Beveridge North West Precinct Structure Plan – Background Report – A critique

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Introduction

The Victorian Planning Authority has released its Beveridge North West Precinct Structure Plan – Background Report (BNWPSP) which is a summary of various studies conducted by various consultants for discussion by stakeholders. The report deals with various aspects of the planned development of the land within the BNWPSP for residential, commercial and other purposes, which all are part of the overall Northern Growth Strategy.

It is remarkable that amongst all of the aspects of the planning discussed in the report, no space or attention is given to the physical nature of the land, the physical environment. It is as if the land is merely a passive and benign base upon which mankind can construct whatever it wants and the immediate and receiving environments are not affected in any way and cannot or will not react to the construction of roads, services, drainage systems, homes and shopping centres. Clearly, the environment has not been a pillar in the planning of land use changes and construction of new community structures.

The BNWPSP is located in the northern part of the catchment of Kalkallo Creek, with the western 50% situated in elevated ridges based on Silurian sedimentary rocks and confined in the north and east by volcanic deposits, basalt, scoria, volcanic ash, etc., and the southern limit largely located in these same volcanic deposits. The lavas, scoria, bombs and rocks ejected by the volcanic cones in the area and nearby, covered parts of the surrounding land at different times. Individual larval flows have age differences of tens of thousands of years and hence their typical soil suites differ significantly in length of time they were exposed to weathering and soil formation. The soil suites developed on these variously aged flows differ in major ways and this has to be taken into account in planning land use.

Keith Grant, working for the CSIRO Division of Applied Geomechanics, mapped all the terrains that had formed on geological parent material for the entire area covered by the Melbourne 1:250,000 topographic map and his report was published in 1972. Recent volcanic deposits, Tertiary and Quaternary basalts, also known as Younger Basalts, cover very large areas in the Melbourne map sheet Within the BNWPSP area, Grant distinguished four kinds of volcanic terrain, lavas and two kinds of terrain on sedimentary rock, Silurian sandstones and mudstones (Yellow marked map units in Figure 1).

Peter Jeffery, working for the Victorian Soil Conservation Authority, mapped the area in somewhat greater detail with respect to soil types, also at scale 1:250,000. This report was published in 1981. A part of his map that includes the BNWPSP is shown as Figure 2.

PROVINCE No. 52.009

AGE: Tertiary - Quaternary
GROUP: Younger Basalt
LITHOLOGY: Basalt, minor tuff, scoria, solvsbergite, trachyte, phonolite

Terrain Pattern No.	Topography	Rock Condition	Earthen Materials Profile	Land use	Vegetation
0 TOPOGRAPHY: Flat to gently undulating					
01	Flat to gently undulating terrain	Crystalline (basalt)	Uniform dark grey heavy-textured expansive clay	Urban development, pasture or agriculture	Built up, grassland, or cultivated
01/2	Flat to gently undulating terrain	Crystalline (basalt)	Duplex red-brown silty clay over heavy-textured clay	Pasture or agriculture	Grassland or cultivated
02	Irregular basalt flows with associated swamps	Crystalline (basalt)	Uniform dark grey shallow heavy-textured expansive clay, much rock outcrop	Pasture, some urban development near Melbourne	Savannah woodland or built up
02/2	Irregular basalt flows with associated swamps	Crystalline (basalt)	Duplex red-brown shallow silty clay over heavy-textured clay, much rock outcrop	Pasture	Grassland
1 TOPOGRAPHY: Undulating terrain					
12	Undulating slightly dissected terrain	Crystalline (basalt)	Uniform dark grey heavy-textured expansive clay	Pasture or agriculture	Grassland or cultivated
12/2	Undulating slightly dissected terrain	Crystalline (basalt)	Uniform or gradational deep red heavy-textured clay or duplex dark brown silty clay over heavy-textured clay	Agriculture or pasture	Cultivated or grassland
2 TOPOGRAPHY: Low volcanic vents					
22	Isolated lava volcanic hills	Crystalline (basalt, minor trachyte, phonolite, solvsbergite)	Mostly rock outcrop	Pasture	Grassland
22/2	Isolated scoria volcanic hills	Semi-consolidated or unconsolidated (scoria)	Uniform or gradational red-brown silty clay over heavy-textured clay over scoria	Pasture or recreation	Grassland
24	Undulating slightly dissected terrain	Crystalline (trachyte, phonolite, solvsbergite)	Uniform dark grey-brown clayey silt or gradational red silty clay over heavy-textured clay	Pasture or agriculture	Grassland or cultivated
3 TOPOGRAPHY: Volcanic plugs					
32	Dissected mamelons	Crystalline (solvsbergite)	Mostly rock outcrop	Unused	Open woodland

Figure 1 Full list of terrain patterns on the Younger Basalts. Yellow marked patterns occur in the Precinct area.

Grant’s field work missed the different-ages of the basalt flows that Jeffery identified later, with the westerly most basalt flow having developed dark grey heavy clays and the easterly flow, which must be much younger in age, having red stony clay soils.

