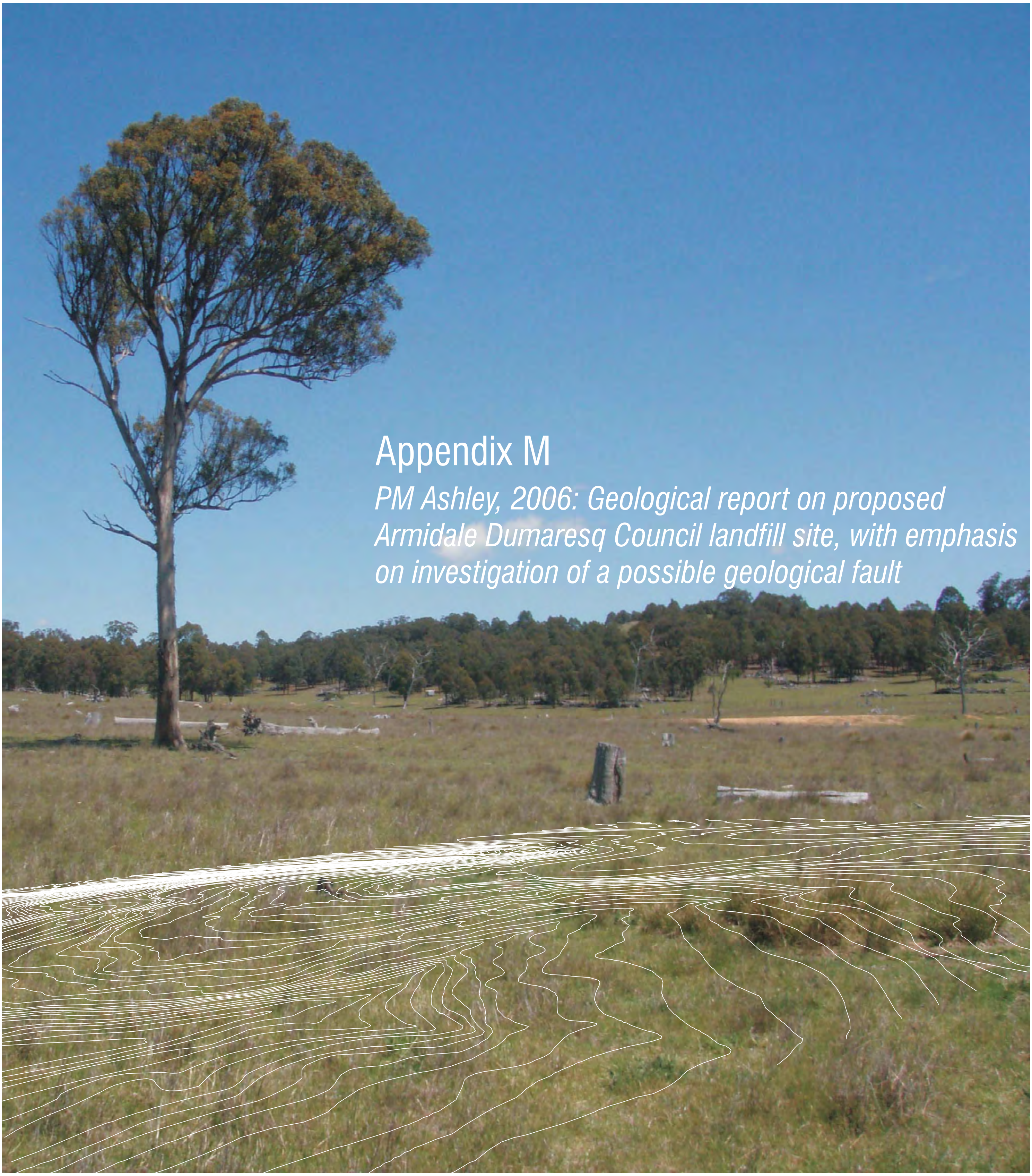
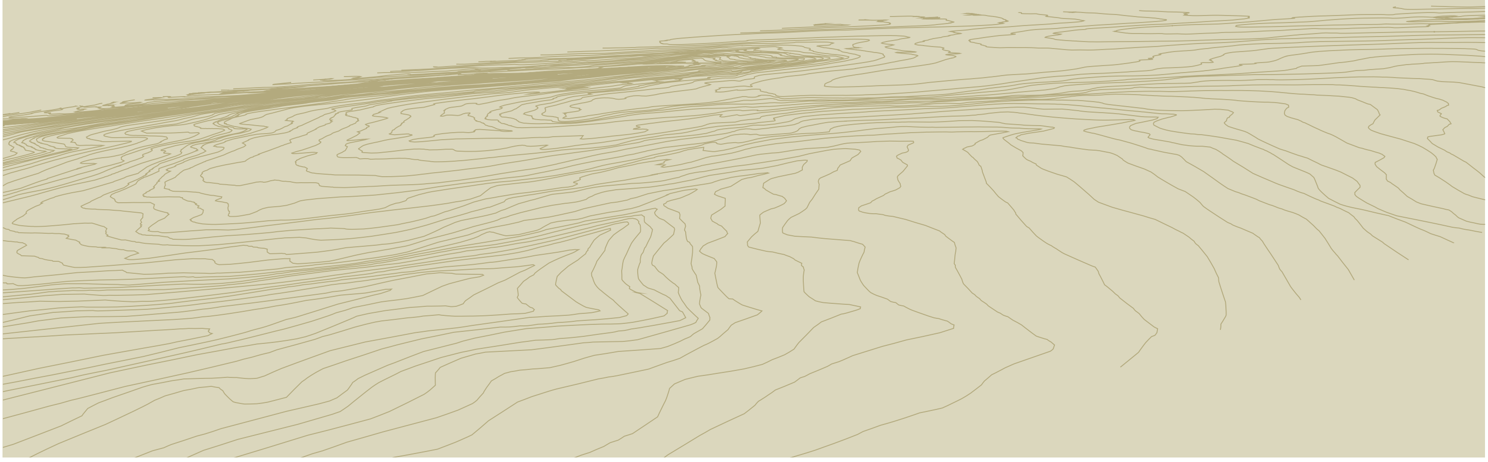


Appendix M

PM Ashley, 2006: Geological report on proposed Armidale Dumaresq Council landfill site, with emphasis on investigation of a possible geological fault

ARMIDALE REGIONAL LANDFILL

Environmental Assessment



Geological report on proposed Armidale Dumaresq Council landfill site, with emphasis on investigation of a possible geological fault

For

EA Systems Pty Ltd

Reference: Purchase Order # 3653

P.M. Ashley
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February, 2006

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EXECUTIVE SUMMARY

The published 1:250 000 Dorrigo-Coffs Harbour geological map covering the Armidale region, including the area of the proposed landfill site for Armidale-Dumaresq Council, shows a linear fault trace marked as “position approximate”, striking about 050° across the southern portion of the proposed landfill site. If the fault existed and displayed any evidence for activity (e.g. earthquakes) or zones of increased porosity and permeability, it may pose geotechnical concern for the siting of the landfill. There may be possible issues of landfill stability and groundwater contamination as a result of potential activity. In order to ascertain if the mapped fault could be identified in the area of the proposed landfill site, a geological mapping program was performed, making observations on rock types and structures and attempting to identify any characteristics that might confirm the presence of a fault and any geologically recent tectonic activity.

