GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER

FORM NO. 1 – To be submitted with Development Application

Development Application for W & E WALKER
Name of Applicant

Address of site **37 Sturdee Lane, Elvina Bay**

Declaration made by geotechnical engineer or engineering geologist or coastal engineer (where applicable) as part of a geotechnical report

I, Peter Thompson (insert name) *on behalf of* Hodgson Consulting Engineers Pty Ltd (Trading or Company Name)

on this the 11th March, 2020 certify that I am a geotechnical engineer or engineering geologist or coastal engineer as defined by the Geotechnical Risk Management Policy for Pittwater - 2009 and I am authorised by the above organisation/company to issue this document and to certify that the organisation/company has a current professional indemnity policy of at least $2million.

Please mark appropriate box

☒ Prepared the detailed Geotechnical Report referenced below in accordance with the Australia Geomechanics Society's Landslide Risk Management Guidelines (AGS 2007) and the Geotechnical Risk Management Policy for Pittwater - 2009

☒ I am willing to technically verify that the detailed Geotechnical Report referenced below has been prepared in accordance with the Australian Geomechanics Society's Landslide Risk Management Guidelines (AGS 2007) and the Geotechnical Risk Management Policy for Pittwater - 2009

☐ Have examined the site and the proposed development in detail and have carried out a risk assessment in accordance with paragraph 6.0 of the Geotechnical Risk Management Policy for Pittwater - 2009. I confirm the results of the risk assessment for the proposed development are in compliance with the Geotechnical Risk Management Policy fro Pittwater - 2009 and further detailed geotechnical reporting is not required for the subject site.

☐ Have examined the site and the proposed development/alteration in detail and am of the opinion that the Development Application only involves Minor Development/Alterations that do not require a Detailed Geotechnical Risk Assessment and hence my report is in accordance with the Geotechnical Risk Management Policy for Pittwater – 2009 requirements for Minor Development/Alterations.

☐ Have examined the site and the proposed development/alteration is separate form and not affected by a Geotechnical Hazard and does not require a Geotechnical report or Risk Assessment and hence my Report is in accordance with the Geotechnical Risk Management Policy for Pittwater – 2009 requirements

☐ Provided the coastal process and coastal forces analysis for inclusion in the Geotechnical Report

Geotechnical Report Details:

Report Title: RISK ANALYSIS & MANAGEMENT FOR PROPOSED INCLINATOR, ALTERATIONS AND ADDITIONS AT 37 STURDEE LANE, ELVINA BAY– QY 00089

Report Date: 11th March, 2020

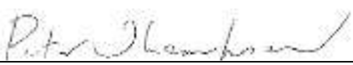
Author : GARTH HODGSON
Reviewer: PETER THOMPSON

Author's Company/Organisation : HODGSON CONSULTING ENGINEERS PTY LTD

Documentation which relate to or are relied upon in report preparation:

Architectural drawings prepared by Stephen Crosby & Associates, Drawing Nos: 2037-DA 01 to DA 04, dated February, 2020.

I am aware that the above Geotechnical Report, prepared for the abovementioned site is to be submitted in support of a Development Application for this site and will be relied on by Pittwater Council as the basis for ensuring that the Geotechnical Risk Management aspects of the proposed development have been adequately addressed to achieve an "Acceptable Risk Management" level for the life of the structure, taken as at least 100 years unless otherwise stated and justified in the Report and that reasonable and practical measures have been identified to remove foreseeable risk.

Signature 

Name Peter Thompson

Chartered Professional Status MIE Aust CPEng

Membership No. 146800

Company Hodgson Consulting Engineers Pty Ltd

GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER

FORM NO. 1(a) - Checklist of Requirements for Geotechnical Risk Management Report for Development Application

Development Application for W & E WALKER
Name of Applicant
Address of site **37 Sturdee Lane, Elvina Bay**

The following checklist covers the minimum requirements to be addressed in a Geotechnical Risk Management Geotechnical Report. This checklist is to accompany the Geotechnical Report and its certification (Form No. 1).