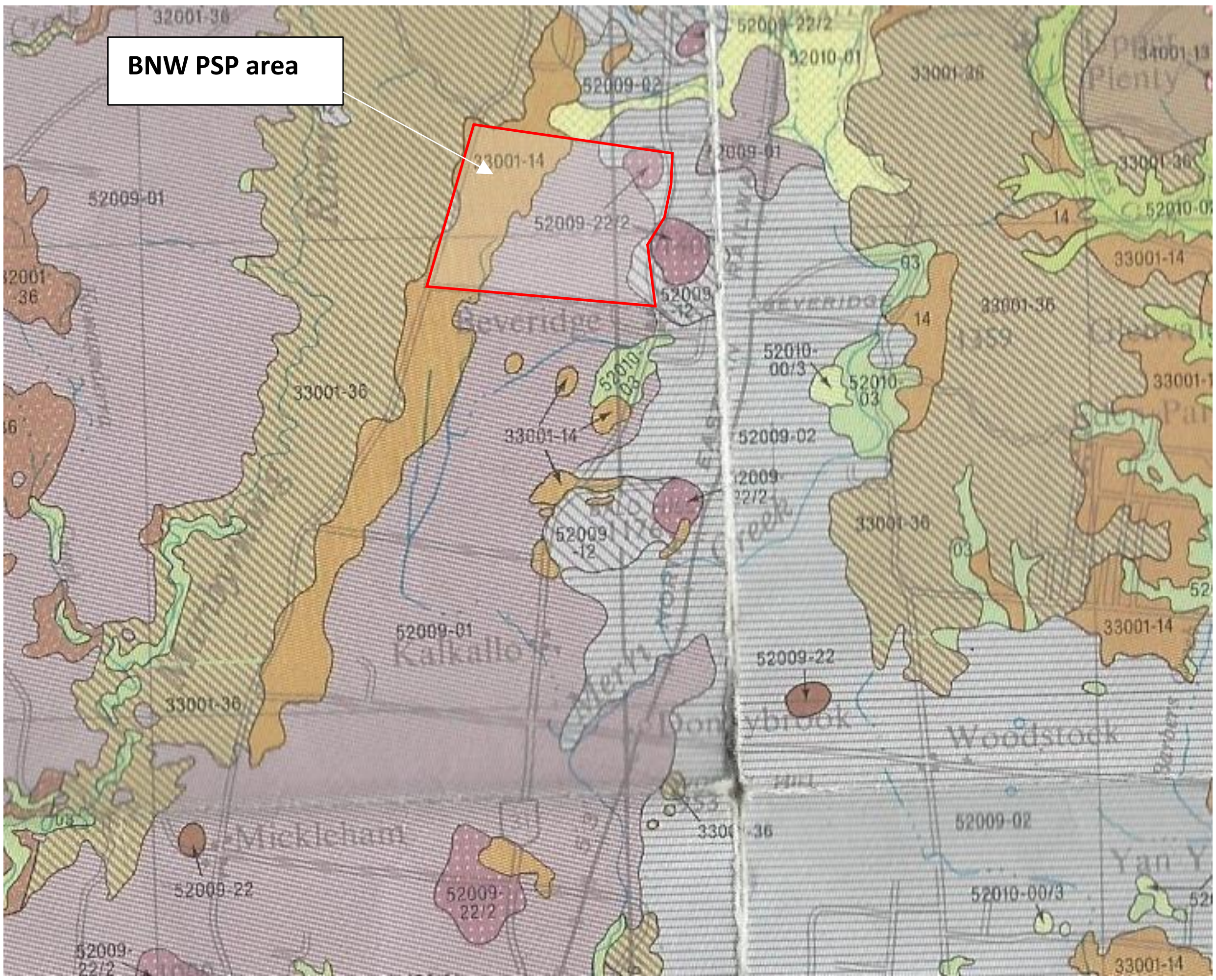

Figure 2 Basalt land patterns 52009-x in and around the BNWPSP. The land patterns having the number 33001-x are all on Silurian sedimentary rocks. Patterns with 52010-x represent Recent alluvial deposits.

The Land System survey by Jeffery paid a great deal more attention to the soil and native vegetation that characterised the Land Units that make up a Land System than Grant did. The reason for this is that the Soil Conservation Authority developed these land system surveys to be used as an inventory of physical and ecological characteristics of the land so that, for any particular agricultural land use, land management could be guided by relevant technology that would maintain the soil in health, its productive capacity and protect the water quality in the natural drainage system. Residential and industrial land uses were not part of its remit, but hobby farms and onsite septic tank management were.

Within the BNWPSP and surrounding land the two main basalt flows had contrasting soil types, as Jeffery noted. His Wollert Land System, on the younger flow, could be considered to have five different Land Components, with about 50% of stony rises having shallow stony red gradational soils and 30% of broad crests of stony rises having shallow stony dark brown clay soils. Some components are characterised by having periodic waterlogging and others may suffer from overland flow and sheet erosion. On the older flow, his Mickleham Land System consisted for about 65% of long gentle slopes with mottled yellow and grey sodic duplex soils. Elsewhere in the land system there are Land Components where periodic waterlogging and streambank erosion are identified as critical hazards.

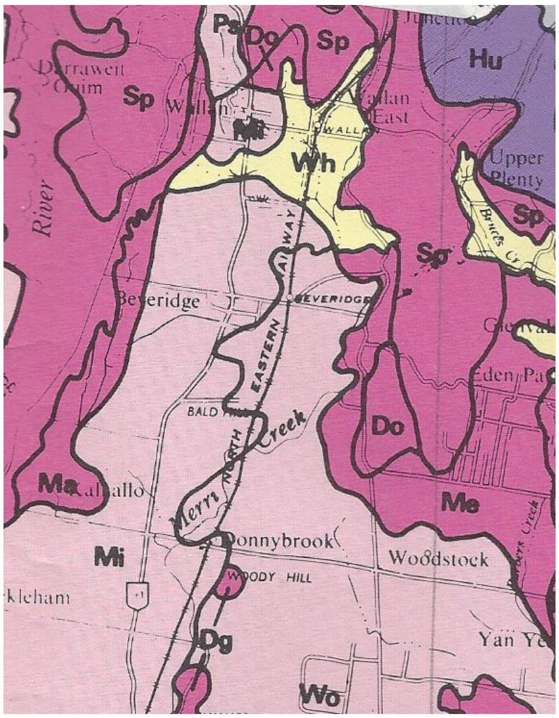

Figure 3 Part of the Land System map by Jeffery.

Note that the Wollert Land System is drawn mainly to the right of Merri Creek. Probably, Merri Creek has been forced to have its channel in the depression where two adjacent basalt flows bump up against each other and create a low-lying sinuous depression.

Both Grant and Jeffery were constrained in the amount of detail they could gather from their field work, having to map at scale 1:250,000. Grant's report is mainly a summing up of topographic detail with <u>very brief</u> soil descriptions. Grant provided no laboratory data for the soils. Jeffery's report contains soils chemical data for 16 soil profiles, where each soil horizon in the soil profile has had a full range of analytical data determined. Jeffery's report also contains a full list of plant species found within 10 m of a soil sampling site.

The Marnong Land System (Ma on the map) is represented in the BNWPSP and is described by Jeffery as having 90% of the area as sloping land with <u>yellow sodic duplex soils, highly dispersible and prone to sheet and tunnel erosion.</u>

For the BNWPSP a fresh investigation and map of much greater detail is required, providing much more detailed relevant information on the soils and land drainage. Jeffery noted that sodic soils were also very common in the entire area he mapped. For the Soil Conservation that was highly relevant because sodic clay soils tend to be highly prone to surface and gully erosion and runoff from sodic soil surfaces has a high fine sediment load.

None of this existing and important information on the land in BNWPSP is acknowledged in the BNW Background Report and, seemingly, was also unknown to any of the specialist consultants who provided text to the Background Report.