Mapping indicated that the previous regional scale map did not have adequate detail to display the distribution of rock types (greywacke, siltstone, mudstone-argillite and chert of the Sandon Beds, and Tertiary sedimentary rocks, basalt and regolith). Measurement of structures indicated that although there is a statistical peak of rock fabric orientations (foliation, cleavage, fractures) at ~040°, it did not conform to the projected “fault” strike of ~050°. Moreover, in the projected position of the “fault”, there was no field evidence for a concentration of features indicative of the presence of a fault, e.g. increased penetrative fabrics such as foliation and cleavage, brittle fracturing or brecciation, or hydrothermal alteration. In addition, there was no topographic expression of the “fault” to suggest any geologically relatively recent motion.

Remote sensing imagery (air photo, Landsat imagery, digital terrain model and inferences from adjacent aeromagnetic and radiometric data sets) did not provide any evidence for the existence of a fault in the position implied from the published geological map.

In conclusion, it is considered that the fault shown on the map has no basis in fact, at least in the proposed landfill site area and for 1-2 km along strike to the northeast and southwest. There should not be a significant bedrock geological reason mitigating against the siting of the proposed landfill (e.g. earthquake risk, groundwater leakage along a fault). However, all other environmental aspects regarding groundwater and surface water migration, soils and slope stability would need to be thoroughly assessed.

Objective of the investigation

To perform geological mapping in the area within and surrounding the proposed Armidale Dumaresq Council landfill site near the Gara River, east of Armidale, with emphasis on identifying evidence for or against the occurrence of a geological fault that has been indicated on published maps as passing across the landfill site.

Background to investigation

A proposed site for a new landfill has been indicated near the Gara River about 12 km east of Armidale and just south of the Waterfall Way (Fig. 1). It is of geotechnical concern that most modern published geological map of the region (Dorrigo-Coffs Harbour 1:250 000 geological sheet; Gilligan et al., 1992) shows a northeast-striking fault passing across the southern portion of the landfill site (Fig. 2). A fault could have implications for (a) egress of groundwater (and leachate) out of, or into the landfill and (b) stability of the structure(s) in the rare case of a seismic event (earthquake).

A geological investigation was sought in order to perform mapping of the landfill site and surrounding area, with emphasis on identifying criteria that would provide evidence for or against the presence of a fault.

Published geology of the proposed landfill site and surrounding area

The earliest detailed semi-regional mapping of the Armidale area including the landfill sites was published in 1967 (Binns et al., 1967). This map does not show the occurrence of a fault in the landfill area or general location. The first edition of the Dorrigo-Coffs Harbour 1:250 000 geological map published in 1969 by the Geological Survey of NSW and the subsequently updated metallogenic map published in 1992 (Gilligan et al, 1992) do show a fault striking approximately northeast (about 050°) across what would be the southern part of the landfill site (Fig. 2). As shown, the fault is about 20 km in length and the map symbol is for it to be “position approximate”.

As shown on the 1992 Dorrigo-Coffs Harbour geological map, the fault is indicated to cross over geological boundaries, but yet there is no displacement indicated. The rationale for showing the fault on the map remains enigmatic and there is no explanation in the notes of Gilligan et al. (1992). In 2001, the then NSW Department of Mineral Resources had an airborne geophysical survey flown over the southern part of the New England region, with the eastern margin of the survey area being very close (within a kilometre) of the landfill site. Interpretation of the geophysical data by Brown (2003) did not show any evidence of a fault (based on magnetic or radiometric results) in the vicinity of the landfill site.

