior and the underlying propensity is toward dishing.

Movement caused by tree roots
In general, growing roots will exert an upward pressure on footings, whereas soil subject to drying because of tree or shrub roots will tend to remove support from under footings by inducing shrinkage.

Complications caused by the structure itself
Most forces that the soil causes to be exerted on structures are vertical – i.e. either up or down. However, because these forces are seldom spread evenly around the footings, and because the building resists uneven movement because of its rigidity, forces are exerted from one part of the building to another. The net result of all these forces is usually rotational. This resultant force often complicates the diagnosis because the visible symptoms do not simply reflect the original cause. A common symptom is binding of doors on the vertical member of the frame.

Effects on full masonry structures
Brickwork will resist cracking where it can. It will attempt to span areas that lose support because of subsided foundations or raised points. It is therefore usual to see cracking at weak points, such as openings for windows or doors.

In the event of construction settlement, cracking will usually remain unchanged after the process of settlement has ceased.

With local shear or erosion, cracking will usually continue to develop until the original cause has been remedied, or until the subsidence has completely neutralised the affected portion of footing and the structure has stabilised on other footings that remain effective.

In the case of swell/shrink effects, the brickwork will in some cases return to its original position after completion of a cycle, however it is more likely that the rotational effect will not be exactly reversed, and it is also usual that brickwork will settle in its new position and will resist the forces trying to return it to its original position. This means that in a case where swelling takes place after construction and cracking occurs, the cracking is likely to at least partly remain after the shrink segment of the cycle is complete. Thus, each time the cycle is repeated, the likelihood is that the cracking will become wider until the sections of brickwork become virtually independent.

With repeated cycles, once the cracking is established, if there is no other complication, it is normal for the incidence of cracking to stabilise, as the building has the articulation it needs to cope with the problem. This is by no means always the case, however, and monitoring of cracks in walls and floors should always be treated seriously.

Upheaval caused by growth of tree roots under footings is not a simple vertical shear stress. There is a tendency for the root to also exert lateral forces that attempt to separate sections of brickwork after initial cracking has occurred.

The normal structural arrangement is that the inner leaf of brickwork in the external walls and at least some of the internal walls (depending on the roof type) comprise the load-bearing structure on which any upper floors, ceilings and the roof are supported. In these cases, it is internally visible cracking that should be the main focus of attention, however there are a few examples of dwellings whose external leaf of masonry plays some supporting role, so this should be checked if there is any doubt. In any case, externally visible cracking is important as a guide to stresses on the structure generally, and it should also be remembered that the external walls must be capable of supporting themselves.

Effects on framed structures
Timber or steel framed buildings are less likely to exhibit cracking due to swell/shrink than masonry buildings because of their flexibility. Also, the doming/dishing effects tend to be lower because of the lighter weight of walls. The main risks to framed buildings are encountered because of the isolated pier footings used under walls. Where erosion or saturation cause a footing to fall away, this can double the span which a wall must bridge. This additional stress can create cracking in wall linings, particularly where there is a weak point in the structure caused by a door or window opening. It is, however, unlikely that framed structures will be so stressed as to suffer serious damage without first exhibiting some or all of the above symptoms for a considerable period. The same warning period should apply in the case of upheaval. It should be noted, however, that where framed buildings are supported by strip footings there is only one leaf of brickwork and therefore the externally visible walls are the supporting structure for the building. In this case, the subfloor masonry walls can be expected to behave as full brickwork walls.

Effects on brick veneer structures
Because the load-bearing structure of a brick veneer building is the frame that makes up the interior leaf of the external walls plus perhaps the internal walls, depending on the type of roof, the building can be expected to behave as a framed structure, except that the external masonry will behave in a similar way to the external leaf of a full masonry structure.

Water Service and Drainage

Where a water service pipe, a sewer or stormwater drainage pipe is in the vicinity of a building, a water leak can cause erosion, swelling or saturation of susceptible soil. Even a minuscule leak can be enough to saturate a clay foundation. A leaking tap near a building can have the same effect. In addition, trenches containing pipes can become watercourses even though backfilled, particularly where broken rubble is used as fill. Water that runs along these trenches can be responsible for serious erosion, interstrata seepage into subfloor areas and saturation.