The Centre for Land Protection Research produced a Land Capability Study of the Shire of Mitchell in 1996 (Technical Report No. 35. By E. Jones, G. Boyle, N. Baxter and M. Bluml) that also included the areas mapped by Jeffery. It included a map at scale 1:100,000 (see below) that actually showed less detail than the 1:250,000 scale maps by Jeffery and Grant by showing both basalt flow-covered land as a single unit (Figure 4).

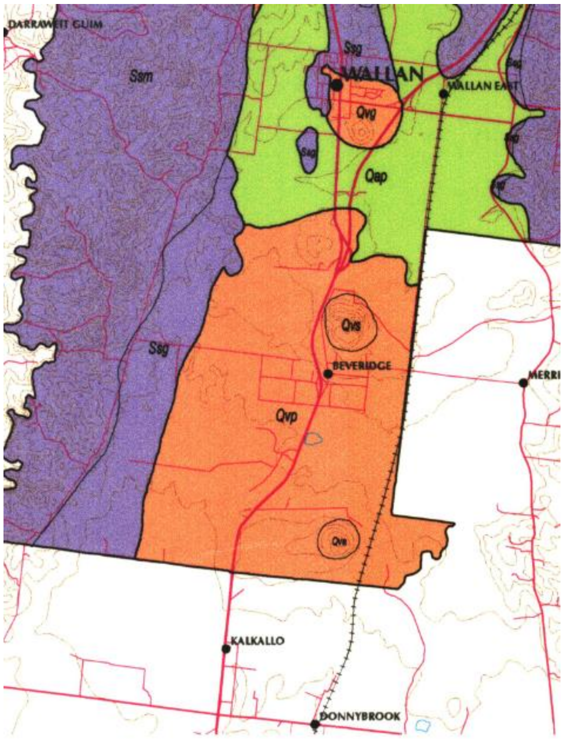

Figure 4 Section of the land systems map by Jones et al., 1996.

Note that the Land Protection Research map is nothing more than just the geological map with the mapping units labelled Qvp, Qvs, Ssg, etc. No distinction is made between the land on basalt flows of widely varying age and degree of weathering and soil development as exist in the Precinct.

The LPR report is aimed at:

"the demand for urban and rural residential development has closely followed population growth. Inappropriate subdivisions and development have occurred in the past in Victoria, resulting in unnecessary development and maintenance costs, and extensive land and water degradation. The use of Land Capability information will assist the Shire of Mitchell in identifying land with major physical limitations for urban and rural development, aid decision making where competing land uses occur" (as stated in the Report.)

The LPR Land Capability Study is largely focused on agricultural land uses as is evident from the list of soil conditions discussed, notwithstanding the minimal inclusion of a land capability ratings Table for "Building Foundations in Urban Development".

The LPR Jones et al. report also deals exhaustively with erosion problems in the Shire. I quote:

Much of the Shire, particularly the steep granitic and sedimentary areas, are highly susceptible to various land degradation problems. Sheet and gully erosion are a major concern on all steep to moderate slopes in the granite and sedimentary terrain. The incidence of gully erosion and salting is also increasing in the gentle sedimentary terrain. Much of the current land degradation problems can be attributed to inappropriate land use and management.

The following paragraph in that report states that:

A land capability study has recently been completed for the former Shire of Broadford. This information has been incorporated into the Shire of Mitchell study to provide consistent representation of land capability information across the new shire.

Whist the Jones et al. mapping was at scale 1:100,000, they have provided the relevant areas of the total map that are of significance to Mitchell Shire at scale 1:25,000. With regard to all the land on the very steep to moderately steep slopes on Silurian sedimentary rocks, the erosion risk (rill erosion) is rated at “Very high” and for gully erosion at “ Very low” although, at this time, the incidence of both types of erosion is “very low to low”. However, the incidence of both rill and gully erosion increases as the slopes on this geology decrease, becoming “High” in the almost level foot slopes or drainage depressions.

In their report is also a Table entitled “Summary of Land Capability Classes” in which five classes of suitability are presented for all of their mapping units, with Class 1 being the best suitability and Class 5 being the worst, and the land use aspects are Agriculture, Urban Development, Rural Residential Development and Susceptibility to Erosion. Only the relevant parts of this table are reproduced below.

SYMBOLS			**LAND CAPABILITY CLASSES**			
1:100 000	**1:25 000**	**Description**	**Agriculture**	**Urban development**	**Rural residential development**	**Susceptibility to erosion**
Qvs	**Qva**	Quaternary volcanics, steep crest	4	4	5	3
Qvm	**Qvc**	Quaternary volcanics, moderately steep slope	4	4	5	5
	Qvd	Quaternary volcanics, moderate slope	4	3	5	5
Qvg	**Qve**	Quaternary volcanics, gentle crest	4	3	5	3
	Qvf	Quaternary volcanics , gentle slope	3	3	5	3
	Qvg	Quaternary volcanics, very gentle slope	4	5	5	3
	Qvh	Quaternary volcanics, drainage depression	3	4	4	3
Qvp	**Qvp**	Quaternary volcanics, plain	4	5	5	3
Sss	**Ssa**	Silurian/Devonian sediments, steep crest/ridge	5	5	5	5
	Ssb	Silurian/Devonian sediments, steep slope	5	5	5	5
Ssm	**Ssc**	Silurian/Devonian sediments, moderately steep slope	5	4	5	5
	Ssd	Silurian/Devonian sediments, moderate slope	5	4	5	5
Ssg	**Sse**	Silurian/Devonian sediments, gentle crest	5	3	5	4
	Ssf	Silurian/Devonian sediments, gentle slope	3	3	3	3
	Ssg	Silurian/Devonian sediments, very gentle slope	3	3	3	3
	Ssh	Silurian/Devonian sediments, drainage depression	3	4	4	4

The part of Jones et al.’s Table 2.2 dealing with the three most limiting capability classes and the consequences of these differences is copied below.   This Table summarises the degrees of limitation to the use of the land in these types of land use and provides general land management guidelines.

