APPENDIX H

Geotechnical Assessment Report

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REPORT ON GEOTECHNICAL ASSESSMENT

PROPOSED RESIDENTIAL SUBDIVISION
TALBINGO VILLAGE
TALBINGO

Prepared for:
SITE PLUS PTY LTD

APRIL 2006
PROJECT 40569

Douglas Partners
Geotechnics • Environment • Groundwater

REPORT
ON
GEOTECHNICAL ASSESSMENT

PROPOSED RESIDENTIAL SUBDIVISION
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TALBINGO

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Project 40569
6 April 2006

REPORT ON GEOTECHNICAL ASSESSMENT
PROPOSED RESIDENTIAL SUBDIVISION
TALBINGO VILLAGE, TALBINGO

1. INTRODUCTION

This report presents the results of a preliminary geotechnical assessment of Lots 35 and 36 in DP 878862 located off Murray Jackson Drive at Talbingo. The work was requested by Site Plus Pty Ltd, project managers and planners for the development.

It is understood that consideration is being given to the re-zoning of existing vacant land adjacent to Talbingo Village for residential use. Assessment was therefore carried out to provide preliminary information on geotechnical aspects to assist in conceptual planning of the estate and for submission to Tumut Council with the re-zoning application.

The assessment comprised a review of published information, field mapping by an experienced geotechnical engineer and sampling of selected surface soils, followed by laboratory testing. Details of the work undertaken are given in the report, together with preliminary comments relating to design and construction practice.

An aerial photograph and site survey plans were provided by the client for the purpose of the assessment.

2. SITE DESCRIPTION AND REGIONAL GEOLOGY

The site, which is known as Lots 35 and 36 in DP 878862, is an irregular shaped area of some 38 ha with maximum north-south and east-west dimensions of 442 m and 1110 m, respectively. Site levels fall towards several northerly trending drainage depressions at grades of 1 in 2 to 1 in 10 with an overall difference in level from the highest part of the site to the lowest estimated to be about 65 m.

At the time of the assessment, the site was vacant and grassed and utilised for cattle grazing.

Reference to the 1:250 000 Wagga Wagga Geological Series Sheet (Ref 1) indicates that the site is underlain by Blowering Porphyry of Silurian age. This formation typically comprises quartz feldspar, porphyry with minor slate greywacke, sandstone, quartzite tuff and andesite.

3. FIELD WORK METHODS

The field work comprised field mapping of the site and adjacent areas by an experienced geotechnical engineer on 17 March 2006 which included qualitative assessment of site stability considerations and sampling of surface soils at selected locations (Samples X1 and X2).

The locations of the site features and soil sampling points are shown on Drawing 1.

4. FIELD WORK RESULTS

The distribution of features noted during the field mapping are given on Drawing 1 (Appendix A) and are further shown on Photoplates 1 – 11.

The principal features noted are as follows:

- relatively uniform surface slopes across the site;
- no obvious signs of salinity or deep-seated instability within the site;
- a number of farm dams are present within the natural drainage depressions with the dam walls probably formed using excavated material from site;

- minor gully erosion (ie: generally less than 1 m depth) within some of the drainage depressions;
- disturbed ground including a shallow lined pit on the crest of the eastern ridge, possibly associated with a burial pit;
- evidence of previous development in the form of levelled terraces mainly asphaltic concrete surfaced (remnant pavements) and some concrete slabs (previous buildings) within the western half of the site;
- the site soils exposed in the creek banks and along sections of the fenceline comprise silty sandy clays typical of soils derived from the weathering of the underlying bedrock;
- weathered rock exposed in the road cuttings along the north-western site boundary and in the base of parts of the drainage gullies;
- a shallow cover of residual soil observed in the road cuttings and drainage gullies;
- lush grass growth downslope of existing dams indicating seepage through or under the dam walls;
- pieces of farming equipment, building material and other miscellaneous rubbish was scattered across the site, concentrated though in two areas;
- a colorbond farm shed was noted midway along the southern side boundary and towards the north-eastern corner of the site;
- an embankment some 6 m in height was noted in the northern (central) portion of the site;
- numerous scattered mature trees were located across the site. Several trees located within the drainage gullies were leaning or fallen, probably as a result of erosion in the gullies or blown over in wind storms;
- boulders and cobbles were located at the surface across most of the site;
- an existing road network (sealed with gravel shoulders in places and concrete kerbs in others) was noted through the central portion of the site.

5. LABORATORY TESTING

Two surface soil samples (X1 and X2) were tested in the laboratory for measurement of Emerson stability class, pH, electrical conductivity, sulphate and chloride. These test provide an indication of the dispersivity potential and salinity of the site soils. The detailed test report sheets are given in Appendix A and the results are summarised in Table 1.

Table 1 – Results of Laboratory Testing

Sample No.	pH	ESN	Chloride (mgCl/kg)	Sulphate ($mgSO_4/kg$)	EC (dS/m) [(1)]	Factor	ECe [(2)] (dS/m)	Material
X1	5.8	7	20	100	0.05	8.5	0.43	Silty Clay
X2	6.1	7	40	190	0.16	8.5	1.36	Silty Clay

Note (1) 1dS/m = 1mS/cm
(2) ECe = EC x factor

Where ECN = Emerson stability class; EC = Electrical Conductivity; Factor = Soil texture factor (Ref 2); ECe = Electrical conductivity of a saturated extract

The results of the Emerson stability class testing has indicated that the soil tested have a low erosion potential. Comments on the salinity testing are given in Section 6.6. On the basis of the chloride and sulphate testing, the soil conditions are considered to be non-aggressive for concrete and steel.

6. COMMENTS

6.1 General

The following comments are based on the results of site reconnaissance, laboratory testing and our involvement in similar projects. It is understood that a residential subdivision is proposed and that further investigations will be undertaken at the appropriate time as the planning and design of the subdivision proceeds. Accordingly, this report and the comments given within must be considered as being preliminary in nature.

6.2 General Development Considerations

6.2.1 Site Classification

Classification of residential lots within the site should comply with the requirements of AS 2870 – 1996 *"Residential Slabs and Footings"* (Ref 3). Likely lot classifications would range from Class S (slightly reactive), Class M (moderately reactive) or Class H (highly reactive) with the final classification dependent on soil reactivity and rock depth. The topographic slope in various sections of the site (ie: adjacent drainage gullies) is moderate and accordingly, it is anticipated that some of the lots will need to consider design and construction techniques that take account of the ground slope and possible Class P conditions. Classifications within these areas would also be dependent on the extent of bulk earthworks.

