Geological and land instability mapping using a GIS package as a building block for the development of a risk assessment procedure

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Abstract

A modern land instability risk assessment procedure must include an accurate geological framework and land instability database. Geological and land instability mapping of the northern suburbs of the City of Wollongong represents a considerable challenge and is to be achieved using computer generated 1:4000 topographic base maps. Using an integrated series of techniques, including computer modelling of the escarpment geology and field mapping techniques, a new series of geological maps has been produced. Meanwhile an exhaustive land instability database of the region has been compiled. A flexible approach to mapping and data compilation is very useful and confirms the viability and resourcefulness of a computer based Geographic Information System package. The second stage of this research project (outside the scope of this paper) is the development and validation of a risk assessment procedure. Validation will generally involve steps to test the assessments on the basis of field observations.

Keywords

procedure, assessment, risk, instability, land, geological, building, gis, mapping, package, development, block

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Geological and land instability mapping using a G.I.S. package as a building block for the development of a risk assessment procedure.

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ABSTRACT: A modern land instability risk assessment procedure must include an accurate geological framework and land instability database. Geological and land instability mapping of the northern suburbs of the City of Wollongong represents a considerable challenge and is to be achieved using computer generated 1:4000 topographic base maps. Using an integrated series of techniques, including computer modelling of the escarpment geology and field mapping techniques, a new series of geological maps has been produced. Meanwhile an exhaustive land instability database of the region has been compiled. A flexible approach to mapping and data compilation is very useful and confirms the viability and resourcefulness of a computer based Geographic Information System package. The second stage of this research project (outside the scope of this paper) is the development and validation of a risk assessment procedure. Validation will generally involve steps to test the assessments on the basis of field observations.

1 INTRODUCTION

The city of Greater Wollongong, including the northern suburbs, is a major urban centre on the south coast of NSW with a population of approximately 300,000 people. A minimum of 164 past and present areas of suspected land instability and landslides are known within the Wollongong City Council (WCC) area. The individual landslides vary in size up to a maximum area of about 1800 square metres. Whilst accurate records are not available, at least 100 houses have been destroyed since the turn of the century by land instability. As well as affecting suburban areas, landslides affect the major road and rail transport routes which link Wollongong to Sydney and other regional centres (Bowman 1972, Pitsis 1992).

This paper relates to a research project which includes the preparation of an accurate geological and land instability database for the northern suburbs of Wollongong. The results of this work will, ultimately, be presented in a map format with an accompanying thesis. In subsequent research these maps will be used to develop a land instability risk assessment procedure which is to be validated on the basis of field inspections and case studies. The project has been carried out within a flexible framework so that it can be developed, expanded and improved in the future. This has been achieved by compiling both the geological and land instability data into a Geographic Information System computer package (GIS), from which the maps are then produced.

The description of the risk assessment procedure, the second phase of this research, is outside the scope of this present paper.

2 GEOGRAPHIC AND GEOLOGICAL SETTING

Wollongong is situated on the coast approximately 80km south of Sydney (figure 1). The city is nestled in a narrow triangular coastal plain flanked on the east by the Pacific Ocean and on the west by the steep slopes topped by sandstone cliff lines which together comprise the Illawarra Escarpment.

The WCC area of 715 square kilometres includes a highland plateau area to the west of the escarpment topped by a near vertical sandstone cliff line which grades down to the east into terraced lower slopes. The eastern and southern margins of the district comprise a coastal plain.

The Sydney Basin comprises a basin sequence of dominantly sedimentary rocks extending in age from approximately Middle Permian to at least Middle Triassic. The study area lies on the south eastern margin of the Sydney Basin (figure 1).

The geological bedrock sequence of the Illawarra district is essentially flat lying with a low angle dip, generally less than five degrees, towards the northwest. This gentle northwesterly dip, whilst superimposed by relatively minor syn-depositional and post-depositional structuring (folding and faulting) is a result of the relative position of the district on the southeastern flanks of the Sydney Basin (figure 1). Normal faulting within the Illawarra area is common, although the fault throws infrequently exceed 5 metres. The structural geology of Wollongong, Kiama and Robertson, mapped on 1:50000 sheets, has been discussed in detail in Bowman (1974).

Figure 1. Study Area location plan showing the extent of Triassic and Permian sediments of the southern half of the Sydney Basin.

The geological units encountered within the district, in ascending order, include the Illawarra Coal Measures (locally including intrusive bodies collectively known as the Gerringong Volcanic facies), the Narrabeen Group and the Hawkesbury Sandstone. A generalised Illawarra Region stratigraphic profile is displayed in Figure 2. The geology of these units has been discussed at length in several previous publications such as Bowman (1974) and Herbert and Helby (1980).