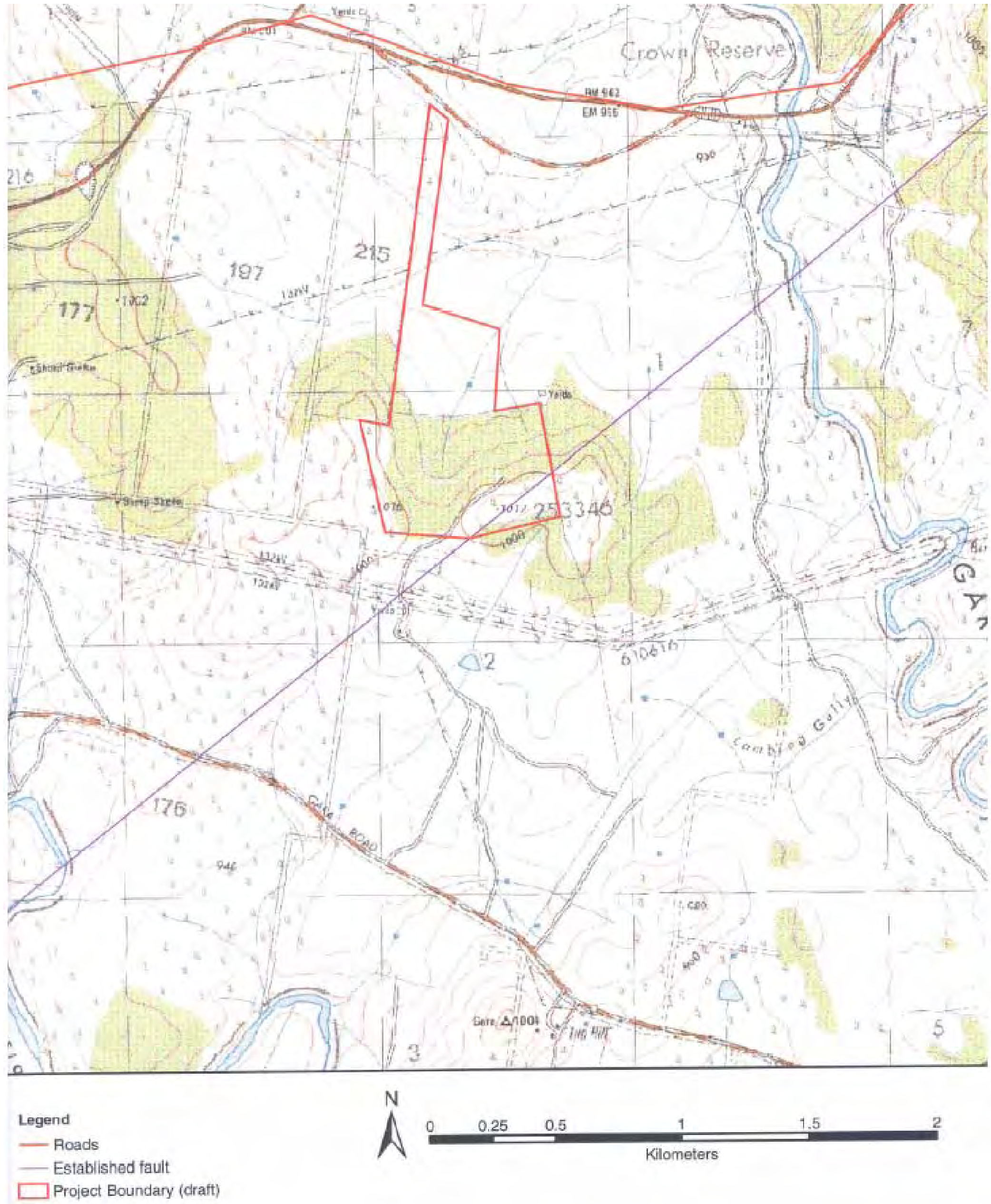

Figure 1: Portion of the Hillgrove 1:25 000 topographic map with the position of the proposed landfill site indicated by the red boundary. The projected trace of the fault indicated on the Dorrigo-Coffs Harbour 1:250 000 geological map is shown by the purple diagonal line. The term "established fault" in the legend was added by EA Systems. The term does not conform to that on the geological map which has the fault designated as "position approximate". The road towards the northern margin of the map is the Waterfall Way.

Using the available mapping and remote sensing data sets

Prior to the field mapping being performed, inspection of available data sets was undertaken. This entailed examination and interpretation of geological and topographic features from the 1969 and 1992 geological maps, the published Hillgrove 1:25 000 topographic map, air photo (supplied by EA Systems) and Landsat

TM imagery (supplied by the Geological Survey of NSW). The latter organisation also gave access to imagery from the magnetic and radiometric survey performed in 2001, and a digital terrain model image.

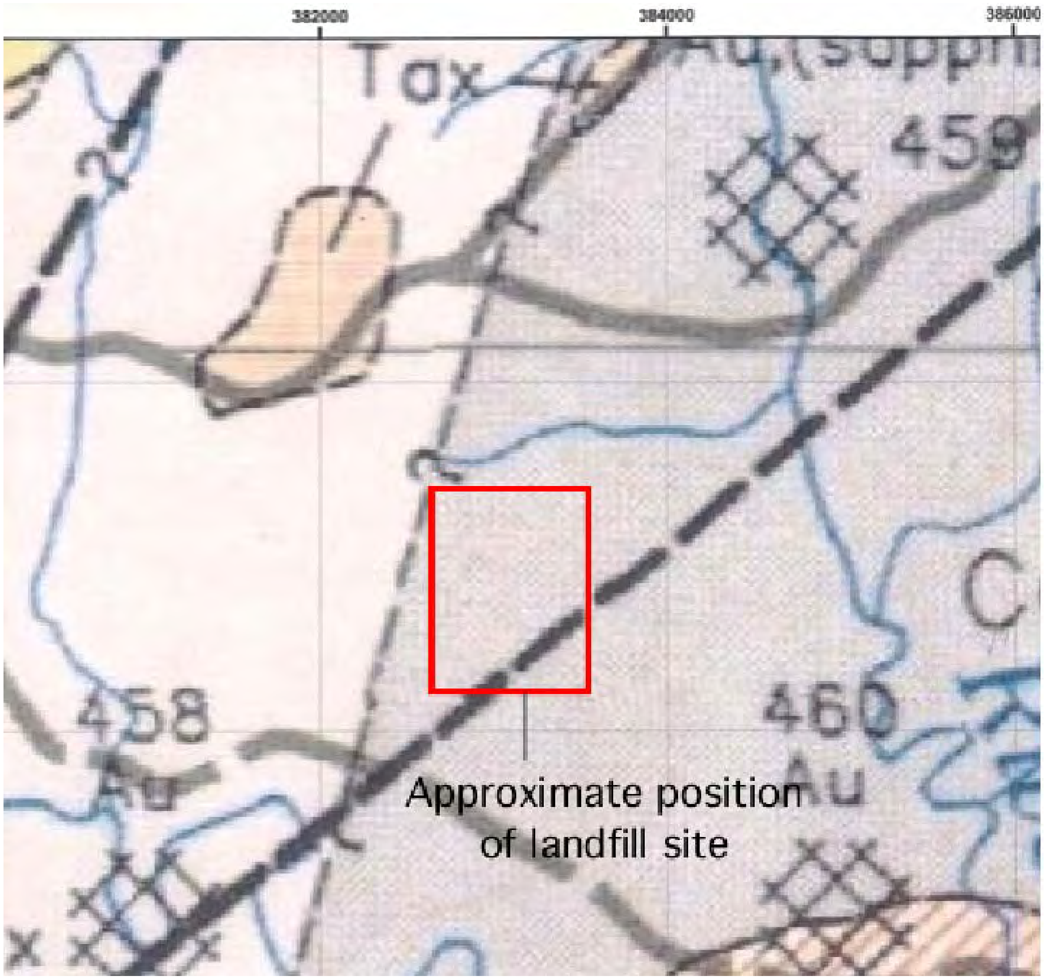

Figure 2: Portion of the Dorrigo-Coffs Harbour geological map (Gilligan et al., 1992), with the approximate position of the landfill site superimposed. The fault symbol (dashed diagonal line) designates "position approximate" on the published map. The pale mauve shading is designated as Girrakool Beds on the geological map.