Geotechnical Report Details:

Report Title: RISK ANALYSIS & MANAGEMENT FOR PROPOSED INCLINATOR, ALTERATIONS AND ADDITIONS AT 37 STURDEE LANE, ELVINA BAY– QY 00089

Report Date: 11th March, 2020

Author : GARTH HODGSON
Reviewer: PETER THOMPSON

Author's Company/Organisation: HODGSON CONSULTING ENGINEERS PTY LTD

Please mark appropriate box

☒ Comprehensive site mapping conducted ....
(date)
☒ Mapping details presented on contoured site plan with geomorphic mapping to a minimum scale of 1:200 (as appropriate)
☒ Subsurface investigation required
- ☐ No Justification ....
- ☒ Yes Date conducted 27/02/2020

☒ Geotechnical model developed and reported as an inferred subsurface type-section
☒ Geotechnical hazards identified
- ☐ Above the site
- ☒ On the site
- ☐ Below the site
- ☐ Beside the site

☒ Geotechnical hazards described and reported
☒ Risk assessment conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
- ☒ Consequence analysis
- ☒ Frequency analysis

☒ Risk calculation
☒ Risk assessment for property conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
☒ Risk assessment for loss of life conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
☒ Assessed risks have been compared to "Acceptable Risk Management" criteria as defined in the Geotechnical Risk Management Policy for Pittwater - 2009
☒ Opinion has been provided that the design can achieve the "Acceptable Risk Management" criteria provided that the specified conditions are achieved.
☒ Design Life Adopted:
- ☒ 100 years
- ☒ Other 15 to 20
specify

☒ Geotechnical Conditions to be applied to all four phases as described in the Geotechnical Risk Management Policy for Pittwater – 2009 have been specified
☒ Additional action to remove risk where reasonable and practical have been identified and included in the report.
☒ Risk Assessment within Bushfire Asset Protection Zone

I am aware that Pittwater Council will rely on the Geotechnical Report, to which this checklist applies, as the basis for ensuring that the geotechnical risk management aspects of the proposal have been adequately addressed to achieve an "Acceptable Risk Management" level for the life of the structure, taken as at least 100 years unless otherwise stated, and justified in the Report and that reasonable and practical measures have been identified to remove foreseeable risk.

Signature [signature]
Name Peter Thompson
Chartered Professional Status MIE Aust CPEng
Membership No. 146800
Company Hodgson Consulting Engineers Pty Ltd

RISK ANALYSIS & MANAGEMENT FOR PROPOSED INCLINATOR, ALTERATIONS AND ADDITIONS AT 37 STURDEE LANE, ELVINA BAY

1. INTRODUCTION.

1.1 This assessment has been prepared to accompany an application for Development Approval with Northern Beaches Council - Pittwater. The requirements of the Geotechnical Risk Management Policy for Pittwater, 2009 have been met.

1.2 The definitions used in this Report are those used in the Geotechnical Risk Management Policy for Pittwater, 2009.

1.3 The methods used in this Assessment are based on those described in Landslide Risk Management March 2007, published by the Australian Geomechanics Society and as modified by the Geotechnical Risk Management Policy for Pittwater, 2009.

1.4 The experience of the principal of Hodgson Consulting Engineers spans a time period over 25 years in the Northern Beaches Council area and Greater Sydney Region.

2. PROPOSED DEVELOPMENT.

2.1 Construct new alterations and additions to the north of the existing residence.

2.2 Construct new inclinator from the waterfront on the southern side of the existing residence.

2.3 Details of the proposed development are shown on a series of architectural drawings prepared by Stephen Crosby & Associates, Drawing Nos: 2037-DA 01 to DA 04, dated February, 2020.

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PO Box 389 Mona Vale NSW 1660
Telephone: 0410 664 359
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3. DESCRIPTION OF SITE & SURROUNDING AREA.

3.1 The site was inspected on the 27th February, 2020.

3.2 This rectangular shaped block is located on the crest of slope and has a northerly and southerly aspect. It is located at the crest of the slope that rises very steeply from the south at average angles of some 30 degrees from the waters of Elvina bay to the crest where the existing residence is placed on a moderate slope falling to the south and north. The moderate slope of 5 to 10 degrees continues falling from the crest to the north increasing in angle to be steep before flattening out near Sturdee Lane and then to the waters of Lovett Bay.

3.3 The site is accessed from the water front of Elvina Bay south of the existing residence. From the water front a stairway winds up to the residence, Photo 1. A very steep slope rises from the water front changing to a moderate to steep slope that leads up to the existing residence. The slope is well vegetated and various well established trees are growing towards the top of the slope, Photo 2. The crest of the slope where the existing residence located is covered by lawn, Photo 3. The existing studio and water tank are in the northern part of the subject property, Photo 4. The grassed slope steepens near the northern boundary down to Sturdee Lane where access is via some landscaped steps, Photo 5.

3.4 The single-storey timber clad residence and is supported on concrete pad footings and is fair to good condition. No signs of significant movement attributed slope instability were observed in the existing residence.