6.2.2 Stability Assessment

The site has been assessed with reference to the Australian Geomechanics Society Sub-Committee on Landslide Risk Management: *"Landslide Risk Management Concepts and Guidelines"* (Ref 4). Based on the observations made during the inspection, assessment has been undertaken for two distinct zones:

- areas of slight relief, which is most of the site (referred to as *"very low to low risk"* as shown on Drawing 1);
- areas of moderate relief (referred to as *"low to moderate risk"* on Drawing 1);

The results of the assessment for each of these areas are outlined in Tables 2 and 3.

Table 2 – Slope Stability Assessment (Area of Slight Relief)

Hazard	Likelihood	Consequence to Proposed Development	Risk to Proposed Development
Creep of surface soils	Unlikely	Minor	Very Low to Low
Active / deep seated slide	Not credible	Major	Very Low

Table 3 – Slope Stability Assessment (Area of Moderate Relief)

Hazard	Likelihood	Consequence to Proposed Development	Risk to Proposed Development
Creep of surface soils	Possible	Minor	Low to Moderate
Active / deep seated slide	Rare	Major	Low to Moderate

In summary, it is considered that most of the site is classified as VERY LOW to LOW risk of damage to property occurring as a result of slope instability. Four areas are considered of LOW to MODERATE risk (refer Drawing 1) due to the slightly greater ground slopes. Notwithstanding the various risk categories nominated, development of the site for residential purposes is considered feasible with erosion control measures and suitable dwelling design to be addressed. It is noted that revisions to the above risk classifications may be necessary following completion of bulk earthworks.

6.2.3 Footings

All footing systems should be designed and constructed in accordance with AS 2870 – 1996 (Ref 3) for the appropriate classification.

For hillside lot construction, reference should be made to the publication by AGS (Ref 4), relevant extracts of which are included in Appendix A.

6.3 Site Preparation and Earthworks

Site preparation for the construction of residential structures should include the removal of topsoils and other deleterious materials from the proposed building areas. In areas that require filling, the stripped surfaces should be proof rolled in the presence of a geotechnical engineer. Any areas exhibiting significant deflections under proof rolling should be appropriately treated by over-excavation and replaced with low plasticity filling placed in near horizontal layers no thicker than 250 mm compacted thickness. Each layer should be compacted to a minimum dry density ratio of 98% relative to standard compaction, with placement moisture contents maintained within 2% of standard optimum. All batters should be constructed no steeper than 3:1 (horizontal:vertical) and appropriately vegetated to reduce the effects of erosion.

It is understood that the several farm dams located onsite are to be filled to facilitate development. The general procedures outlined above should be adopted for the backfilling of these dams. Prior to bulk earthworks, the dams will require draining, excavation of the embankment and wet soil at the base of the dam. Significant excavation depths with the base of the dam should be allowed for to take into consideration the build up of wet clays and silts.

To validate site classifications, sufficient field inspections and in-situ testing of future earthworks should be undertaken in order to satisfy the requirements of a Level 1 inspection and testing service as defined in AS 3798 – 1996 (Ref 5).

Earthworks required for pavement construction will need to be based on batters formed no steeper than 3:1 (H:V) in the residual clays and 1.5:1 (H:V) in weathered rock. All batters should be suitable protected against erosion with toe and spoon drains constructed as a means of controlling surface flows on the batters.

6.4 Site Maintenance and Drainage

The developed lots should be maintained in accordance with the CSIRO publication *"Guide to Home Owners on Foundation Maintenance and Footing Performance"*, a copy of which is included in Appendix A. Whilst it must be accepted that minor cracking in most structures is inevitable, the guide describes suggested site maintenance practices aimed at minimising foundation movement to keep cracking within acceptable limits. Adequate surface drainage should be installed and maintained at the site. All collected stormwater, groundwater and roof runoff should be discharged into the stormwater disposal system.

6.5 Pavements

6.5.1 Preliminary Thickness Designs

Table 4 summarises a range of pavement thickness designs based on the procedures given in APRG (Ref 6) for varying traffic loadings and subgrade CBR values. Suggested material quality and compaction requirements are given in Table 5.

Table 4 – Preliminary Pavement Thickness Design

Traffic Loading (ESA)	Total Pavement Thickness (mm)			
	CBR < 3%	CBR 3%	CBR 4%	CBR 5%
1×10^4	400 (550)	400	335	290
5×10^4	450 (600)	450	375	320
1×10^5	470 (620)	470	390	340
5×10^5	530 (650)	530	445	380
1×10^5	550 (700)	550	470	395

Note: Bracketed figures indicate total boxing depth, taking into account 150 mm of subgrade replacement

The pavement gravels should be placed and compacted in layers no thicker than 150 mm with control exercised over placement moisture contents. If layer thicknesses greater than 150 mm are proposed, it may be necessary to test the top and bottom of the layer to ensure that the minimum level of compaction has been achieved through the layer.

Table 5 – Pavement Material Quality and Compaction

Layer	Material Quality	Minimum Compaction
Wearing Course	To conform to APRG – Report 21	To conform to APRG – Report 21
Base Course	To conform to APRG – Report 21 Soaked CBR ≥ 80%, PI ≤ 6%	Minimum dry density ratio of 98% Modified (AS 1289 Test 5.2.1)
Sub-base Course	To conform to APRG – Report 21 Soaked CBR ≥ 30%, PI ≤ 12%	Minimum dry density ratio of 95% Modified (AS 1289 Test 5.2.1)
Subgrade Replacement	Soaked CBR ≥ 20%	Minimum dry density ratio of 100% Standard (AS 1289 Test 5.1.1)
Subgrade	-	Minimum dry density ratio of 100% Standard (AS 1289 Test 5.1.1)

Where PI = plasticity index

Whilst the use of lesser quality pavement materials than that detailed in Table 5 may be feasible, some compromise in either performance and/or pavement life must be anticipated and accepted. It is also suggested that advice be sought from Council if lesser quality pavement materials are proposed.