Although the 1992 Dorrigo-Coffs Harbour regional geological map indicates that the rock unit underlying the landfill site and environs is the late Palaeozoic age Girrakool Beds, the most recent interpretation by Brown (2003), based on the geophysical data, indicates that the rocks are most likely part of the late Palaeozoic Sandon Beds, a unit of low grade metamorphosed and folded deep marine sedimentary rocks that crop out extensively in the central and western parts of the New England region. The mapping performed at the landfill site and surrounds (see later) indicates that the rocks are most likely part of the Sandon beds as interpreted by Brown (2003).

Inspection of the following remote sensing data gave the following results:

a) air photo interpretation: no linears or other features are indicated in the topography to suggest the presence of a fault in the projected position (Fig. 3).
b) Landsat TM: same result.
c) Digital terrain model (DTM): There are no linears in the projected position or strike (050°) of the fault, although there is a single weak linear just southeast of the landfill site with a strike of 025° (Fig. 4).
d) Aeromagnetic survey image (first vertical derivative {1VD}): The survey area has its eastern boundary about 1 km west of the landfill site. However, weak northeast-striking linears are apparent to the southwest of the landfill site but cannot necessarily be interpreted as representing faults. They could well be representing subtle changes in rock type.
e) Airborne radiometric survey: Like the magnetic survey, the eastern boundary is about 1 km west of the landfill site. Data from the eastern-most portion of the survey area do not display any linear features and the variation in radiometric properties on the image is interpreted as reflecting differences in rock type, not a fault.

Figure 3: Aerial photograph of the landfill site and immediate surrounding area. The projected fault trace has been omitted, but it trends approximately northeast across the image from near the southwest corner to the northeast corner. The landfill site occupies much of the wooded area just left of centre. The image is approximately 2 km east-west. It is relevant to note that there is no topographic expression or photo-linear corresponding to the projected position of the fault.

As indicated above, there is no published information on the rationale for the fault trace being shown on the geological maps. It is speculated that it might represent a linear feature interpreted from air photos, perhaps by geologists or geology students at the University of New England in the late 1960's.

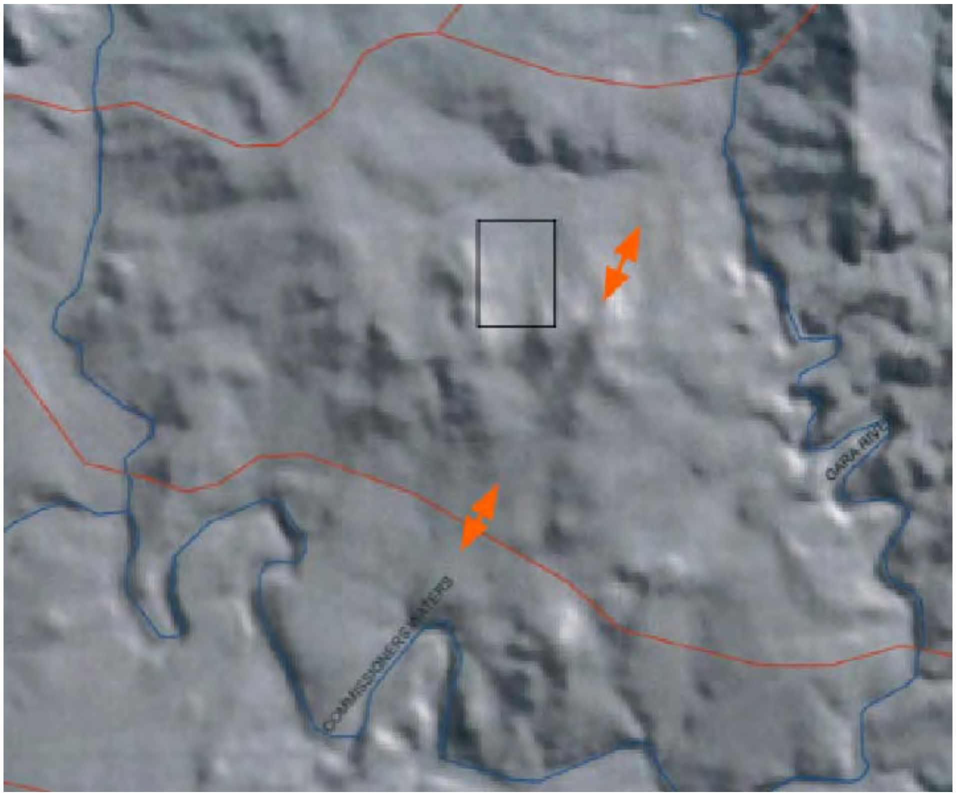

Figure 4: Portion of the digital terrain model supplied by the Geological Survey of NSW, covering the area of the landfill site (shown approximately by the rectangle) and surrounds. A single weak linear (indicated by arrows) is evident to the southeast of the site, but has a strike of ~025°, whereas the projected fault has a strike of ~050°.

Anticipated indicators of the presence of a fault from surface mapping

If there were likely to be an underlying fault, or zone of faulting, one or more of the following criteria might be anticipated to occur, and be recognisable assuming that there is sufficient surface outcrop:

1) evidence of shearing, fracturing, brecciation or stronger cleavage development in the rocks, particularly that having a NE-trending strike (consistent with the strike of the proposed fault line).
2) evidence of hydrothermal alteration focussed along a fault (might change the texture, mineralogy, colour and competency of the rock).
3) abrupt changes in rock type, or in structural style, e.g. bedding or cleavage orientation.
4) topographic evidence. e.g. presence of a linear scarp, or depression (valley). Topographic indications might be expected if there had been geologically relatively recent motion on a fault (e.g. in the past few tens of millions of years).

Methodology for surface mapping

Following the acquisition of maps and remote sensing data sets, surface mapping was performed at the landfill site and its surrounds on January 31 and February 1, 2006. Mapping was guided by an aerial photo and the topographic map and plotted in the field at a scale of 1:12 500. Mapping was performed by traversing, with recording of rock type and structural data in detail at 34 locations, with many other casual observations. Structural measurements had strike directions measured with respect to magnetic north (about 12° east of true north). These are designated by the suffix “M” in the text. Locations were recorded by GPS and several photographs were taken of lithological and structural features. The total area covered by the traverses was approximately 3 km^2, but covering a roughly elliptical area 4 km long and up to 1.2 km wide, elongate in an approximately northeast direction, largely between Commissioners Waters and the Gara River (Fig. 5). Mapping was performed at the main landfill site and on the surrounding properties of Waters, Crisp and Quaife.