3.5 The subject property and adjoining properties are mapped as H1 hazard areas on the Council Geotechnical Hazard Map. Our observations indicate the surrounding slopes do not present a significant risk of instability to the subject property. The subject property is partially mapped as H1 hazard being the very steep slope at the southern end of the property. The northern end of the property is unclassified.

4. GEOLOGY OF THE SITE.

4.1 The Sydney geological series sheet, at a scale of 1:100,000 indicates the site is underlain by interbedded sandstones, siltstones and shales of the Upper Narrabeen Group. The Narrabeen Group Rocks are Late Permian to Middle Triassic in age with the early rocks not outcropping in the area under discussion. The materials from which the rocks were formed consist of gravels, coarse to fine sands, silts and clays. They were deposited in a riverine type environment with larger floods causing fans of finer materials. The direction of deposition changed during the period of formation. The lower beds are very variable with the variations decreasing as the junction with the Hawkesbury Sandstones is approached. This is marked by the highest of persistent shale beds over thicker sandstone beds which are similar in composition to the Hawkesbury Sandstones.

4.2 The slope materials are colluvial in origin at the surface and become residual with depth. They consist of topsoil over sandy clays and clays that merge into the weathered rock at depths varying from 0.7 to 2.0 metres or deeper where filling has been carried out.

5. SUBSURFACE INVESTIGATION AND SITE CLASSIFICATION.

5.1 Four Dynamic Cone Penetrometer (DCP) tests were conducted in the locations shown on the site plan. The tests were conducted to the Australian Standard for ground testing: AS 1289.6.3.2 – 1997 (R2013). The results of these tests are as follows:

NUMBER OF BLOWS - Conducted using a 9kg hammer, 510mm drop and conical tip -				
DEPTH (m)	**DCP#1**	**DCP#2**	**DCP#3**	**DCP#4**
0.0 to 0.3	4	3	1	1
0.3 to 0.6	5	7	4	24
0.6 to 0.9	10	10	15	**8/0.035**
0.9 to 1.2	37	31	15	
1.2 to 1.5	44	17	68	
1.5 to 1.8	**12/0.020**	25	**12/0.020**	
1.8 to 2.1		**76/0.255**		
End of Test Depth	**1.520**	**2.055**	**1.520**	**0.635**
~ RL top of test AHD	**9.00**	**10.00**	**3.50**	**1.20**
~ RL end of test AHD	**7.48**	**7.945**	**1.98**	**0.565**

5. SUBSURFACE INVESTIGATION AND SITE CLASSIFICATION. (Continued)

DCP TESTING NOTES:

DCP#1	12 Blows for 0.020m then 8 blows for 0.020m. Slight Double Bounce. Refusal in weathered shale rock, hard clay or floater. Tip damp and clean.
DCP#2	76 Blows for 0.255m then 8 blows for 0.010m. Slight Double Bounce. Refusal in weathered shale rock, hard clay or floater. Tip dry with white shale on very tip.
DCP#3	12 Blows for 0.020m then 8 blows for 0.020m. Slight Double Bounce. Refusal in weathered shale rock, hard clay or floater. Tip dry with white shale on very tip.
DCP#4	8 Blows for 0.035m then 8 blows for 0.010m. Slight Double Bounce. Refusal in weathered shale rock, hard clay or floater. Tip dry with cream orange shale on tip.
Further Notes	When ringing bouncing rock is not encountered, end of test occurs when there is less than 0.02m of penetration for 8 blows or danger of equipment damage is imminent. No significant standing water table was identified in our testing.

5.2 The equipment chosen to undertake ground investigations provides the most cost effective method for understanding the subsurface conditions. Our interpretation of the subsurface conditions is limited to the results of testing undertaken and the known geology in the area. While every care is taken to accurately identify the subsurface conditions on-site, variation between the interpreted model presented herein, and the actual conditions onsite may occur. Should actual ground conditions vary from those anticipated, we would recommend the geotechnical engineer be informed as soon as possible to advise if modifications to our recommendations are required.

5.3 SITE CLASSIFICATION.

The natural soil profile of the existing site is classified Class M, defined as 'Moderately reactive clay or silt sites, which may experience moderate ground movement from moisture changes' as defined by AS 2870 - 2011. Where bedrock is encountered the site is classified as Class A.

6. DRAINAGE OF THE SITE.

6.1 ON THE SITE.

The site is naturally well drained with surface and subsurface runoff draining toward the southern and northern boundary and to Elvina Bay and Lovett Bay respectively. No natural watercourses were observed on site.