6.5.2 Drainage

Surface and subsurface drainage should be installed and maintained to protect the pavement and subgrade. The subsurface drains should be located at a minimum of 0.5 m depth below the excavation level. Guidelines on the arrangement of subsurface drainage is given on Page 20 of ARRB – SR41 (Ref 7). It should be noted that if the sub-base is of low permeability relative to the base layer, then the subsurface drain must intersect all pavement layers as shown in ARRB – SR41.

6.6 Salinity Assessment

The following sub-sections discuss the implications of the laboratory test results to salinity potential.

pH: DIPNR (formerly Department of Land and Water Conservation, DLWC) classify neutral soils as those with a 1:5 soil:water extract pH in the range 6.6 – 7.3, acid soils as those having a pH of below 6.6 and alkaline soils as having a pH greater than 7.3. Plant growth is usually sustained with a pH in the range 5.5 – 8. In strongly acidic soils (ie: below pH 5.5), metals are more readily available to plants, potentially reaching toxic levels (to plants) and some nutrients become unavailable. At pH levels above 8, molybdenum becomes more readily available and nutrients including iron, copper and zinc become less available. Surface samples X1 and X2 had pH levels within the 5.5 – 8 range and as such, can be considered to be within the ideal range to promote plant growth.

Electrical Conductivity: According to CALM (Ref 8), electrical conductivity (ECe) values below 2 dS/m are classified as *"non-saline"*, 2 – 4 dS/m as *"slightly saline"* and 4 – 8 dS/m as *"moderately saline"*. The soil sample tested indicated *"non-saline"* conditions and as such, the results of the limited testing completed to date indicate a low salinity potential.

6.7 Site Contamination

Based on our visual inspection of the site, no obvious signs of site contamination were observed. It is noted however, that the site was heavily grassed in parts at the time of the inspection potentially covering signs of contamination and that the investigation undertaken was for preliminary purposes only. Notwithstanding that, it is anticipated that the silty clays and weathered rock would probably be classified as Virgin Excavated Natural Material (VENM) on the provision it is not mixed with other material. A detailed site inspection and soil sampling/testing will be required to confirm the waste classification of the soil prior to construction.

6.8 Summary

The preliminary site assessment has indicated that the site is suitable for residential development with comments given on salinity potential, likely lot classification, stability and pavement thicknesses. Conceptual comments on design and construction aspects are also given in the report. Further testing and assessment will be required as the design of the subdivision proceeds and as such, this report must be considered as being preliminary in nature.

7. LIMITATIONS

This report has been prepared for the exclusive use of Site Plus Pty Ltd for specific application to a proposed residential subdivision of Lots 35 and 36 in DP 878862 located of Murray Jackson Drive at Talbingo. This report's conclusions or recommendations may not necessarily apply if the nature, design or location of the proposed development is changed. If changes are contemplated, DP should review them to assess their impact on this report's applicability.

DOUGLAS PARTNERS PTY LTD

For:
Michael J Jones
Associate

Reviewed by:

G W McIntosh
Managing Principal

References:

1. Geology of Wagga Wagga 1:250 000 Geological Series Sheet S1 55-15, NSW Dept of Mines, (1966).
2. Site Investigation for Urban Salinity, DLWC (2002).
3. Australian Standard AS 2870 – 1996 *Residential Slabs and Footings.*
4. AGS – Landslide Risk Management Concepts and Guidelines, Australian Geomechanics Society, Sub-committee on Landslide Risk Management, 2000.
5. Australian Standard AS 3798 – 1996 *Guidelines on Earthworks for Commercial and Residential Developments.*
6. APRG – Report No 21 – *A Guide to the Design of New Pavements for Light Traffic*, Austroads Pavement Research Group, 1997.
7. ARRB – SR41 – A Structural Design Guide for Flexible Residential Street Pavements, Australian Road Research Board, Special Report No. 41, 1989.
8. CALM, "What do all the numbers mean?" (1992).

APPENDIX A

Notes Relating to This Report
Photoplates
Laboratory Test Report Sheets
CSIRO Publication
AGS Extract
Drawing 1

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NOTES RELATING TO THIS REPORT

Introduction

These notes have been provided to amplify the geotechnical report in regard to classification methods, specialist field procedures and certain matters relating to the Discussion and Comments section. Not all, of course, are necessarily relevant to all reports.

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

Description and Classification Methods

The methods of description and classification of soils and rocks used in this report are based on Australian Standard 1726, Geotechnical Site Investigations Code. In general, descriptions cover the following properties - strength or density, colour, structure, soil or rock type and inclusions.

Soil types are described according to the predominating particle size, qualified by the grading of other particles present (eg. sandy clay) on the following bases:

Soil Classification	Particle Size
Clay	less than 0.002 mm
Silt	0.002 to 0.06 mm
Sand	0.06 to 2.00 mm
Gravel	2.00 to 60.00 mm

Cohesive soils are classified on the basis of strength either by laboratory testing or engineering examination. The strength terms are defined as follows.

Classification	Undrained Shear Strength kPa
Very soft	less than 12
Soft	12—25
Firm	25—50
Stiff	50—100
Very stiff	100—200
Hard	Greater than 200

Non-cohesive soils are classified on the basis of relative density, generally from the results of standard penetration tests (SPT) or Dutch cone penetrometer tests (CPT) as below:

Relative Density	SPT "N" Value (blows/300 mm)	CPT Cone Value (q_c — MPa)
Very loose	less than 5	less than 2
Loose	5—10	2—5
Medium dense	10—30	5—15
Dense	30—50	15—25
Very dense	greater than 50	greater than 25

Rock types are classified by their geological names. Where relevant, further information regarding rock classification is given on the following sheet.

Sampling

Sampling is carried out during drilling to allow engineering examination (and laboratory testing where required) of the soil or rock.

Disturbed samples taken during drilling provide information on colour, type, inclusions and, depending upon the degree of disturbance, some information on strength and structure.

Undisturbed samples are taken by pushing a thin-walled sample tube into the soil and withdrawing with a sample of the soil in a relatively undisturbed state. Such samples yield information on structure and strength, and are necessary for laboratory determination of shear strength and compressibility. Undisturbed sampling is generally effective only in cohesive soils.

Details of the type and method of sampling are given in the report.

Drilling Methods.

The following is a brief summary of drilling methods currently adopted by the Company and some comments on their use and application.