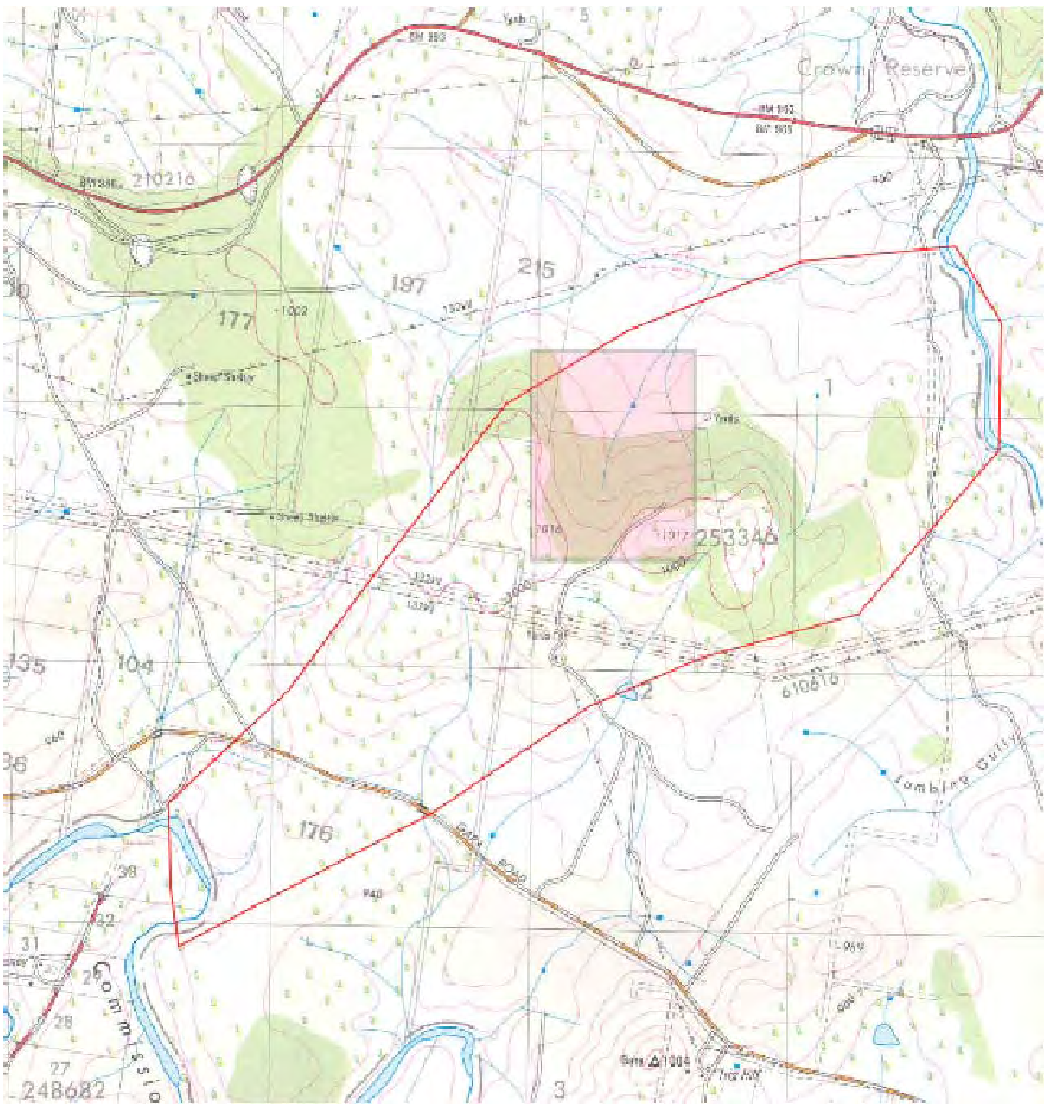

Figure 5: Area mapped (red boundary), with approximate site of landfill site (pink).

Results

Rock types and regolith

The relatively detailed mapping at 1:12 500 scale produced a different picture of the rock types than what is conveyed by the published geological maps. The underlying substrate rocks are interpreted to be part of the Sandon Beds (rather than Girrakool Beds) because of the presence of thick (hundreds of metres) packages of medium to coarse grained greywacke. This forms one of the two main lithological suites of the area, viz: massive to weakly foliated greywacke (Fig. 6), apparently intercalated in places with siltstone and mudstone-argillite and very minor chert. The greywacke-dominated association crops out mainly to the west (Commissioners Waters to just west of Crisp's homestead) and in the northeast (Gara River area and northeast of the landfill site) (Fig. 7). The other lithological package largely occupies the central part of the area, including the landfill site (Fig. 7). It is dominated by fine grained mudstone-argillite and chert (Fig. 8). Although the latter rock crops out prominently (e.g. forming many hilltops), it apparent abundance may be exaggerated because it is resistant. Several outcrops of chert form linear masses with a strike of 330°-340°M. This orientation is parallel with rare weak, steeply dipping bedding phenomena observed in some greywacke outcrops and suggests that the overall rock package may have a northwest to northerly strike and is steeply dipping. This is obviously at variance with the strike of the projected fault.

Figure 6: Weakly cleaved greywacke at grid reference 381682mE, 6617358mN. Strike of cleavage is 010°-015°M.

On the southeastern, southern and southwestern sides of the hills forming the southern margin of the landfill site, there are several poorly outcropping areas of interpreted Tertiary age sedimentary rocks (ferruginous and siliceous cemented quartz-rich gravel {conglomerate} and sandstone, along with a few masses of ferruginous cemented transported regolith (Figs 7, 9). These sedimentary materials appear to form only a thin, discontinuous veneer (up to a few metres thick) resting unconformably on the Sandon Beds. They probably represent remnants of former fluvial deposits. Closely associated with the Tertiary sediments about 0.5 km east of the Crisp homestead, there is a small (50-100 m diameter) mass of Tertiary basalt (Fig. 7), perhaps representing an erosional remnant of a lava flow or small intrusion.