6. DRAINAGE OF THE SITE. (Continued)

6.2 SURROUNDING AREA.

Overland stormwater flow entering the site from the adjoining properties was not evident. Normal overland runoff could enter the site from above during heavy or extended rainfall.

7. GEOTECHNICAL HAZARDS.

7.1 ABOVE THE SITE.

No geotechnical hazards likely to adversely affect the subject property were observed above the site.

7.2 ON THE SITE.

The southern part of the site is classed slip affected under Council's Policy and a H1 Hazard. A failure of the slope across the property is considered to be a potential hazard **(HAZARD ONE)**.

The excavation for the base of the inclinator pit is into toe of the very steep slope of depth up to 4.0 metres. The excavations for the proposed inclinator pit considered to be a potential hazard **(HAZARD TWO)**.

7.3 BELOW THE SITE.

No geotechnical hazards likely to adversely affect the subject property were observed below the site.

7.4 BESIDE THE SITE.

The areas beside the site are also classed slip affected hazard areas. These blocks have similar elevation and geomorphology to the subject property. No geotechnical hazards likely to adversely affect the subject property were observed beside the site.

8. RISK ASSESSMENT.

8.1 ABOVE THE SITE.

As no geotechnical hazards likely to adversely affect the subject site were observed above the site, no risk analysis is required.

8. RISK ASSESSMENT. (Continued)

8.2 ON THE SITE.

8.2.1 HAZARD ONE Qualitative Risk Assessment on Property

The slope of the land surface falls across the southern part of the property at approximate average angles of 25 to 35 degrees. While considered stable in its current condition the likelihood of the slope failing and impacting on the house or inclinator is assessed as 'Unlikely' (10^{-4}). The consequences to property of such a failure are assessed as 'Minor' (5%). The risk to property is 'Low' (5×10^{-6}).

8.2.2 HAZARD ONE Quantitative Risk Assessment on Life

For loss of life risk can be calculated as follows:

$\mathbf{R_{(LoI)} = P_{(H)} \times P_{(SH)} \times P_{(TS)} \times V_{(DT)}}$ (See Appendix for full explanation of terms)

8.2.2.1 Annual Probability

No evidence of significant movement was observed on the site.

$\mathbf{P_{(H)}} =$ 0.0001/annum

8.2.2.2 Probability of Spatial Impact

The house is situated towards the crest of the moderate slope.

$\mathbf{P_{(SH)}} =$ 0.1

8.2.2.3 Possibility of the Location Being Occupied During Failure

The average household is taken to be occupied by 4 people. It is estimated that 1 person is in the house for 20 hours a day, 7 days a week. It is estimated 3 people are in the house 12 hours a day, 5 days a week.

For the person most at risk:

$$\frac{20}{24} x \frac{7}{7} = 0.83$$

$\mathbf{P_{(TS)}} =$ 0.83

8.2.2.4 Probability of Loss of Life on Impact of Failure

Based on the volume of land sliding and its likely velocity when it hits the house, it is estimated that the vulnerability of a person to being killed in the house when a landslide hits is 0.01

$\mathbf{V_{(DT)}} =$ 0.01

8. **RISK ASSESSMENT. (Continued)**

8.2.2.5 Risk Estimation

$\mathbf{R_{(LoI)}}$ **=** 0.0001 x 0.1 x 0.83 x 0.01
= 0.000000083
$\mathbf{R_{(LoI)}}$ **=** 8.3 x 10^{-8}/annum. **NOTE:** This level of risk is **'ACCEPTABLE',** provided the recommendations in **Section 10** are followed.

8.2.3 HAZARD TWO Qualitative Risk Assessment on Property

The excavation for the base of the inclinator pit is into the toe of the very steep slope of depth up to 4.0 metres. Provided good engineering and building practices are followed and the recommendations given in Section 10 are undertaken the likelihood of the cut failing and impacting on the worksite is assessed as 'Unlikely' (10^{-4}). The consequences to property of such a failure are assessed as 'Medium' (20%). The risk to property is 'Low' (2 x 10^{-5}).