Test Pits — these are excavated with a backhoe or a tracked excavator, allowing close examination of the in-situ soils if it is safe to descent into the pit. The depth of penetration is limited to about 3 m for a backhoe and up to 6 m for an excavator. A potential disadvantage is the disturbance caused by the excavation.

Large Diameter Auger (eg. Pengo) — the hole is advanced by a rotating plate or short spiral auger, generally 300 mm or larger in diameter. The cuttings are returned to the surface at intervals (generally of not more than 0.5 m) and are disturbed but usually unchanged in moisture content. Identification of soil strata is generally much more reliable than with continuous spiral flight augers, and is usually supplemented by occasional undisturbed tube sampling.

Continuous Sample Drilling — the hole is advanced by pushing a 100 mm diameter socket into the ground and withdrawing it at intervals to extrude the sample. This is the most reliable method of drilling in soils, since moisture content is unchanged and soil structure, strength, etc. is only marginally affected.

Continuous Spiral Flight Augers — the hole is advanced using 90—115 mm diameter continuous spiral flight augers which are withdrawn at intervals to allow sampling or in-situ testing. This is a relatively economical means of drilling in clays and in sands above the water table. Samples are returned to the surface, or may be collected after withdrawal of the auger flights, but they are very disturbed and may be contaminated. Information from the drilling (as distinct from specific sampling by SPTs or undisturbed samples) is of relatively lower reliability, due to remoulding, contamination or softening of samples by ground water.

Non-core Rotary Drilling — the hole is advanced by a rotary bit, with water being pumped down the drill rods and returned up the annulus, carrying the drill cuttings. Only major changes in stratification can be determined from the cuttings, together with some information from 'feel' and rate of penetration.

Rotary Mud Drilling — similar to rotary drilling, but using drilling mud as a circulating fluid. The mud tends to mask the cuttings and reliable identification is again only possible from separate intact sampling (eg. from SPT).

Continuous Core Drilling — a continuous core sample is obtained using a diamond-tipped core barrel, usually 50 mm internal diameter. Provided full core recovery is achieved (which is not always possible in very weak rocks and granular soils), this technique provides a very reliable (but relatively expensive) method of investigation.

Standard Penetration Tests

Standard penetration tests (abbreviated as SPT) are used mainly in non-cohesive soils, but occasionally also in cohesive soils as a means of determining density or strength and also of obtaining a relatively undisturbed sample. The test procedure is described in Australian Standard 1289, "Methods of Testing Soils for Engineering Purposes" — Test 6.3.1.

The test is carried out in a borehole by driving a 50 mm diameter split sample tube under the impact of a 63 kg hammer with a free fall of 760 mm. It is normal for the tube to be driven in three successive 150 mm increments and the 'N' value is taken as the number of blows for the last 300 mm. In dense sands, very hard clays or weak rock, the full 450 mm penetration may not be practicable and the test is discontinued.

The test results are reported in the following form.

- In the case where full penetration is obtained with successive blow counts for each 150 mm of say 4, 6 and 7

  as 4, 6, 7
  N = 13

- In the case where the test is discontinued short of full penetration, say after 15 blows for the first 150 mm and 30 blows for the next 40 mm

  as 15, 30/40 mm.

The results of the tests can be related empirically to the engineering properties of the soil.

Occasionally, the test method is used to obtain samples in 50 mm diameter thin walled sample tubes in clays. In such circumstances, the test results are shown on the borelogs in brackets.

Cone Penetrometer Testing and Interpretation

Cone penetrometer testing (sometimes referred to as Dutch cone — abbreviated as CPT) described in this report has been carried out using an electrical friction cone penetrometer. The test is described in Australian Standard 1289, Test 6.4.1.

In the tests, a 35 mm diameter rod with a cone-tipped end is pushed continuously into the soil, the reaction being provided by a specially designed truck or rig which is fitted with an hydraulic ram system. Measurements are made of the end bearing resistance on the cone and the friction resistance on a separate 130 mm long sleeve, immediately behind the cone. Transducers in the tip of the assembly are connected by electrical wires passing through the centre of the push rods to an amplifier and recorder unit mounted on the control truck.

As penetration occurs (at a rate of approximately 20 mm per second) the information is plotted on a computer screen and at the end of the test is stored on the computer for later plotting of the results.

The information provided on the plotted results comprises: —

- Cone resistance — the actual end bearing force divided by the cross sectional area of the cone — expressed in MPa.
- Sleeve friction — the frictional force on the sleeve divided by the surface area — expressed in kPa.
- Friction ratio — the ratio of sleeve friction to cone resistance, expressed in percent.

There are two scales available for measurement of cone resistance. The lower scale (0—5 MPa) is used in very soft soils where increased sensitivity is required and is shown in the graphs as a dotted line. The main scale (0—50 MPa) is less sensitive and is shown as a full line.

The ratios of the sleeve friction to cone resistance will vary with the type of soil encountered, with higher relative friction in clays than in sands. Friction ratios of 1%—2% are commonly encountered in sands and very soft clays rising to 4%—10% in stiff clays.

In sands, the relationship between cone resistance and SPT value is commonly in the range:—

$$q_c \text{ (MPa)} = (0.4 \text{ to } 0.6) \text{ N (blows per 300 mm)}$$

In clays, the relationship between undrained shear strength and cone resistance is commonly in the range:—

$$q_c = (12 \text{ to } 18)\ c_u$$

Interpretation of CPT values can also be made to allow estimation of modulus or compressibility values to allow calculation of foundation settlements.

Inferred stratification as shown on the attached reports is assessed from the cone and friction traces and from experience and information from nearby boreholes, etc. This information is presented for general guidance, but must be regarded as being to some extent interpretive. The test method provides a continuous profile of engineering properties, and where precise information on soil classification is required, direct drilling and sampling may be preferable.

Hand Penetrometers

Hand penetrometer tests are carried out by driving a rod into the ground with a falling weight hammer and measuring the blows for successive 150 mm increments of penetration. Normally, there is a depth limitation of 1.2 m but this may be extended in certain conditions by the use of extension rods.

Two relatively similar tests are used.