Class 3	Fair	Moderate engineering difficulties and/or a moderately high erosion hazard exists during construction.	Areas with a fair capability for the proposed use. Specialised designs and techniques are required to minimise the impact of the development on the environment.
Class 4	Poor	Considerable engineering difficulties during development and/or a high erosion hazard exists during and after construction.	Areas with poor capability for the proposed use. Extensively modified design and installation techniques, exceptionally careful site preparation and management are necessary to minimise the impact of the development on the environment.
Class 5	Very poor	Long term severe instability, erosion hazards or engineering difficulties which cannot be practically overcome with current technology.	Performance of the land for the proposed use is unsatisfactory. Severe deterioration of the environment will occur if development is attempted in these areas.

I understand that the Shire of Mitchell incorporated these erosion susceptibilities in its own Land Use Plan but that the VPA removed them in relation to the PSP structure plan.

The apparent absence of understanding of soil sodicity as a major constraining environmental factor

Jones et al. briefly discuss soil sodicity and soil dispersibility in their report on page 14 and the authors recommend it be measured through the Emerson Aggregate Test as shown below. It recommends that soil dispersibility can adequately be assessed by the aggregate test and that it is not necessary to measure exchangeable sodium percentages[1].

> ***A.9 Dispersibility***
>
> *Sustainable land use requires that the soil be able to withstand the physical forces of cultivation and compaction without adverse structural change. Soil aggregate stability can be measured by the Emerson Aggregate Test (Emerson 1977). In the case of secondary roads, dispersion can significantly affect the condition of the road when slopes are greater than 4%. Because of the close correlation between dispersible soils and high exchangeable sodium percentages in those soils, it is unnecessary to include both criteria in the capability rating table.*

The Jones et al. 1996 Report contains a Table with soil chemical analysis data but the map unit Qvp, which encloses the Precinct, apparently was not sampled. In this report, as in Jeffery's report, the chemical analyses of the soil include all the soil horizons identified in the soil profile. This is the normal procedure in soil science when a full soil assessment is required.

Yet, the first thing that a reader of the Background Report for the BNWPSP will notice, is that zero attention is paid to the soils of the area within the Structure Plan with regard to erosion, serious soil sodicity, soil dispersion, salinity, highly turbid runoff and stream water degradation. The writers have

[1] I remark here that without numbers on ESP and CEC one cannot determine the amount of gypsum required to overcome the dispersion of the clay soils. The Emerson test is not related to a gypsum requirement. The term "sodic" occurs four times in the report, exclusively in the soil classification names, and the term "sodicity", to qualify the chemistry of the soil, is never used.

not bothered themselves to find any previous information on the landscapes and soils such as is available from the CSIRO[2] and the former Soil Conservation Authority[3]. It is as if for the authors the soil merely exists to hold the trees up to render the landscape visually attractive and support whatever man-made structures and services a planner might dream up.

The documents supporting the Structure Plan, listed below, demonstrate the above conclusion.

Technical investigation and findings that were used to inform the preparation of this report and the Beveridge North West PSP include:

- *Arboricultural Assessment, Precinct Structure Plan 1059*, Beveridge North West, Tree Logic Pty Ltd, November 2013
- Beveridge North – West Landscape and Visual Assessment, Planisphere Planning and Design, October 2014
- Beveridge North West Precinct Structure Plan Area, Site Suitability Assessment, VW07335, Jacobs Group Australia Pty Ltd, July2014
- Beveridge North West Precinct Structure Plan, Utilities Servicing and Infrastructure Assessment, Cardno Victoria Pty Ltd, March 2014
- Beveridge North West PSP 1059, Beveridge, Aboriginal Heritage Impact Assessment (AHIA), CHMP #12766, Archaeological and Heritage Management Solutions Pty Ltd (AHMS), February 2014
- Beveridge North West PSP Groundwater Quality Assessment, VW07335, Jacobs Group Australia Pty Ltd, July2014
- PSP 1059 Beveridge North West Post – Contact Heritage Assessment, HV Report #4372, Archaeological and Heritage Management Solutions Pty Ltd (AHMS), February 2014
- Targeted Cultural Values Inspection of PSP 1059 Beveridge North West, Wurundjeri Woi-wurrung Cultural Heritage Aboriginal Corporation, October 2014 (Revised 2019)
- Scattered Tree Assessment, Beveridge North West (PSP 1059), Victoria, Ecology and Heritage Partners Pty Ltd, November 2013
- Beveridge North West Precinct Structure Plan –Economic Assessment, Essential Economics Pty Ltd, July 2019.
- Beveridge North West PSP Strategic Transport Modelling Assessment, GTA Consultants (Vic) Pty Ltd, December 2018.
- Beveridge North West PSP Infrastructure Designs and Costings, Cardno Victoria Pty Ltd, July 2019
- Bushfire Development Report for the Beveridge North West Precinct Structure Plan, Terramatrix, July 2019.

It is also quite remarkable that with respect to the soils of the Precinct, the Background Report has only two concerns, geotechnical properties and soil contamination. The word “soil” occurs only seven times in the entire report and never identifies its function in the planning of the development beyond

[2] Grant, K. 1972. Terrain Classification for Engineering Purposes of the Melbourne Area.
[3] Jeffery, P.J. 1981. A Study of the Land in the Catchments to the North of Melbourne. Soil Conservation Authority.

geotechnical properties and contamination. It seems as if the Jones et al. Report has gone missing. Moreover, in relation to geotechnical properties the chemical characteristics of the soil does not figure at all. The importance of sodicity, in terms of soil behaviours such as dispersion, erodibility and tunnelling, and loss of hydraulic conductivity that prevents adequate internal drainage is never reflected upon.

It is possible that the "Site suitability" report by Jacobs, which I have not read, might make some references to the soils and their high erosion risk due to their sodicity, but in the Background Report the words "sodicity", "sodic" and "erosion" in relation to soils simply do not occur.

A thorough scan of the Background report demonstrates that, as far as Jacobs is concerned, the soil is merely the weathered residual stuff overlying siltstone/sandstone and the highly reactive residual basaltic clay. This could have been written by a geologist who has never ventured beyond hard rocks.

> ## Geology
>
> The report identified that the eastern part of the precinct is likely to be underlain by highly reactive residual basaltic clay, overlaying basalt rock and the western half underlain by residual soils, overlaying weathered siltstone/sandstone.

The superficial analysis continues with the following statement:

> Kalkallo Creek flows north-south through the precinct and provides an opportunity to create a high amenity 'blue-green' corridor within the precinct. However, it should be noted that given the extent of erosion resulting from past farming practices, remediation works are required.

In other words, whatever happened before is the fault of the farmers, and one does not need to inquire whether it was just farming practices or if the soil due to its texture and chemistry was highly prone to erosion even if no farming had taken place.