8.2.4 HAZARD ONE Quantitative Risk Assessment on Life

For loss of life, risk can be calculated as follows:
$\mathbf{R_{(LoI)} = P_{(H)} \times P_{(SH)} \times P_{(TS)} \times V_{(DT)}}$ (See Appendix for full explanation of terms)

8.2.4.1 Annual Probability

Provided the recommendations in Section 10 are followed and any soil portions of the cut are battered back and kept dry, batter failure is considered unlikely.
$\mathbf{P_{(H)}}$ = 0.0001/annum

8.2.4.2 Probability of Spatial Impact

People will be working below the cut.
$\mathbf{P_{(SH)}}$ **=** 0.3

8.2.4.3 Possibility of the Location Being Occupied During Failure

The average domestic worksite is taken to be occupied by 5 people. It is estimated that 1 person is below the cut for 10 hours a day, 6 days a week. It is estimated 4 people are below the cut 7 hours a day, 5 days a week.
For the person most at risk:

$$\frac{10}{24} x \frac{6}{7} = 0.36$$

$\mathbf{P_{(TS)}}$ **=** 0.36

8. RISK ASSESSMENT. (Continued)

8.2.4.4 Probability of Loss of Life on Impact of Failure

Based on the volume of land failing and its likely velocity when it hits the work area, it is estimated that the vulnerability of a person to being killed below the cut when the batter fails is 0.2

$\mathbf{V_{(DT)}}$ **=** 0.2

8.2.4.5 Risk Estimation

$\mathbf{R_{(LoI)}}$ **=** 0.0001 x 0.3 x 0.36 x 0.2
= 0.00000216

$\mathbf{R_{(LoI)}}$ **=** 2.16×10^{-6}/annum **NOTE:** This level of risk is **'ACCEPTABLE'** provided the recommendations given in **Section 10** are undertaken.

8.3 BELOW THE SITE.

As no geotechnical hazards likely to adversely impact upon the subject site were observed below the site, no risk analysis is required.

8.4 BESIDE THE SITE.

As no geotechnical hazards likely to adversely impact upon the subject site were observed beside the site, no risk analysis is required.

9. SUITABILITY OF DEVELOPMENT FOR SITE.

9.1 GENERAL COMMENTS.

The proposed development is considered suitable for the site.

9.2 GEOTECHNICAL COMMENTS.

No geotechnical hazards will be created by the completion of the proposed development in accordance with the requirements of this Report and good engineering and building practice.

9.3 CONCLUSIONS.

The site and the proposed development can achieve the Acceptable Risk Management criteria outlined in the Pittwater Geotechnical Risk Policy provided the recommendations given in **Section 10** are undertaken.

10. RISK MANAGEMENT.

10.1. TYPE OF STRUCTURE.

The proposed structures are considered suitable for this site.

10.2. EXCAVATIONS.

10.2.1 All excavation recommendations as outlined below should be read in conjunction with Safe Work Australia's *'Excavation Work – Code of Practice'*, published October, 2013.

10.2.2 Excavations for the proposed foundations of the northern alterations and additions and inclinator rail support footings will require minimal excavation for the piered footings. These piered footings will encounter soil material and clays overlying the weathered rock of the Narrabeen Group to approximate depths of 1.0 to 1.6 metres or deeper where filling has been carried out.

10.2.3 Excavations for the proposed inclinator pit base foundations will require excavation into the very steep slope to an approximate height of 4.0 metres. The pit base foundation will most likely require piered footings at the water side of the foundations. These piered footings will encounter soil material and clays overlying the weathered rock of the Narrabeen Group to approximate depths of 1.0 to 1.6 metres or deeper where filling has been carried out.

10.2.4 The Softer material above the inclinator pit base excavation will have to be temporarily or permanently retained. A series temporary smaller retaining walls or shoring mat be used to stabilise the slope above the excavation till the permanent retaining wall around the base pit can be constructed and backfilled. Surface runoff is to be diverted around the excavation area.

The weathered shale to be found near the base of the inclinator pit may stand near vertical for a short period of time provided the exposed cut face is covered and protected form the sun and rain. We would recommend that if a long period of rain is expected then the exposed weathered shale is to be temporarily supported till such time that a permanent retaining wall can be constructed.

A suitably qualified structural engineer is to design and certify the temporary and or permanent retaining or shoring structures.

10. RISK MANAGEMENT. (Continued)

10.2.5 All excavated materials left onsite will need to comply with the conditions in Section 10.3 or be retained by an engineer designed retaining wall or structure.

10.2.6 All excavated material is to be removed from the site in accordance with current Office of Environment and Heritage (OEH) regulations.

10.3. FILLS.

10.3.1 If filling is required, all fills are to be placed in layers not more than 250 mm thick and compacted to not less than 95% of Standard Optimum Dry Density at plus or minus 2% of Standard Optimum Moisture Content.

10.3.2 The fill batters are to be not steeper than 1 vertical to 1.7 horizontal or they are to be supported by properly designed and constructed retaining walls.