- Perth sand penetrometer — a 16 mm diameter flat-ended rod is driven with a 9 kg hammer, dropping 600 mm (AS 1289, Test 6.3.3). This test was developed for testing the density of sands (originating in Perth) and is mainly used in granular soils and filling.
- Cone penetrometer (sometimes known as the Scala Penetrometer) — a 16 mm rod with a 20 mm diameter cone end is driven with a 9 kg hammer dropping 510 mm (AS 1289, Test 6.3.2). The test was developed initially for pavement subgrade investigations, and published correlations of the test results with California bearing ratio have been published by various Road Authorities.

Laboratory Testing

Laboratory testing is carried out in accordance with Australian Standard 1289 "Methods of Testing Soil for Engineering Purposes". Details of the test procedure used are given on the individual report forms.

Bore Logs

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

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

Ground Water

Where ground water levels are measured in boreholes, there are several potential problems;

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

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

Engineering Reports

Engineering reports are prepared by qualified personnel and are based on the information obtained and on current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal (eg. a three storey building), the information and interpretation may not be relevant if the design proposal is changed (eg. to a twenty storey building). If this happens, the Company will be pleased to review the report and the sufficiency of the investigation work.

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

- unexpected variations in ground conditions — the potential for this will depend partly on bore spacing and sampling frequency
- changes in policy or interpretation of policy by statutory authorities
- the actions of contractors responding to commercial pressures.

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

Site Anomalies

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

Reproduction of Information for Contractual Purposes

Attention is drawn to the document "Guidelines for the Provision of Geotechnical Information in Tender Documents", published by the Institution of Engineers, Australia. Where information obtained from this investigation is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a specially edited document. The Company would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Site Inspection

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

PHOTO 1

PHOTO 2

TITLE	PROJECT	
Proposed Residential Subdivision Talbingo Village, TALBINGO	40569	Douglas Partners Geotechnics · Environment · Groundwater

PHOTO 3

PHOTO 4

TITLE	PROJECT	
Proposed Residential Subdivision Talbingo Village, TALBINGO	40569	Douglas Partners Geotechnics · Environment · Groundwater

PHOTO 5

PHOTO 6

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PHOTO 10

TITLE Proposed Residential Subdivision Talbingo Village, TALBINGO	PROJECT 40569	Douglas Partners Geotechnics · Environment · Groundwater

PHOTO 11

PHOTO 12

TITLE	PROJECT	
Proposed Residential Subdivision Talbingo Village, TALBINGO	40569	Douglas Partners Geotechnics · Environment · Groundwater

PHOTO 13

PHOTO 14

TITLE	PROJECT	
Proposed Residential Subdivision Talbingo Village, TALBINGO	40569	Douglas Partners Geotechnics - Environment - Groundwater

PHOTO 15

PHOTO 16

TITLE	PROJECT	
Proposed Residential Subdivision Talbingo Village, TALBINGO	40569	Douglas Partners Geotechnics · Environment · Groundwater

PHOTO 17

PHOTO 18

TITLE	PROJECT	
Proposed Residential Subdivision Talbingo Village, TALBINGO	40569	Douglas Partners Geotechnics · Environment · Groundwater

PHOTO 19

PHOTO 20

TITLE	PROJECT	
Proposed Residential Subdivision Talbingo Village, TALBINGO	40569	Douglas Partners Geotechnics · Environment · Groundwater

PHOTO 21

PHOTO 22

TITLE	PROJECT	
Proposed Residential Subdivision Talbingo Village, TALBINGO	40569	Douglas Partners Geotechnics · Environment · Groundwater

Corrosion & Scaling Assessment:
Soil Reporting Profile

Test Type I pHEC,SO4,Cl,EAT
Order No Job No: 40569
Reference Talbingo
Sample Name #1
Sample No. 96449
Date Received 22/03/2006 Total No Pages: 1 of 1
Client: Douglas Partners (Wollongong)
Michael Jones
PO Box 486
UNANDERRA NSW 2526

Quality System
Quality Endorsed Company
ISO 9001
Lic QEC21650
SAI Global

Sydney Environmental and Soil Laboratory
Specialists in Soil Chemistry, Agronomy and Contamination Assessments

Sydney Environmental & Soil Laboratory Pty Ltd
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Web: www.sesl.com.au

Tests are performed under a quality system certified as complying with ISO 9002.
Results & Conclusions assume that sampling is representative. This document shall not be reproduced except in full

TEST	RESULT	COMMENTS
pH in water (1:2)	5.8	medium acidity
EC mS/cm (1:2)	0.05	very low salt content
Texture Class		
Soil Permeability Class		
SOLUBLE ANION ANALYSIS		
Sulphate (1:2) $mgSO_4$ / kg	100	low, non-aggressive towards concrete
Chloride (1:2) mgCl / kg	20	low, non-corrosive towards steel
* Resistivity Ω.m		

* Resistivity tested on a saturated sample/paste (Note:- 10,000 mg/L = 1%)

Recommendations

Emerson Stability Class (H20): 7

This soil has medium acidity with a very low salt content. The acidity is considered mildly to non-aggressive towards concrete, and non-aggressive towards steel. To be more specific a soil permeability class needs to be assigned. The acidity should be treated with 300 g/sqm of lime incorporated into the surface 150 mm of the soil.

The chloride and sulfate levels are low and non-aggressive towards concrete and steel.

The Emerson Stability Class indicates the most stable classes of aggregates. Very few erosion problems, but swelling aggregates can be mechanically weak and should not be trafficked or ploughed when at or above field capacity.

Explanation of the Methods:
pH, EC, Soluble SO_4: Bradley et al., (1983); **Cl**, (4500-Cl- E; APHA, 1998); **Texture Class,** AS2159:1995; **Resistivity,** AS1289.4.4.1:1997.

Checked by .... Consultant ....