> A site survey that was undertaken identified an additional artefact scatter and highlighted the loss of two of the artefact scatters (one due to erosion and the other from the construction of a vehicle track). The north-west portion of Kalkallo Creek has a high level of cultural sensitivity particularly as it contains multiple artefact scatters.

Again, here there is an observation that has nothing to do with the fundamental properties of the soil that could contribute to severe erosion and tunnelling from major earth movement.

> Excavation and removal of underground storage tanks, soil remediation and tank pit validation if USTs are found on properties.

Here the emphasis of the Background Report is on soil contamination.

> Further drilling and collection of soil samples for the purposes of assessing the geotechnical soil properties for building foundations and road design. This may be undertaken through the preparation of a Sampling, Analysis and Quality Plan (SAQP) followed by a Phase 2 Environmental Site Assessment (which may include targeted sampling of soils and groundwater).
>
> Classification and appropriate removal (if required) of various stockpiles and dumped materials observed at sites across the study area. This includes subsequent validation following removal. It may be the case that sampling of some stockpiles of soil observed may indicate that the material is suitable for re-use as part of future development and as such removal may not be required in all instances.

Once again, the focus of the Background Report is on geotechnical properties and soil contamination. However, there is no identification of which geotechnical properties are to be determined and how they impact may on the planned developments. It is as if the VPA is simply saying that if a built house will stand up, a newly constructed road can be driven over or sewer line installed in the ground are completed, there is no need to sharpen the focus on the soil's behaviour under the new development pressures.

I have evidence that under current geotechnical practice in the Merrifield area, another new residential and commercial development, only a few kilometres away, a major geotechnical consultant based in Melbourne reported the sodium, calcium, potassium and magnesium in soil samples as *mg/kg*, as if these cations are contaminants. There was no understanding by the consultant of what these chemical data really mean in relation to the geotechnical behaviour of the soil. These engineers did not ask the laboratory to report these cations as *percentage exchangeable cations (%)* and determine the *total cation exchange capacity in milli-equivalents per gram* of the soil. Soil salinity and soil pH were also measured, but these properties were not interpreted in terms of soil structure stability and dispersiveness. Soil salinity was measured as *Resistivity at 25^{o}C (Ohm.cm)*, whereas to be of use in understanding and correcting the high dispersion of the clay soils, it should be expressed as *µS/cm*.

Sodic clay soils disperse very readily in water, producing highly turbid runoff that threatens ecological quality in receiving water bodies and adds to their sediment loading. Sodic clay soils are also highly prone to gully and tunnel erosion. Soil sodicity can be countered by changing the proportions of exchangeable sodium, calcium and magnesium in favour of calcium. However, dispersion can also be countered by increasing the salinity of the water in contact with the soil clay fraction. In fact, the application of gypsum does both, increase calcium levels and the EC. The behaviour of a clay soil therefore is strongly controlled by two properties: the relative predominance of exchangeable sodium over calcium and magnesium and its total salinity, measured as EC.

For practical purposes, a soil may be classed as sodic if its percentage of exchangeable sodium is greater than 6 (ESP > 6). In reality, it also depends on the mineralogy of the clay fraction.   Clay minerals like kaolinite, illite, montmorillonite (smectite), etc., are flat mineral structures arranged like pages in a book. Smectite clay minerals are very common in the soils developed on basalt and in such clay mineral structures the bond between adjacent mineral sheets is weak so that water easily can enter, bringing about dispersion.

In general, in acidic soils the positively charged edges of clay minerals tend to form "card house" structures, edge to face structures, which keep the clays coagulated and stable. The soils in the Precinct, especially those on basalt, tend to have highly alkaline reactions which inhibit these stable configurations.   Card house structures are also promoted by a preponderance of calcium ions amongst the exchangeable cations. In sodic soils, it is sodium that is too dominant leading to a tendency to disperse in water.

This lack of soil chemistry understanding of geotechnical engineers is exhibited elsewhere. One suspects that clay mineralogy and soil chemistry are not taught to geotechnical engineers at university. The soil science fraternity on the other hand has known about these soil properties for decades.

Australia happens to be the continent with the greatest extent of sodic soils. CSIRO produced one of the earliest papers[4] on the effect of electrolyte concentration and sodicity on soil permeability in 1955. Quirk and Schofield's paper was recognised in 2013 by the European Journal of Soil Science as a Landmark paper.

[4] Quirk, J.P. and Schofield, R.K., The effect of electrolyte concentration on soil permeability". J. of Soil Science, Vol. 7, No. 2, 1955.

In 1995, the CSIRO published the papers contributed on the topic of sodic soil during the First National Conference and Workshop on Sodic Soils held in 1992 in Adelaide under the title “Australian Sodic Soils – Distribution, Properties and Management”. Following from this, the Australian Journal of Soil Research published a Special Issue on soil sodicity in 2001 with 22 papers on this topic.

The geotechnical and civil engineering profession, seemingly, is more than half a century behind in its understanding of soil sodicity.

Quirk and Schofield illustrate these factors in a general diagram (Figure 5) to illustrate that when soils do not break up and disperse, but maintain their internal structure of solid particles and interconnected voids, when exposed to water, they also maintain their hydraulic conductivity.

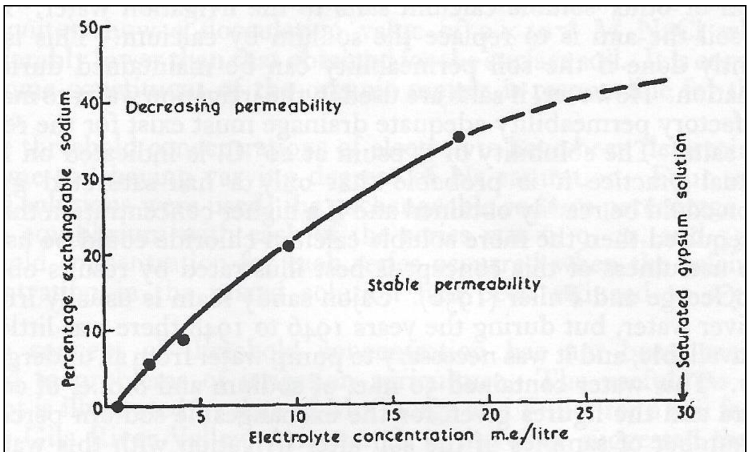

FIG. 9.