10.4. FOUNDATION MATERIALS AND FOOTINGS.

It is recommended that all footings be supported on and socketed into the underlying bedrock, using piers as necessary. The design allowable bearing pressures are 450 kPa for spread footings or shallow piers. All footings are to be founded on material of similar consistency to minimise potential for differential settlement.

Note: The local geology is comprised of highly variable interbedded clays, shales and sandstones, with abundant detached joint blocks and sandstone floaters at surface and in the upper profile. Conditions may alter significantly across short distances. This variability should be anticipated and accounted for in the design and construction of any new foundations.

10.5. STORM WATER DRAINAGE.

All storm water runoff from the development is to be connected to the existing storm water system for the block through any tanks or onsite detention systems that may be required by the regulating authorities. This drainage work is to comply with the relevant Australian standards (AS/NZS 3500 Plumbing and Drainage).

10. RISK MANAGEMENT. (Continued)

10.6. SUBSURFACE DRAINAGE.

Any retaining walls are to be back filled with non-cohesive free draining material to provide a drainage layer immediately behind the wall. The free draining material is to be separated from the ground materials by geotextile fabric. Standard under pool drainage is acceptable.

10.7. INSPECTIONS.

It is essential that the foundation materials of all footing excavations be inspected and approved before concrete is placed. This includes retaining wall footings. Failure to advise the geotechnical engineer for these inspections could delay or stop the issuance of relevant certificates.

11. GEOTECHNICAL CONDITIONS FOR ISSUE OF CONSTRUCTION CERTIFICATE.

It is recommended that the following geotechnical conditions be applied to the Development Approval:-

The work is to be carried out in accordance with the Risk Management Report QY 00089 dated 11th March, 2020.

The Geotechnical Engineer is to inspect and approve the foundation materials of any footing excavations before concrete is placed.

12. GEOTECHNICAL CONDITIONS FOR ISSUE OF OCCUPATION CERTIFICATE.

The Geotechnical Engineer is to certify the following geotechnical aspects of the development:-

The work was carried out in accordance with the Risk Management Report QY 00089 dated 11th March, 2020..

The Geotechnical Engineer inspected and approved the foundation material of all footing excavations.

13. RISK ANALYSIS SUMMARY.

HAZARDS	Hazard One	Hazard Two
TYPE	The site is classed slip affected under Council's Policy and a H1 Hazard. A failure of the slope across the property is considered to be a potential hazard.	The excavation for the base of the inclinator pit is into toe of the very steep slope of depth up to 4.0 metres. The excavations for the proposed inclinator pit considered to be a potential hazard.
LIKELIHOOD	'Unlikely' (10^{-4})	'Unlikely' (10^{-4})
CONSEQUENCES TO PROPERTY	'Minor' (5%)	'Medium' (20%)
RISK TO PROPERTY	'Low'(5×10^{-6})	'Low'(5×10^{-6})
RISK TO LIFE	8.3×10^{-8}/annum	2.16×10^{-6}/annum
COMMENTS	This level of risk is **'ACCEPTABLE'** provided the conditions in **Section 10** are followed.	This level of risk is **'ACCEPTABLE'** provided the conditions in **Section 10** are followed.

HODGSON CONSULTING ENGINEERS PTY. LTD.

Author

Garth Hodgson MIE Aust
Member No. 2211514
Civil/Geotechnical & Structural Engineer