M. Fraser Date of Report 06/04/2006 S. Crook

Corrosion & Scaling Assessment:
Soil Reporting Profile

Test Type I pHEC,SO4,Cl,EAT
Order No Job No: 40569
Reference Talbingo
Sample Name #2
Sample No. 96450
Date Received 22/03/2006 Total No Pages: 1 of 1
Client: Douglas Partners (Wollongong)
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PO Box 486
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TEST	RESULT	COMMENTS
pH in water (1:2)	6.1	slight acidity
EC mS/cm (1:2)	0.16	low salt content
Texture Class		
Soil Permeability Class		
SOLUBLE ANION ANALYSIS		
Sulphate (1:2) $mgSO_4$ / kg	190	low, non-aggressive towards concrete
Chloride (1:2) mgCl / kg	40	low, non-corrosive towards steel
* Resistivity Ω.m		

* Resistivity tested on a saturated sample/paste (Note:- 10,000 mg/L = 1%)

Recommendations

Emerson Stability Class (H20): 7

This soil has slight acidity with a low salt content. The acidity is considered mildly to non-aggressive towards concrete, and non-aggressive towards steel. To be more specific a soil permeability class needs to be assigned. The acidity should be treated with 200 g/sqm of lime incorporated into the surface 150 mm of the soil.

The chloride and sulfate levels are low and non-aggressive towards concrete and steel.

The Emerson Stability Class indicates the most stable classes of aggregates. Very few erosion problems, but swelling aggregates can be mechanically weak and should not be trafficked or ploughed when at or above field capacity.

Explanation of the Methods:
pH, EC, Soluble SO₄ Bradley et al., (1983); **Cl,** (4500-Cl- E; APHA, 1998); **Texture Class,** AS2159:1995; **Resistivity,** AS1289.4.4.1:1997.

Checked by ....

M. Fraser Date of Report 06/04/2006

Consultant ....
S. Crook

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).

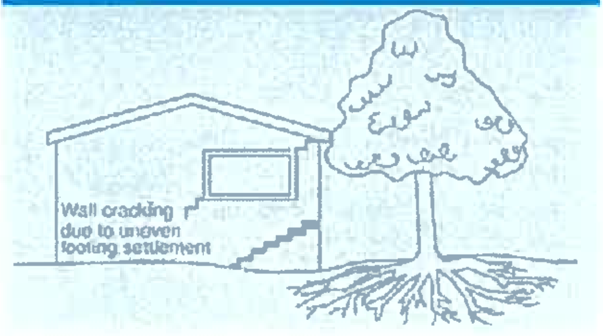
Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

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.

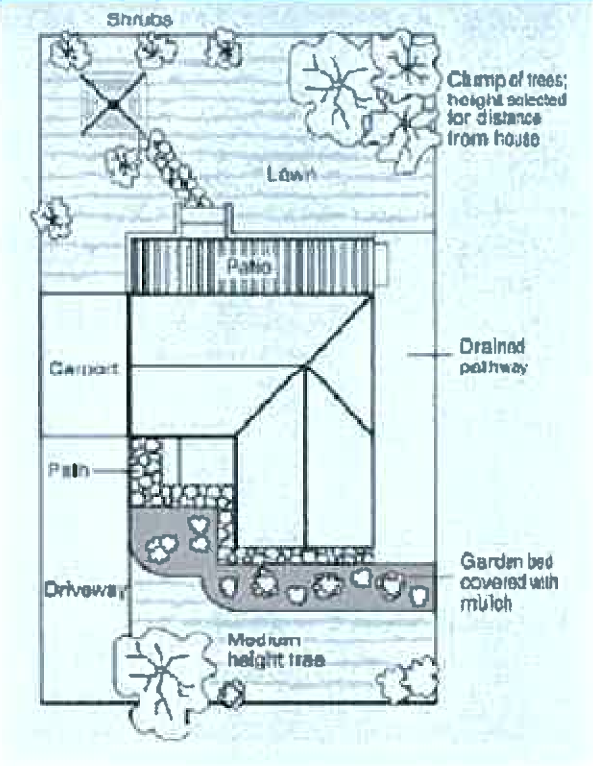
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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.

This BTF was prepared by John Lewer FAIB, MIAMA, Partner, Construction Diagnosis.

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APPENDIX G

LANDSLIDE RISK ASSESSMENT – EXAMPLE OF QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY

Qualitative Measures of Likelihood

Level	Descriptor	Description	Indicative Annual Probability
A	ALMOST CERTAIN	The event is expected to occur	$>\approx 10^{-1}$
B	LIKELY	The event will probably occur under adverse conditions	$\approx 10^{-2}$
C	POSSIBLE	The event could occur under adverse conditions	$\approx 10^{-3}$
D	UNLIKELY	The event might occur under very adverse circumstances	$\approx 10^{-4}$
E	RARE	The event is conceivable but only under exceptional circumstances.	$\approx 10^{-5}$
F	NOT CREDIBLE	The event is inconceivable or fanciful	$<10^{-6}$

Note: "≈" means that the indicative value may vary by say ± ½ of an order of magnitude, or more

Qualitative Measures of Consequences to Property

Level	Descriptor	Description
1	CATASTROPHIC	Structure completely destroyed or large scale damage requiring major engineering works for stabilisation.
2	MAJOR	Extensive damage to most of structure, or extending beyond site boundaries requiring significant stabilisation works.
3	MEDIUM	Moderate damage to some of structure, or significant part of site requiring large stabilisation works.
4	MINOR	Limited damage to part of structure, or part of site requiring some reinstatement/stabilisation works.
5	INSIGNIFICANT	Little damage.

Note: The "Description" may be edited to suit a particular case.

Qualitative Risk Analysis Matrix – Level of Risk to Property

LIKELIHOOD	CONSEQUENCES to PROPERTY				
	1: CATASTROPHIC	2: MAJOR	3: MEDIUM	4: MINOR	5: INSIGNIFICANT
A – ALMOST CERTAIN	VH	VH	H	H	M
B – LIKELY	VH	H	H	M	L-M
C – POSSIBLE	H	H	M	L-M	VL-L
D – UNLIKELY	M-H	M	L-M	VL-L	VL
E – RARE	M-L	L-M	VL-L	VL	VL
F – NOT CREDIBLE	VL	VL	VL	VL	VL

Risk Level Implications

Risk Level		Example Implications(1)
VH	VERY HIGH RISK	Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to acceptable levels; may be too expensive and not practical
H	HIGH RISK	Detailed investigation, planning and implementation of treatment options required to reduce risk to acceptable levels
M	MODERATE RISK	Tolerable provided treatment plan is implemented to maintain or reduce risks. May be accepted. May require investigation and planning of treatment options.
L	LOW RISK	Usually accepted. Treatment requirements and responsibility to be defined to maintain or reduce risk.
VL	VERY LOW RISK	Acceptable. Manage by normal slope maintenance procedures.