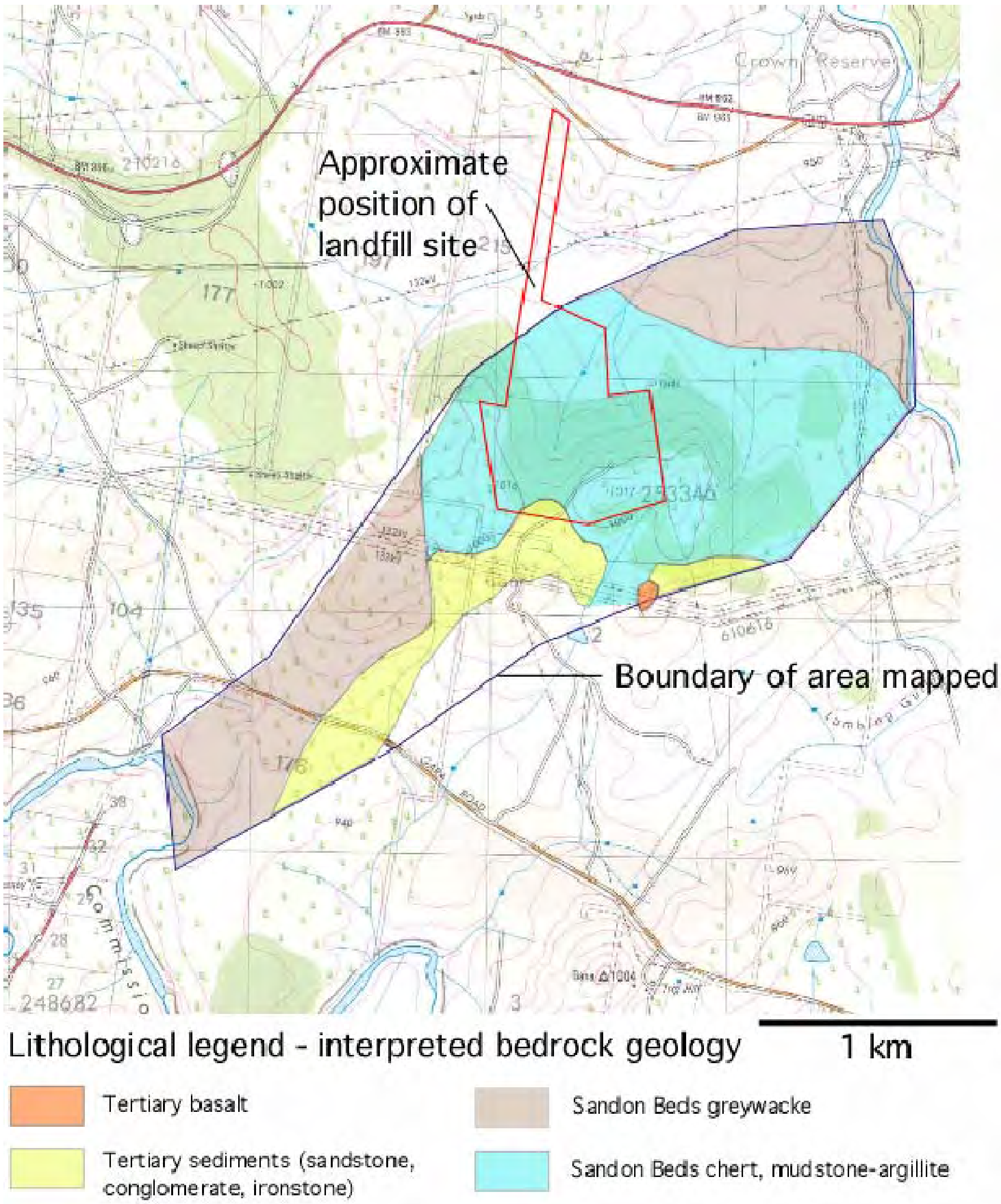

Figure 7: Bedrock geology (rock types) interpreted from reconnaissance mapping, including the area of the landfill site.

Figure 8: Fractured chert, with associated sheared zone in cherty mudstone (centre) at grid reference 383750mE, 6618650mN. Strike of foliation is 060°M.

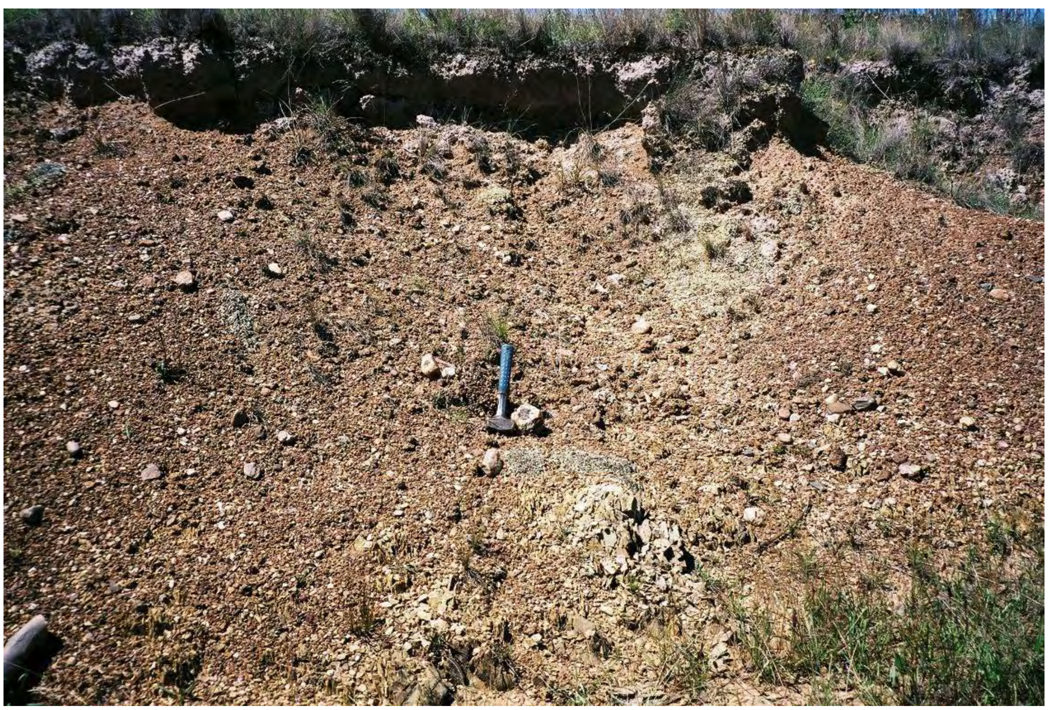

Figure 9: Cleaved greywacke-siltstone (bottom of image) overlain by transported Tertiary gravel and ironstone regolith at grid reference 382206mE, 6617524mN. Strike of foliation in bedrock is 020°M.