Reviewer

Peter Thompson MIE Aust CPEng
Member No. 146800
Civil/Geotechnical Engineer

Photo 1

Photo 2

Photo 3

Photo 4

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Photo 5

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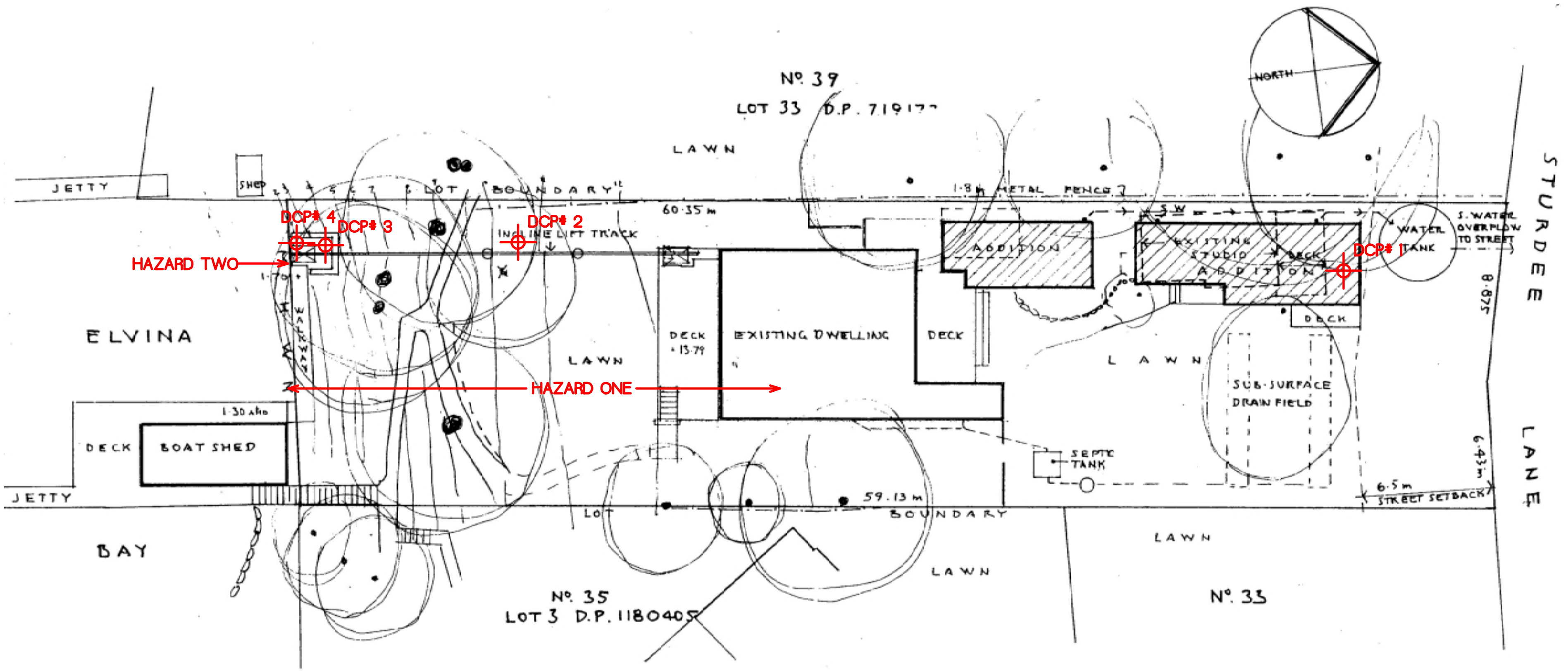

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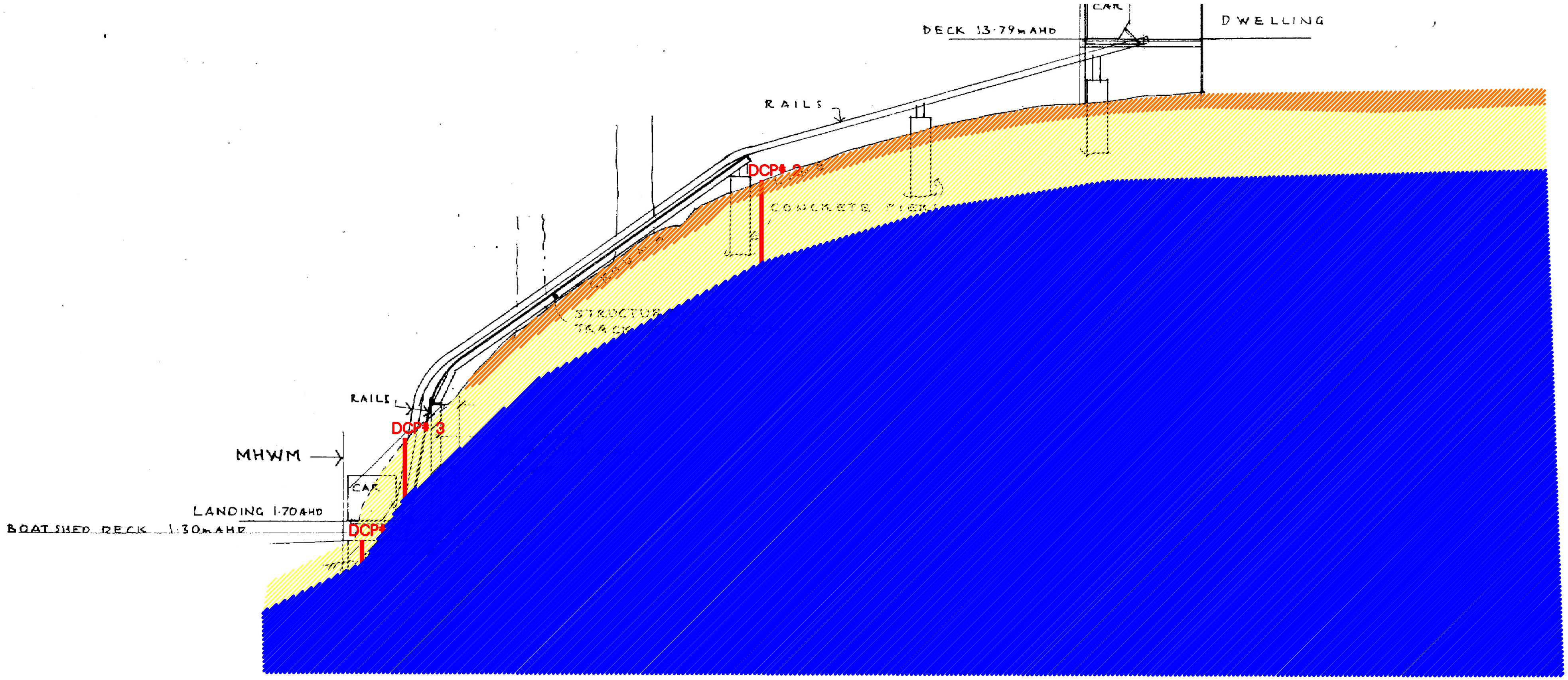
GEOTECHNICAL | CIVIL | STRUCTURAL