Note: (1) The implications for a particular situation are to be determined by all parties to the risk assessment, these are only given as a general guide

(2) Judicious use of dual descriptors for Likelihood, Consequence and Risk to reflect the uncertainty of the estimate may be appropriate in some cases

APPENDIX J

SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

	GOOD ENGINEERING PRACTICE	POOR ENGINEERING PRACTICE
ADVICE		
GEOTECHNICAL ASSESSMENT	Obtain advice from a qualified, experienced geotechnical consultant at early stage of planning and before site works.	Prepare detailed plan and start site works before geotechnical advice
PLANNING		
SITE PLANNING	Having obtained geotechnical advice, plan the development with the risk arising from the identified hazards and consequences in mind.	Plan development without regard for the Risk
DESIGN AND CONSTRUCTION		
HOUSE DESIGN	Use flexible structures which incorporate properly designed brickwork, timber or steel frames, timber or panel cladding. Consider use of split levels. Use decks for recreational areas where appropriate	Floor plans which require extensive cutting and filling. Movement intolerant structures.
SITE CLEARING	Retain natural vegetation wherever practicable.	Indiscriminately clear the site
ACCESS & DRIVEWAYS	Satisfy requirements below for cuts, fills, retaining walls and drainage. Council specifications for grades may need to be modified. Driveways and parking areas may need to be fully supported on piers.	Excavate and fill for site access before geotechnical advice.
EARTHWORKS	Retain natural contours wherever possible.	Indiscriminant bulk earthworks.
CUTS	Minimise depth. Support with engineered retaining walls or batter to appropriate slope. Provide drainage measures and erosion control.	Large scale cuts and benching. Unsupported cuts. Ignore drainage requirements
FILLS	Minimise height. Strip vegetation and topsoil and key into natural slopes prior to filling. Use clean fill materials and compact to engineering standards. Batter to appropriate slope or support with engineered retaining wall. Provide surface drainage and appropriate subsurface drainage.	Loose or poorly compacted fill, which if it fails, may flow a considerable distance including onto property below. Block natural drainage lines. Fill over existing vegetation and topsoil. Include stumps, trees, vegetation, topsoil, boulders, building rubble etc in fill.
ROCK OUTCROPS & BOULDERS	Remove or stabilise boulders which may have unacceptable risk. Support rock faces where necessary.	Disturb or undercut detached blocks or boulders.
RETAINING WALLS	Engineer design to resist applied soil and water forces. Found on rock where practicable. Provide subsurface drainage within wall backfill and surface drainage on slope above. Construct wall as soon as possible after cut/fill operation.	Construct a structurally inadequate wall such as sandstone flagging, brick or unreinforced blockwork. Lack of subsurface drains and weepholes.
FOOTINGS	Found within rock where practicable. Use rows of piers or strip footings oriented up and down slope. Design for lateral creep pressures if necessary. Backfill footing excavations to exclude ingress of surface water.	Found on topsoil, loose fill, detached boulders or undercut cliffs.
SWIMMING POOLS	Engineer designed. Support on piers to rock where practicable. Provide with under-drainage and gravity drain outlet where practicable. Design for high soil pressures which may develop on uphill side whilst there may be little or no lateral support on downhill side.	
DRAINAGE		
SURFACE	Provide at tops of cut and fill slopes. Discharge to street drainage or natural water courses. Provide general falls to prevent blockage by siltation and incorporate silt traps. Line to minimise infiltration and make flexible where possible. Special structures to dissipate energy at changes of slope and/or direction.	Discharge at top of fills and cuts. Allow water to pond on bench areas.
SUBSURFACE	Provide filter around subsurface drain. Provide drain behind retaining walls. Use flexible pipelines with access for maintenance. Prevent inflow of surface water.	Discharge roof runoff into absorption trenches.
SEPTIC & SULLAGE	Usually requires pump-out or mains sewer systems; absorption trenches may be possible in some areas if risk is acceptable. Storage tanks should be water-tight and adequately founded.	Discharge sullage directly onto and into slopes. Use absorption trenches without consideration of landslide risk.
EROSION CONTROL & LANDSCAPING	Control erosion as this may lead to instability. Revegetate cleared area.	Failure to observe earthworks and drainage recommendations when landscaping.
DRAWINGS AND SITE VISITS DURING CONSTRUCTION		
DRAWINGS	Building Application drawings should be viewed by geotechnical consultant	
SITE VISITS	Site Visits by consultant may be appropriate during construction/	
INSPECTION AND MAINTENANCE BY OWNER		
OWNER'S RESPONSIBILITY	Clean drainage systems; repair broken joints in drains and leaks in supply pipes. Where structural distress is evident see advice. If seepage observed, determine causes or seek advice on consequences.	