Structures

Many outcrops in the mapped area display some form of structural fabric. Measurements of the strike orientation of the various fabrics are listed in the Appendix. Fabrics include a moderately developed cleavage in the finer grained rocks such as mudstone-argillite, fracture sets and locally anastomosing cleavage in chert-mudstone package (Fig. 8), and weak cleavage, grading to a faint elongation of outcrop pattern, in the greywacke (Fig. 6). Sedimentary bedding layering is very rare and is mainly inferred from orientation of chert outcrops. Penetrative structures such as cleavage and fractures display a relatively narrow range of orientations, mostly between 005°-060°M (Figs 10, 11). Of the 58 structural measurements made, 50 fall within this sector and all have steep dips (>70°). The remaining 8 structural measurements fall in the sectors 315°-340°M and 060°-070°M, with some of these being possible bedding orientations. The average orientation of the main array of measurements is 028°M, with a statistical peak at 030°M (Fig. 10).

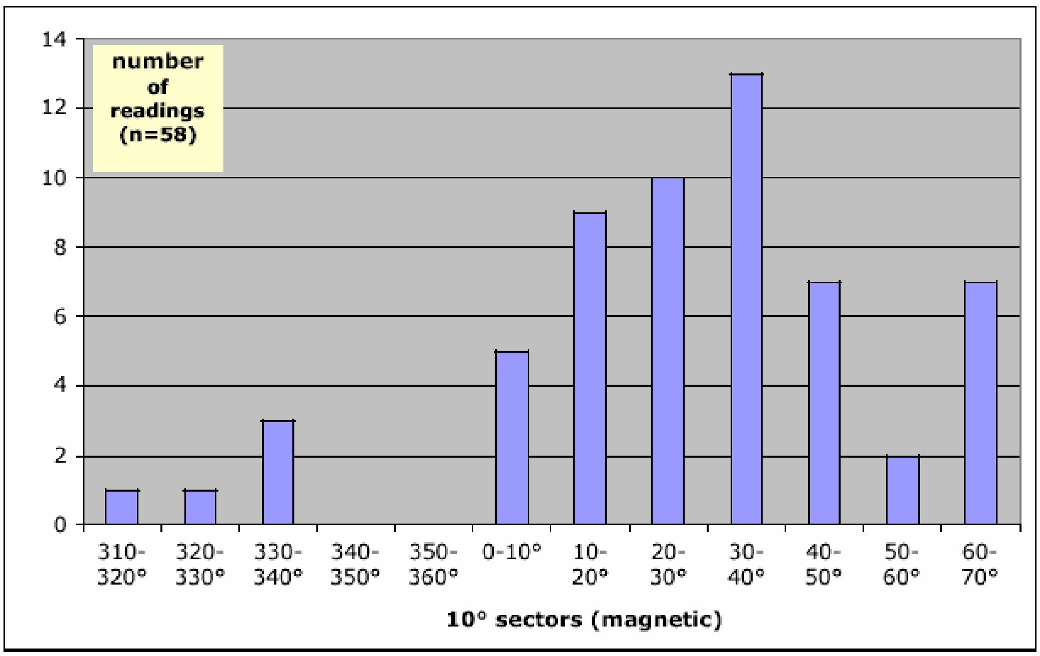

Figure 10: Histogram of azimuths (magnetic) measured from rock fabrics (cleavage, foliation, fractures, bedding, fault) in the area mapped. Note that the majority of measurements (50) fall into the sector 005°-060°M, with a mean value of 028°M (about 040° true north) and median value of 030°M (about 042° true north). The strike of the projected "fault" is approximately 052° true north.

Although the average orientation of the main array of measurements is similar to the strike of the fault shown on the Dorrigo-Coffs Harbour geological map, it is not co-incident. Converting the magnetic orientations to true north orientations, the average orientation is 040°, whereas the strike of the fault shown is 052°. In the projected position of the fault, surface outcrops do not display any increased concentration of penetrative structures, e.g. shear zones, stronger cleavage development, or of zones of brecciation or hydrothermal alteration. On the DTM (Fig. 4), there is a single weak linear feature (corresponding in the field to a shallow valley), with a strike of 025°.