Figure 5

Stable rates of water infiltration and water movement in the soil are of prime concern to irrigationists. The general function between the water’s Sodium Absorption Ratio (SAR) and its salinity (EC) and stability of soil structure is portrayed in the diagram below (Fig. 6).

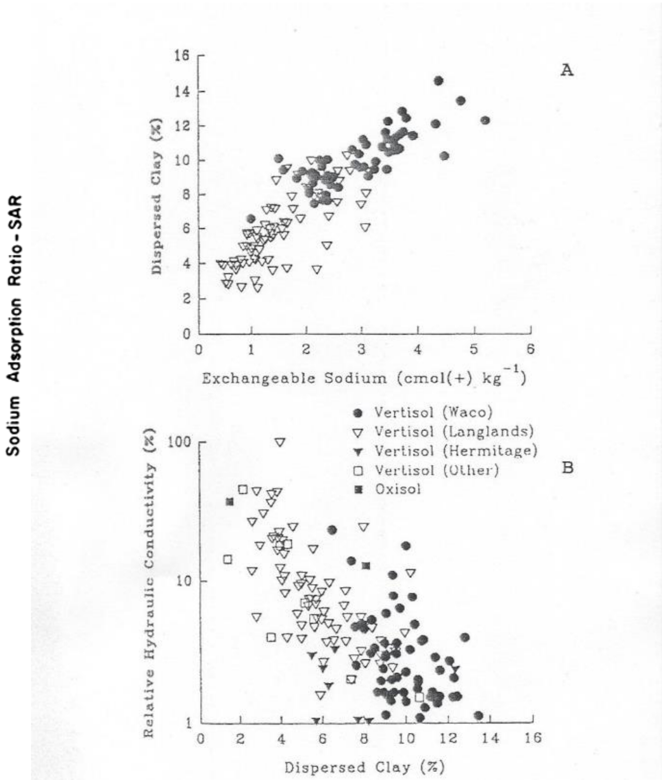

Fig. 25. (A) Relationship between exchangeable Na and dispersible clay for Australian Vertisols. (B) Relationship between dispersible clay and the HC of soil crusts formed on Australian Vertisols and Oxisols (So and Cook 1993).

Figure 6 - (Ayers R.S. and Westcot D.W. 1976 *Water quality for agriculture*. *FAO* Irrigation and Drainage Paper 29, *FAO*, Rome.)

SAR is defined as: $\text{SAR} = \dfrac{Na}{\sqrt{(Ca+Mg)/2}}$

where sodium, calcium, and magnesium concentrations are expressed in milliequivalents/litre. SAR allows assessment of the state of flocculation or of dispersion of clay aggregates in a soil.

So and Cook (1993)[5] investigated the relationship between sodicity of clays and their hydraulic conductivity and dispersing tendency. The results are shown extremely convincingly in a couple of diagrams.

There is only one dot point, a square representing an oxisol, a soil that represents a final stage in weathering, with largely kaolinitic and bauxitic clay, with a low cation exchange capacity, and with ferruginous skins around the clay minerals, that is unaffected by sodicity. We find such clays on the Kinglake Plateau.

Vertisol is the name used by soil scientists for the highly sensitive cracking clays that are common in the Western basalt plains.

In 2009 the Tasmanian Department of Primary Industries and Water published a Technical Reference Manual entitled “Dispersive Soils and their Management”[6] in which the following do’s and don’ts are summarised as follows:

Should Do	*Should Not Do.*
»» Apply gypsum to potentially dispersive soils. »» Cover exposed dispersive soils with topsoil. »» Vegetate all bare areas with vigorous pasture. »» Seek professional geotechnical advice before commencing construction works including dam construction, roads and building foundations.	»» Expose dispersive subsoils to rain. »» Allow water to pond on dispersive soils. »» Concentrate stormwater in drainage lines containing dispersive soils. »» Use table drains, trenches or cut and fill construction techniques in areas containing dispersive soils. »» Scalp or extract topsoil from areas with dispersive subsoils.

[5] So, H.B. and Cook, G.D., The effect of dispersion on the hydraulic conductivity of surface seals in clay soil. Soil Technology 325-330.

[6] The Manual was written by Marcus Hardie, a Land Management Officer with the Department with contributions from others from the University of Tasmania, LMRS Pty Ltd, Hobart, and Natural Resources Management South.

The Technical Reference Manual makes the essential point that:

"Initiation of tunnel erosion is predominantly a chemical process, so it makes sense to use chemical amelioration strategies when attempting to prevent or repair tunnel erosion in dispersive soils."

The science and technology for stabilising dispersive soils is not well developed. In agriculture, gypsum ($CASO_4.2H_2O$) and lime ($CaCO_3$), also hydrated lime ($Ca(OH)_2$) have been used to increase the soluble calcium levels in the soil at the expense of sodium and sometimes magnesium as well. Lime and hydrated lime work less effectively if the receiving soil has a high pH because that reduces the solubility of these materials and therefore their impact on the soil's ionic chemistry. The use of these materials in tunnel erosion affected land has had limited application and limited success. There is still much to be learnt about these technologies.

It appears that civil and geotechnical engineers have relied mainly on observing "safe" slope angles in cut slopes when constructing waterways in dispersive sodic clay soils and as can be seen in Merrifield that has been disastrous.

How to investigate the suitability of land for development

The first step is to conduct a **land system study**, focussing on the terrain, the relationship of the soils to the terrain (**geomorphology**) and the nature of the soil profile along a vertical axis. Soils are the product of the weathering of the local parent material, bedrock or transported sediment, and the weathering process differs between the surface layers and the base of the soil body. A land system study is an inventory of natural elements in the landscape and how these interact with each other and with the local climatic regime. Therefore, a land system is a complex mapping unit made up of smaller, internally much more uniform land components. Land system studies have been undertaken with the main objective of understanding all natural processes that operate in a landscape, so that land users will maintain great care not to disrupt these processes and preserve the natural dynamics while benefitting from the biological productivity of the land.

The science that enables a full understanding of soils in the landscape to be obtained is **soil science**. **Geomorphology** deals with the removal, sedimentation, and mineralogical changes of a body of soil in a landscape over geological time periods.