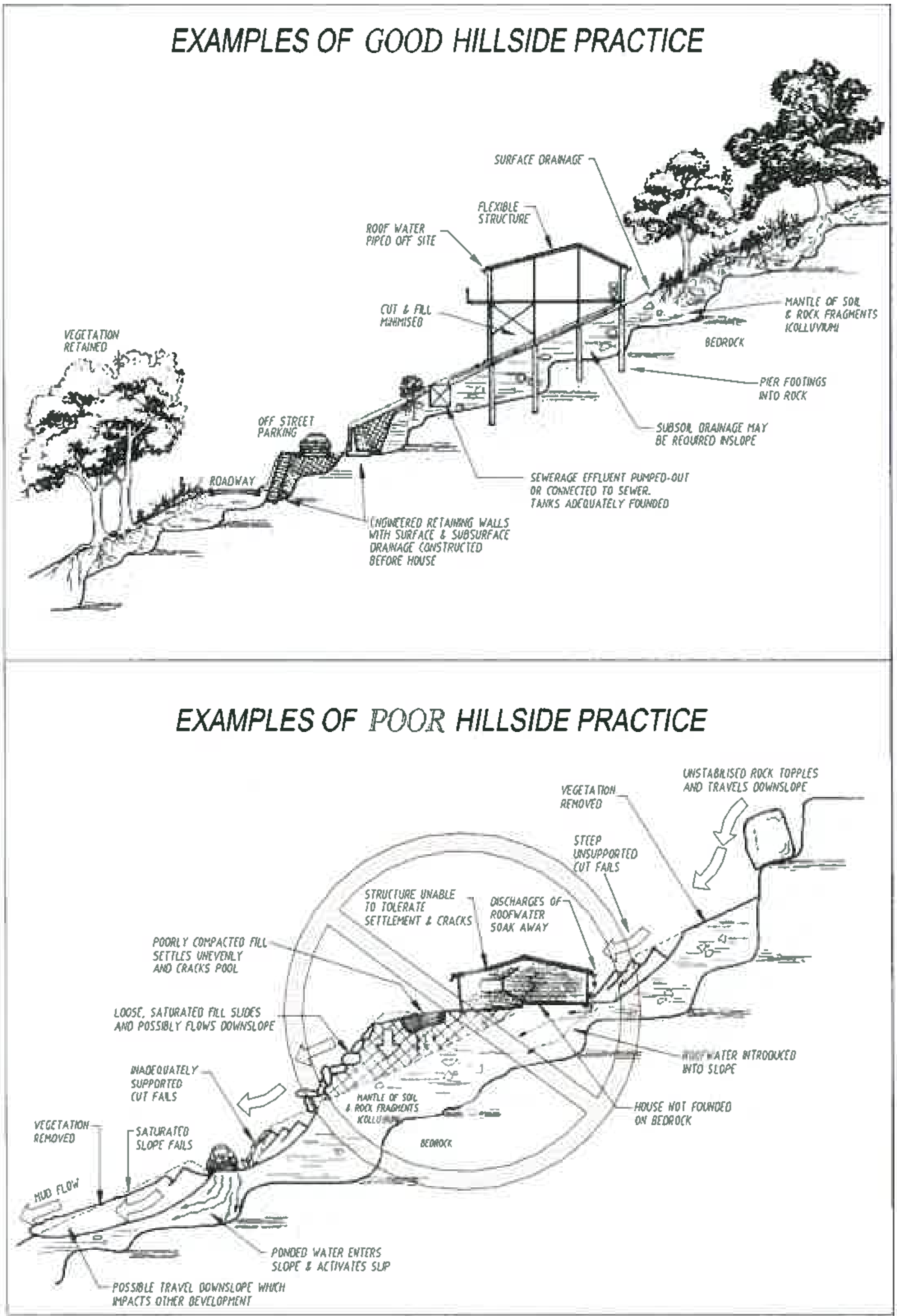
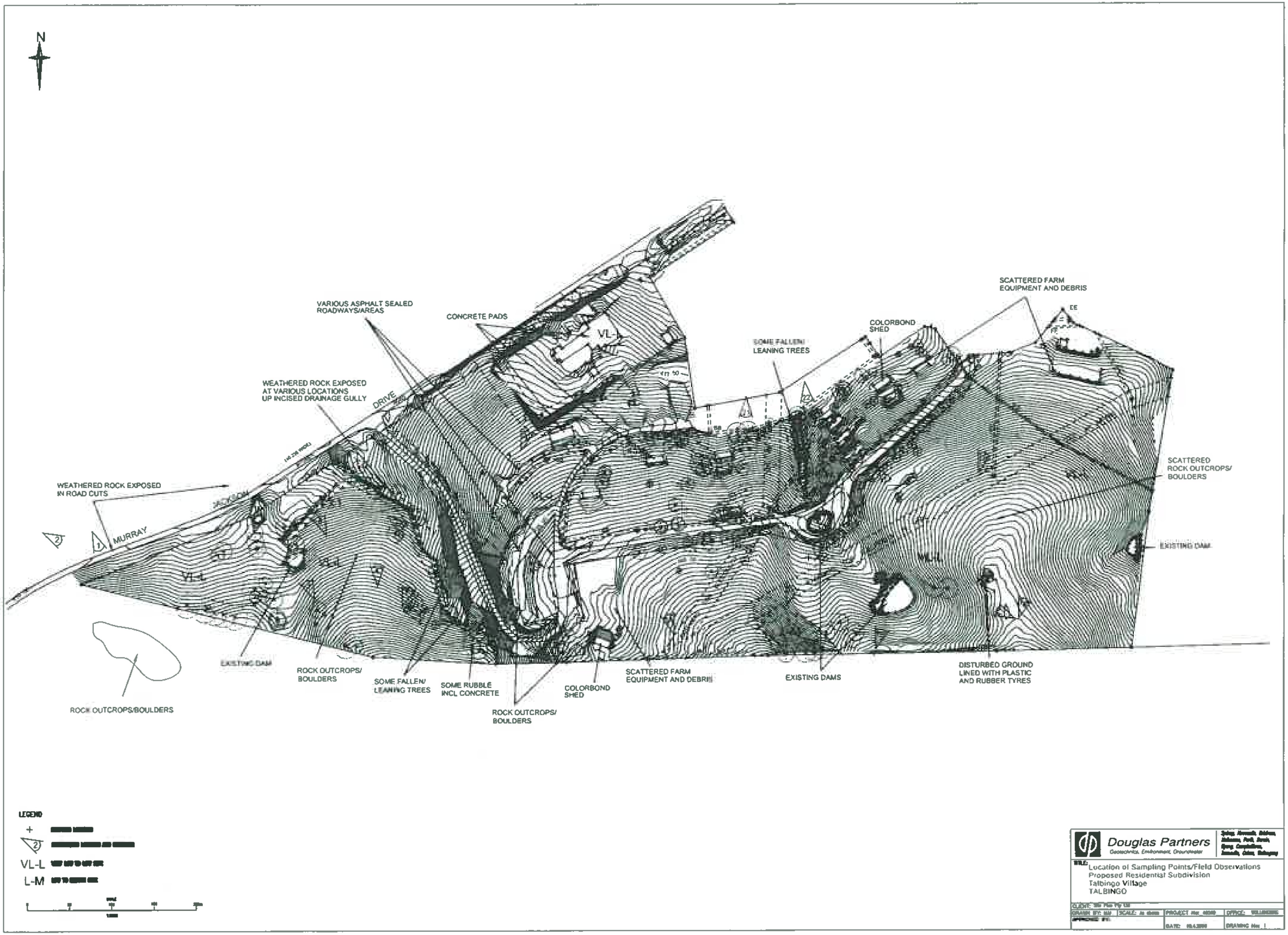


Figure J1 Illustrations of Good and Poor Hillside Practice



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