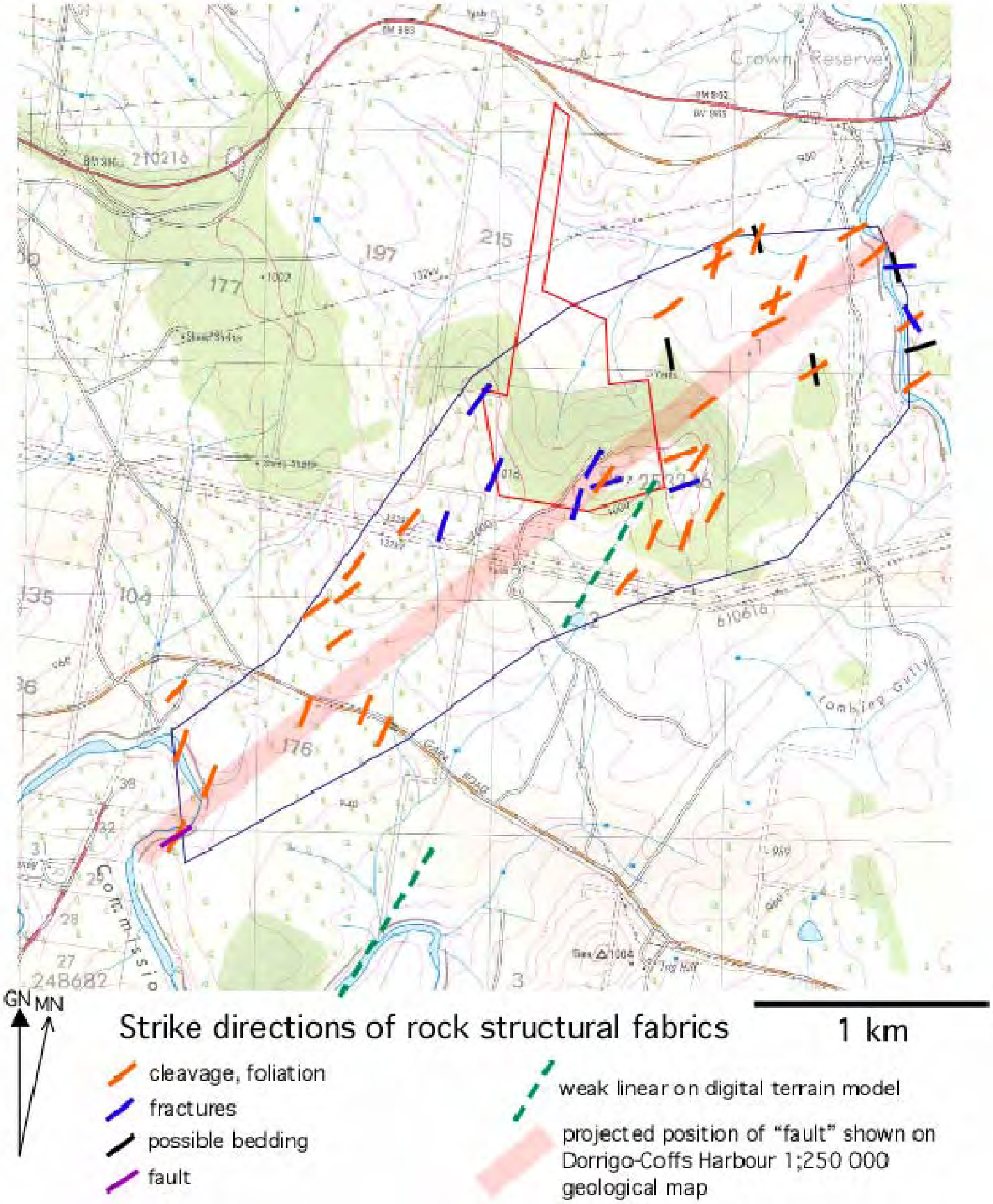

Figure 11: Strike directions of rock structural fabrics (cleavage, foliation, fractures, bedding, fault) in the area mapped (blue boundary). Also displayed are the weak linear from the digital terrain model (see Fig. 4), the projected position of the "fault" shown on the Dorrigo-Coffs Harbour 1:250 000 geological map and the approximate position of the landfill site (red boundary).

Sedimentary bedding phenomena are rare in the mapped area and are largely inferred from (a) orientation of a few of the elongate chert bodies, (b) possible steeply dipping thin bedding layers in the greywacke, (c) possible layering in "broken formation" mudstone-argillite and (d) boundaries between the greywacke-dominated and chert-mudstone-dominated sedimentary packages. It may be inferred from (a), (b) and (d) that bedding orientations strike largely north-northwest to northwest, although criteria from (c) along the Gara River could indicate steeply dipping bedding striking at 060°-070°M.

Evidence for or against a fault

From the detailed field observations and structural measurements, and the examination of remote sensing data and maps, it is interpreted that there is no well-defined fault in the vicinity of the landfill site. It is surmised that the fault shown on the 1:250 000 geological maps is not based on fact, at least in the regional surrounding the landfill site. It could have been inferred from some form of photo-linears to the northeast or southwest of the landfill site, but there is no explanation in published geological notes (e.g. Gilligan et al., 1992). Field observations do not support the occurrence of a fault. None of the following criteria were observed:

(a) Zones of stronger shearing or cleavage development co-linear with the projected position of the fault
(b) Zones of brecciation or hydrothermal alteration co-linear with the projected position of the fault
(c) Offsetting of rock units or changes in structural style across the projected position of the fault
(d) Topographic expression, e.g. a valley or a scarp

No field criteria could be confidently stated to be supportive of the presence of a fault. In places, the rocks of the landfill area and surrounds do have structural fabrics (e.g. cleavage, local fracture zones) that are within 10-15° of the projected fault strike, but these are no different to the same features at considerable distance (e.g. hundreds of metres) away from the projected position of the fault. In addition, the remote sensing data (air photo, Landsat image and DTM) are not indicative of a fault in the position indicated and projections of weak magnetic linears from the margin of the aeromagnetic survey area cannot unequivocally be considered as due to a fault.

Conclusions

Detailed field mapping and structural measurements, along with examination of publically available remote sensing and map data, did not show evidence of a fault in the area of the planned landfill site for Armidale Dumaresq Council and the surrounding region (up to 1-2 km away).

Although the sedimentary rocks forming the substrate to the area (greywacke, mudstone and chert) do contain weak to moderate cleavage, grading into a foliation, and regions of fracturing, they are not concentrated into any particular zone (e.g. co-linear with the position of the fault shown on the 1992 edition of the Dorrigo-Coffs Harbour geological map). It is considered that the fault shown on the map has no basis in fact, at least in the proposed landfill site area and for 1-2 km along strike to the northeast and southwest.

Acknowledgement

Nancy Vickery of the NSW Geological Survey, Armidale office, kindly supplied remote sensing imagery over the area of interest.

References

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Brown, R.E., 2003. Peel South Exploration NSW geophysics – interpretation of new data for exploration and geological investigations in the western New England area of New South Wales. Quarterly Notes of the Geological Survey of NSW, 114, 1-27.

Gilligan, L.B., Brownlow, J.W., Cameron, R.G. and Henley, H.F., 1992. Dorrigo-Coffs Harbour 1:250 000 metallogenic map. Metallogenic study and mineral deposit data sheets. New South Wales Geological Survey, Sydney, 509 pp.

Appendix

Record of strike measurements of rock fabrics (cleavage, foliation, fractures, bedding). Grid references conform with those on the published Hillgrove 1;25 000 topgraphic map. All azimuths are magnetic. All dips on fabrics are steep and range between 70°-90°.

Location	Easting	Northing	Strike	Type
1	383750	6618650	030-060	foliation
2	383835	6618646	035	foliation
3	383800	6618578	060	fractures
4	383945	6618439	020-035	foliation
5	383946	6618196	020-025	fractures
6	383632	6618022	035	foliation
7	383505	6618039	035	cleavage
8	383753	6618325	020-030	cleavage
9	383500	6618526	060, 025	fractures, foliation
10	383425	6618597	020	fractures
11	382981	6618548	010	fractures
12	382957	6618843	025	fractures
14	383388	6618849	010-015	fractures, foliation
16	382435	6617524	020	cleavage
17	382206	6617517	015-020	cleavage
18	382287	6617829	035	cleavage
19	382434	6618142	025-030	cleavage
20	382811	6618311	005-010	fractures
21	381693	6617609	030	cleavage
22	381682	6617358	010-015	cleavage
nearby			005-010	cleavage
23	381676	6616969	015	cleavage
nearby			040	fault, quartz vein
24	384160	6619240	050	cleavage

nearby			005, 050	cleavage
25	384041	6619588	005-010	cleavage
			330	?bedding
nearby			040	cleavage
			320	?bedding
26	383919	6619497	005, 040	cleavage
27	383778	6619272	040	cleavage
28	383690	6619068	335	?bedding
29	383885	6618816	035-040	cleavage
30	384371	6618980	335	?bedding
			030-060	cleavage
31	384570	6619591	030-050	cleavage
32	384661	6619497	330	?bedding
			070	fractures
33	384731	6619244	040, 315	fractures
34	384769	6619116	060-070	?bedding
nearby			030-040	cleavage