Because the formation of soil occurs across a vertical gradient, subsoil strata may have entirely different chemical and physical properties from upper strata in the profile. As rainwater leaches down a soil profile it dissolves the more soluble mineral components first and transports these into lower parts and, in many cases, these are lost to the groundwater. Those upper parts of the profile may develop an acid reaction if a greater part of the soluble and exchangeable calcium, magnesium, potassium and sodium are leached down so that exchangeable hydrogen ions become dominant. In low rainfall areas leaching will not be able to remove the soluble and exchangeable metals (cations) entirely from the soil profile and they will concentrate and/or become their respective carbonate, sulphate or chloride salts. Often this causes the subsoil or parts of it to become strongly alkaline. The vegetation on the soil will cause a portion of the metals to be returned to the topsoil in the form of litter. All these processes operate in a vertical dimension.

Therefore, sampling a soil must ensure that all significant portions that can be distinguished from one another should be sampled and analysed in a laboratory[7]. A good assessment of a soil profile is one that covers the entire profile. From such an investigation one may then assess their inherent weaknesses to degradation and develop controls such as treatment with gypsum to bring about flocculation and minimise dispersion and soil erodibility.

A good **land capability study** is based on a good **land system study**. This is done by developing criteria through analysis of the weaknesses that may exist within a given soil profile and considering how, by managing soil disruption through better mechanical, chemical or biological techniques, major soil deterioration can be avoided. It is not possible to conduct a land capability assessment without have a system of relevant criteria first, otherwise it is just guesswork. A good land capability assessment system is based on quantifying the risks facing the use of the land for human uses and setting up a graduated system of protective measures depending on the intensity of the land use and the severity of the risks.

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[7] Many geotechnical engineers sample soil profiles in a haphazard manner as they are not aware of the chemical and often mineralogical differences that exist in different parts of the profile. Therefore, the data they obtain may not define those parts of the soil profile that matter in a development.

Both a land system study and a land capability assessment require field work. Even if remote sensing technology is employed, only field work can confirm results obtained by remote techniques. Field work requires also the use of aerial photography, not only to navigate one's position in the field, but also detect gradual and abrupt changes in the image that relate to physical factors in the field such as changes in soil moisture or efflorescence of salt, etc.

Identifying and defining the land systems and land units within a land system that make up a part of the land system is the beginning of a land system survey upon which a land capability assessment is based.

The is a need to concentrate on the entire soil profile because during development as there will be scalping and soil properties change with depth. There is a need to determine the full depth of soils to bedrock, determine which part of the soil profile has favourable chemical and mineralogical properties that minimise erosion and dispersion; determine what must be done to stabilise dispersive soils chemically or by alternative methods. Care must be taken not economise too severely on lab costs.

Field work intensity is to be guided by the following publications.

- Bie SW, Beckett PHT (1970). The costs of soil survey. Soils and Fertilisers **33**, .203-217
- Bie SW, Beckett PHT (1971) Quality control in soil survey. The costs of soil survey. Journal of Soil Science **22**, 453-465
- Gunn RH, Beattie JA, Reid RE, van de Graaff RHM (Eds) (1988). 'Australian Soil and Land Survey Handbook: Guidelines for Conducting Surveys'. (Inkata Press, Melbourne)
- McDonald RC (1975) 'Guidelines for soil survey in Queensland'. Agricultural Chemistry Branch, Technical Report No. 6.
- McDonald RC, Isbell RF, Speight JG, Walker J, Hopkins MS (1990). Australian Soil and Land Survey: Field Handbook. (Inkata Press, Melbourne and Sydney)

Bie and Beckett (1970, 1971) did an international survey of soil survey organisational practices and summarised their findings in the form of a logarithmic function:

$$\log_{10}E = 7.41 + 1.57 \log_{10}S \qquad (1)$$

where E is survey effort in man-days per km^2 in the field and S is map scale expressed as a fraction. This function can be portrayed on double logarithmic paper to facilitate reading off the value of E for any chosen scale S.

For example, assuming a map scale of 1:25 000, then:

$$\log E = 7.41 + 1.57 \log (1/25{,}000) \qquad (2)$$

Hence, the survey effort (E) on this scale is approximately 3.2 man-days per km^2 assuming an experienced soil surveyor is employed and suitably equipped.

The Beveridge North West PSP applies to approximately 1250 hectares of land, a relatively small area that could be covered by a single soil surveyor in 40 days. A soil survey, however, should be preferably involve more than one soil surveyor, two soil surveyors working together would lead to better analysis of the landscape and soils in area concerned.

If the scale of the map is 1:25,000, the old MMBW aerial photography could be used if still held somewhere. Use existing black & white aerial photography for the study and mapping; colour aerial photos to be used if no B&W photos are available.

As per the protocols, there is a need to set quantitative limits to classes of risk of land deterioration and then delineate the land capability classes on a map.

With the map as an **objective data base**, carry out a land capability study, interpreting the data in terms of best land management and what land management measures are needed to protect the entire environment, the soil, the surface drainage and stream drainage system and the built environment.

An aerial image of the subject PSP area, below, shows all farm dams having turbid water, which is typical of sodic clays dispersing in water. The water in the stream, Kalkallo Creek, also is highly turbid due to all forms of erosion and clay dispersion in its head waters, which arise in hilly country underlain by Silurian sedimentary rock. Kalkallo Creek flows though a deeply incised eroded trench that shows no sign of slowing down, despite past attempts to stabilise it with physical methods.

The variation in darkness of the green shades and the contours provided on another map can be used to delineate with much more accuracy where the boundaries are of the land that is based on the Silurian sedimentary rocks, the land on the basalt flows and the land on the volcanic ash and scoria. In this manner one could delineate the various land systems in the Precinct. However, what these cannot do is provide detailed information on the land components inside each land system.

Conclusions

1. A detailed independent Land and Terrain and Land Capability Study is required to determine whether this country should be allowed to be developed;
2. The soils of the western portion of the site are at extreme risk of erosion now and particularly when disturbed;
3. It is imprudent to develop on this country with a known high risk of erosion as the consequences are likely to be unstoppable and not answerable with physical engineering techniques.

Chemical processes affecting soil characteristics creating a depth function of soil properties

Basaltic cracking clay in Deer Park showing illuviated lime stratum

Mineral breakup during weathering releases various elements, bases, such as calcium, sodium, potassium and magnesium but also silicates and other metals like iron and nickel that existed in the rock. Depending on their solubility they are gradually washed down the soil profile until, as the water in the soil is taken up by the vegetation, their concentration exceeds their solubility when they precipitate out and concentrate at various levels in the soil profile. The depth function of barium (see graph) will be similar to that of calcium which was not measured in this case.