SITE PLAN - DCP LOCATIONS & HAZARD	
Job No QY 00089	Address 37 STURDEE LANE ELVINA BAY NSW
Scale NTS	



NOTE
INTERPRETED SUB SURFACE SECTION ONLY.
ACTUAL GROUND CONDITIONS MAY VARY.

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TYPE SECTION	
Job No QY 00089	Address 37 STURDEE LANE ELVINA BAY NSW
Scale NTS	

STRATA PROFILE LEGEND	
Fill	Narrabeen Group Rocks
Sandy Topsoil	Hawkesbury Sandstone
Sandy Loam	

7 RISK ESTIMATION

7.1 QUANTITATIVE RISK ESTIMATION

Quantitative risk estimation involves integration of the frequency analysis and the consequences.
For property, the risk can be calculated from:
$\mathbf{R}_{(Prop)} = \mathbf{P}_{(H)} \times \mathbf{P}_{(S:H)} \times \mathbf{P}_{(T:S)} \times \mathbf{V}_{(Prop:S)} \times \mathbf{E}$ **(1)**

Where
$\mathbf{R}_{(Prop)}$ is the risk (annual loss of property value).

$\mathbf{P}_{(H)}$ is the annual probability of the landslide.

$\mathbf{P}_{(S:H)}$ is the probability of spatial impact by the landslide on the property, taking into account the travel distance and travel direction.

$\mathbf{P}_{(T:S)}$ is the temporal spatial probability. For houses and other buildings $\mathbf{P}_{(T:S)}= 1.0$. For Vehicles and other moving elements at risk $1.0< \mathbf{P}_{(T:S)} >0$.

$\mathbf{V}_{(Prop:S)}$ is the vulnerability of the property to the spatial impact (proportion of property value lost).

E is the element at risk (e.g. the value or net present value of the property).
For loss of life, the individual risk can be calculated from:

$\mathbf{R}_{(LoL)} = \mathbf{P}_{(H)} \times \mathbf{P}_{(S:H)} \times \mathbf{P}_{(T:S)} \times \mathbf{V}_{(D:T)}$ **(2)**
Where

$\mathbf{R}_{(LoL)}$ is the risk (annual probability of loss of life (death) of an individual).

$\mathbf{P}_{(H)}$ is the annual probability of the landslide.

$\mathbf{P}_{(S:H)}$ is the probability of spatial impact of the landslide impacting a building (location) taking into account the travel distance and travel direction given the event.

$\mathbf{P}_{(T:S)}$ is the temporal spatial probability (e.g. of the building or location being occupied by the individual) given the spatial impact and allowing for the possibility of evacuation given there is warning of the landslide occurrence.

$\mathbf{V}_{(D:T)}$ is the vulnerability of the individual (probability of loss of life of the individual given the impact).
A full risk analysis involves consideration of all landslide hazards for the site (e.g. large, deep seated landsliding, smaller slides, boulder falls, debris flows) and all the elements at risk.

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For comparison with tolerable risk criteria, the individual risk from all the landslide hazards affecting the person most at risk, or the property, should be summed.

The assessment must clearly state whether it pertains to ‘as existing’ conditions or following implementation of recommended risk mitigation measures, thereby giving the ‘residual risk’.