Pipe leakage and trench water flows also encourage tree and shrub roots to the source of water, complicating and exacerbating the problem.
Poor roof plumbing can result in large volumes of rainwater being concentrated in a small area of soil:

- Incorrect falls in roof guttering may result in overflows, as may gutters blocked with leaves etc.
- Corroded guttering or downpipes can spill water to ground.
- Downpipes not positively connected to a proper stormwater collection system will direct a concentration of water to soil that is directly adjacent to footings, sometimes causing large-scale problems such as erosion, saturation and migration of water under the building.

Seriousness of Cracking

In general, most cracking found in masonry walls is a cosmetic nuisance only and can be kept in repair or even ignored. The table below is a reproduction of Table C1 of AS 2870.

AS 2870 also publishes figures relating to cracking in concrete floors, however because wall cracking will usually reach the critical point significantly earlier than cracking in slabs, this table is not reproduced here.

Prevention/Cure

Plumbing
Where building movement is caused by water service, roof plumbing, sewer or stormwater failure, the remedy is to repair the problem. It is prudent, however, to consider also rerouting pipes away from the building where possible, and relocating taps to positions where any leakage will not direct water to the building vicinity. Even where gully traps are present, there is sometimes sufficient spill to create erosion or saturation, particularly in modern installations using smaller diameter PVC fixtures. Indeed, some gully traps are not situated directly under the taps that are installed to charge them, with the result that water from the tap may enter the backfilled trench that houses the sewer piping. If the trench has been poorly backfilled, the water will either pond or flow along the bottom of the trench. As these trenches usually run alongside the footings and can be at a similar depth, it is not hard to see how any water that is thus directed into a trench can easily affect the foundation's ability to support footings or even gain entry to the subfloor area.

Ground drainage
In all soils there is the capacity for water to travel on the surface and below it. Surface water flows can be established by inspection during and after heavy or prolonged rain. If necessary, a grated drain system connected to the stormwater collection system is usually an easy solution.

It is, however, sometimes necessary when attempting to prevent water migration that testing be carried out to establish watertable height and subsoil water flows. This subject is referred to in BTF 19 and may properly be regarded as an area for an expert consultant.

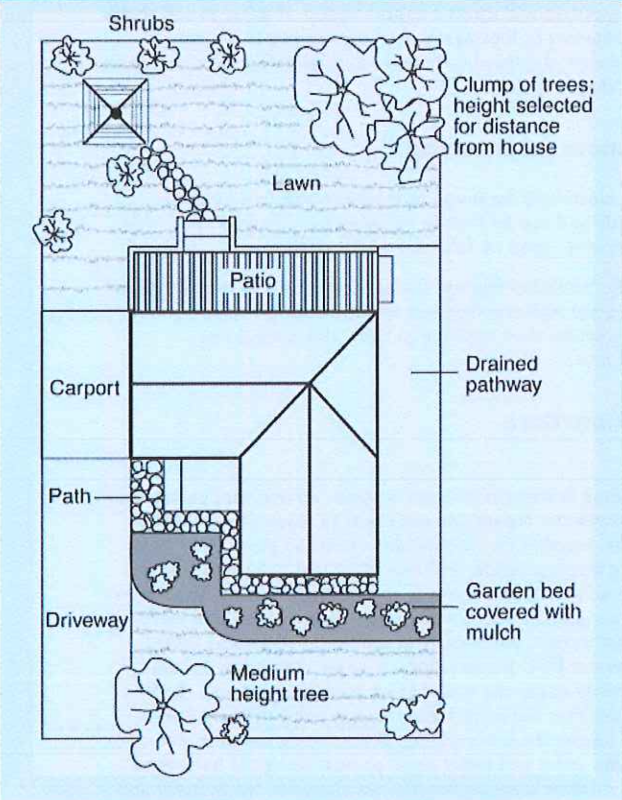
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

For this reason, particularly where problems exist or are likely to occur, it is recommended that an apron of paving be installed around as much of the building perimeter as necessary. This paving