Therefore, chemical conditions in the profile vary with the depth. Salinity measured as electric conductivity and soil pH will increase with depth when salts and calcium, sodium and magnesium become more concentrated in the lower profile.

In higher rainfall climates, the solutes are mostly leached out altogether and when most of the bases in the soil's cation exchange capacity have been replaced by hydrogen ions, the soil profile will be acidic throughout.

Soil chemical analyses should be carried out on all the distinguishable layers of the profile to understand it and to be able to decide which strata are the most prone to soil dispersion, and erosion, and which strata can safely be excavated and reused elsewhere.

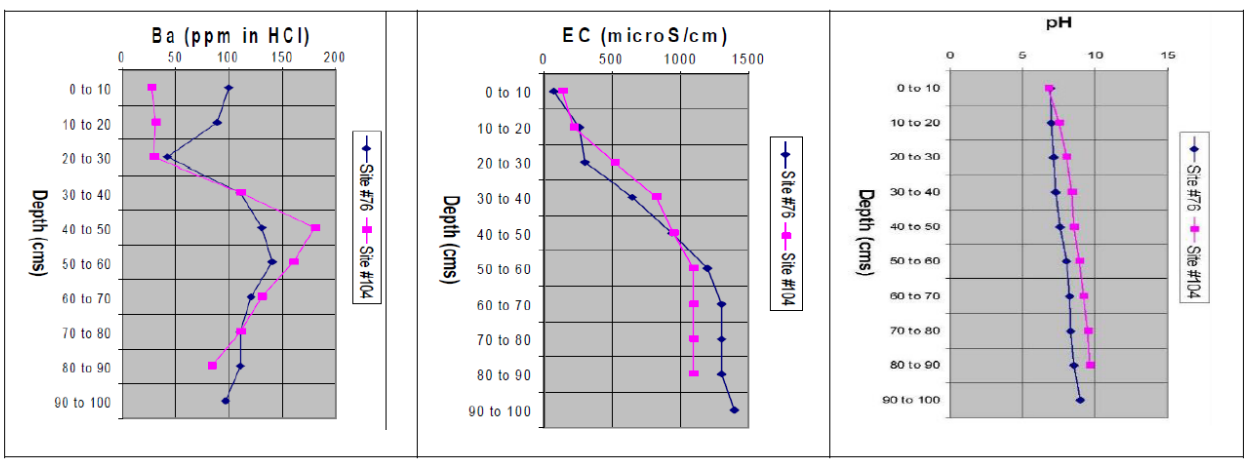

Figure 12. Depth functions of Ba, salinity (EC) and pH

Examples of mistakes to be avoided

The example below of soil chemical analyses done by geotechnical/civil engineers.

Table 1: Summary of soil chemistry test results

Test pit ID	TP-01	TP-03	TP-06	TP-10	TP-11	TP-12
Sample depth (m)	0.5 – 0.6	1.8 – 1.9	2.5 – 2.6	0.3 – 0.4	3.6 – 3.8	2.0 – 2.1
pH	7.5	8.6	8.4	7.4	5.7	5.3
Moisture content (%)	35.1	18.8	22.4	31.1	26.1	25.8
Resistivity at 25°C (ohm.cm)	14 700	1530	1690	13 900	962	781
Sulfate as SO_4 (mg/kg)	<10	160	100	30	330	290
Chloride (mg/kg)	1050	760	910	730	2010	2760
Major cations (mg/kg)						
. Calcium	120	220	250	480	<10	30
. Magnesium	440	840	980	990	20	50
. Sodium	250	1090	1030	310	1160	1460
. Potassium	510	640	790	970	<10	<10
Organic matter (%)	1.5	<0.5	<0.5	2.9	<0.5	<0.5
Total organic carbon (%)	0.9	<0.5	<0.5	1.7	<0.5	<0.5

In relation to soil stability, prevention of erosion and soil dispersion, one needs to have data on the exchangeable cations, Ca-Mg-K-Na-H, in terms of milli-equivalents/100 g, the percentage of exchangeable sodium (ESP), salinity in terms of µS/cm or dS/m. It is necessary also to measure the Dispersion Coefficient in the lab. In the Table above one can see that the sample from TP-10 came from close to the soil surface and therefore represented the more heavily leached part of the soil profile. No surprise then it has low amount of chloride, ditto sulphate and a high resistivity (i.e. low electric conductivity) as opposed the sample taken at 2.0-2.1 m depth in another test pit, where there soil is much more saline (high chloride and sulphate) and a very low resistivity (high conductivity).

Note also there has been no attempt to sample and analyse a complete soil profile. Nobody knows why these samples have been taken from all sorts of portions of the soil profiles in these test pits.

When funds are expended on laboratory data, why not express the results immediately in units that are relevant to chemical and structural soil stability?

Soil erosion not due to a farmer's activities, but to geotech and civil engineers not understanding sodic soils and how they perform with rainwater. Note the shallow surface rivulet entering the slump at the top. To the left a series of much smaller concentrated surface rivulets are the direct cause of the smaller slumps.

Sodic clay in contact with low salt water like rainwater tends to "explode" and disperse immediately.

Note also the turbidity of the water in the drain. This water will ultimately flow into another body of water and render it turbid as well. Sunlight then cannot enter the water column and aquatic plants can then not photosynthesize.

Tunnels excavated for sewerage, electricity and gas services in sodic clays are at high risk of becoming erosion tunnels that later develop into gullies, particularly on slopes when the overburden is not supported anymore.

 Protective geotextile unable to be anchored to the dispersing underlying sodic clay - Merrifield	 Rainfall surface flow starting an erosion gully – Mandalay; note the turbidity of the ponded water
 Saline subsurface soil preventing adequate grass establishment - Mandalay	 Shallow layer of stagnant surface water in drain is relatively clear due to salinity of the groundwater oozing out of the soil - Mandalay

Tunnel and sheet erosion in sodic soils formed on Ordovician sedimentary rocks in the Emu Bottom, Sunbury area

Clearing of the land, overgrazing by farmers and imported rabbits are mainly responsible for this massive land degradation. This land was mapped by Jeffery as the Sunbury Land System and the site shown above is in its general “slope” land unit, occupying some 50% of the land system. It was described as having mottled yellow brown sodic duplex soils subject to soil dispersion, sheet and tunnel erosion. This land is very similar to the land along the western elevated country of the Beveridge North West Precinct on Silurian rocks.