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

Description of typical damage and required repair	Approximate crack width limit (see Note 3)	Damage category
Hairline cracks	<0.1 mm	0
Fine cracks which do not need repair	<1 mm	1
Cracks noticeable but easily filled. Doors and windows stick slightly	<5 mm	2
Cracks can be repaired and possibly a small amount of wall will need to be replaced. Doors and windows stick. Service pipes can fracture. Weathertightness often impaired	5–15 mm (or a number of cracks 3 mm or more in one group)	3
Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows. Window and door frames distort. Walls lean or bulge noticeably, some loss of bearing in beams. Service pipes disrupted	15–25 mm but also depend on number of cracks	4

Gardens for a reactive site



should extend outwards a minimum of 900 mm (more in highly reactive soil) and should have a minimum fall away from the building of 1:60. The finished paving should be no less than 100 mm below brick vent bases.

It is prudent to relocate drainage pipes away from this paving, if possible, to avoid complications from future leakage. If this is not practical, earthenware pipes should be replaced by PVC and backfilling should be of the same soil type as the surrounding soil and compacted to the same density.

Except in areas where freezing of water is an issue, it is wise to remove taps in the building area and relocate them well away from the building – preferably not uphill from it (see BTF 19).

It may be desirable to install a grated drain at the outside edge of the paving on the uphill side of the building. If subsoil drainage is needed this can be installed under the surface drain.

Condensation

In buildings with a subfloor void such as where bearers and joists support flooring, insufficient ventilation creates ideal conditions for condensation, particularly where there is little clearance between the floor and the ground. Condensation adds to the moisture already present in the subfloor and significantly slows the process of drying out. Installation of an adequate subfloor ventilation system, either natural or mechanical, is desirable.

Warning: Although this Building Technology File deals with cracking in buildings, it should be said that subfloor moisture can result in the development of other problems, notably:

- Water that is transmitted into masonry, metal or timber building elements causes damage and/or decay to those elements.
- High subfloor humidity and moisture content create an ideal environment for various pests, including termites and spiders.
- Where high moisture levels are transmitted to the flooring and walls, an increase in the dust mite count can ensue within the living areas. Dust mites, as well as dampness in general, can be a health hazard to inhabitants, particularly those who are abnormally susceptible to respiratory ailments.

The garden

The ideal vegetation layout is to have lawn or plants that require only light watering immediately adjacent to the drainage or paving edge, then more demanding plants, shrubs and trees spread out in that order.

Overwatering due to misuse of automatic watering systems is a common cause of saturation and water migration under footings. If it is necessary to use these systems, it is important to remove garden beds to a completely safe distance from buildings.

Existing trees

Where a tree is causing a problem of soil drying or there is the existence or threat of upheaval of footings, if the offending roots are subsidiary and their removal will not significantly damage the tree, they should be severed and a concrete or metal barrier placed vertically in the soil to prevent future root growth in the direction of the building. If it is not possible to remove the relevant roots without damage to the tree, an application to remove the tree should be made to the local authority. A prudent plan is to transplant likely offenders before they become a problem.

Information on trees, plants and shrubs

State departments overseeing agriculture can give information regarding root patterns, volume of water needed and safe distance from buildings of most species. Botanic gardens are also sources of information. For information on plant roots and drains, see Building Technology File 17.

Excavation

Excavation around footings must be properly engineered. Soil supporting footings can only be safely excavated at an angle that allows the soil under the footing to remain stable. This angle is called the angle of repose (or friction) and varies significantly between soil types and conditions. Removal of soil within the angle of repose will cause subsidence.

Remediation

Where erosion has occurred that has washed away soil adjacent to footings, soil of the same classification should be introduced and compacted to the same density. Where footings have been undermined, augmentation or other specialist work may be required. Remediation of footings and foundations is generally the realm of a specialist consultant.

Where isolated footings rise and fall because of swell/shrink effect, the homeowner may be tempted to alleviate floor bounce by filling the gap that has appeared between the bearer and the pier with blocking. The danger here is that when the next swell segment of the cycle occurs, the extra blocking will push the floor up into an accentuated dome and may also cause local shear failure in the soil. If it is necessary to use blocking, it should be by a pair of fine wedges and monitoring should be carried out fortnightly.

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