AGE	GROUP	SUBGROUP	FORMATION
			Hawkesbury Sandstone
TRIASSIC			Newport Formation
	NARRABEEN GROUP	CLIFTON SUB GROUP	Garie Beach Formation
			Bald Hill Claystone
			Bulgo Sandstone
			Stanwell Park Claystone
			Scarborough Sandstone
PERMIAN			Wombarra Claystone
			Coalcliff Sandstone
	ILLAWARRA COAL MEASURES	SYDNEY SUB GROUP	Bulli Seam
			Eckersley Formation
			Wongawilli Coal Seam
			Kembla Sandstone
			Allans Creek Formation
			Darkes Forest Sandstone
			Bargo Claystone
			Tongarra Coal
			Wilton Formation
		CUMBERLAND SUB GROUP	Erins Vale Formation
			Pheasants Nest Formation

Figure 2. Generalised Stratigraphic Column of the northern Illawarra District.

The Illawarra Coal Measures contain numerous economically significant coal seams. Of these, the most notable are in descending stratigraphic order the Bulli Seam, the Balgownie Seam, the Wongawilli Seam and the Tongarra Seam. These coal seams are often associated with some cases of land instability.

Extending from near the base of the upper cliff line to the waters edge in most parts of the district, the ground surface is covered by debris of colluvial origin. This material comprises variably weathered bedrock fragments supported in a matrix of finer material dominantly weathered to sand, sandy clay and clay and brought downslope under the influence of gravity.

3 METHODOLOGY

As a major sponsor of this project, the Wollongong City Council has made some of its computer facilities available for this project. The council uses Genasys II Australia Pty Ltd’s Genamap GIS application running on various HP platforms in combination with an Ingres database. The GIS system employs cadastral information as the central spatial reference. The contours have been supplied by the Central Mapping Authority (CMA) via the Land Information Centre at Bathurst and have been determined photogrammetrically at a 2m contour interval. International Survey Grid, Australian Map Grid and latitude longitude coordinate systems are available.

Maps with a scale of 1:4000 have been used as map bases during this research and cover the entire Wollongong City Council urban area in 76 map sheets, including 33 map sheets covering the subject area (figure 3). Experience of working in the local area on a wide variety of engineering geology projects has confirmed that the 1:4000 CMA maps are reliable and accurate. The 2m contour interval and specific contour form present an accurate map for desktop overview type purposes. Whilst the maps are no substitute for detailed site surveys, they provide an excellent supplement once site work commences.

Computer modelling of the escarpment geology has been achieved based on these 1:4000 maps using geological stratigraphy obtained from boreholes drilled (both prior to and after Bowmans research) between the coastline and two kilometres west of the escarpment. The boreholes were primarily coal exploration boreholes researched from the libraries of mining companies such as Broken Hill Pty Ltd, Kembla Coal and Coke, and Shell. Information from some boreholes concerned with geotechnical investigations has also been incorporated in the mapping.

4 LAND INSTABILITY DATABASE

All known cases of instability within the subject area have been recorded on the 1:4000 sheets. In addition to these maps, a tabulated summary with references for each case has been compiled.

The mapped record of instability represents a compilation of works (such as site plans, photographs and descriptions) prepared by other workers. It must be noted here that drafted margins of possible land instability are time-dependant features and must be subject to periodic review. Hence the drafted extent of possible land instability , as shown in the maps should be considered as depicting only a stage in the development of landsliding or hillslope movement.

5 GEOLOGICAL MAPPING

An integrated series of techniques have been used which include, computer modelling, field mapping and inference from existing maps. Each of these techniques is discussed below.

5.1 Computer Modelling.

Iinitially the subject area has been subdivided into eight fault confined discrete geological blocks based on the presence of major faults (ACIRL 1989). During the modelling and field mapping work the faults have been shown as vertical. The faults are shown at the surface in the same position at which they have been encountered at depth in the Bulli/Wongawilli Coal seams, unless field evidence suggested otherwise.

Borehole information (including ISG coordinates, borehole collar relative level, stratigraphic profile, hole depth and date of drilling) was entered into an Ingres data base. The database contains 124 boreholes and major faults. The data base comprises of the most accurate data that was accessible.

Where a sufficient density of stratigraphic information was available, computer generated stratigraphic surfaces were produced by passing a surface through the relevant formation tops from each borehole site within a fault isolated block. This technique involved interpolation only (kriging then triangulated irregular network - TIN - modelling, Bonham-Carter 1994) between known real points. Three horizons, the base of the Stanwell Park Claystone, Base of the Bulli Coal and the base of the Wongawilli Seam were contoured by this method over five of the 1:4000 map sheet.

Each contoured stratigraphic surface was then examined on graphical workstations by an array of cross sections whereby an extrapolated or interpolated intersection point (subcrop) with the natural surface of the escarpment was digitised. The cross sections were set out approximately perpendicular to the escarpment at 500m centres.

Where a sufficient density of stratigraphic information was not available to generate a contoured stratigraphic surface, simple cross sections based on borehole stratigraphy were generated. A stratigraphic profile thus generated was extrapolated/interpolated to the various intersection points (subcrops) with the natural surface of the escarpment. Each subcrop point was digitised. The digitised (subcrop) points were then plotted out in plan form. The points provide a guide to stratigraphic positioning at various intervals along the escarpment. Each consecutive point is joined by an outcrop/subcrop line typically running parallel or subparallel to the contours producing a computer generated geological map.

5.2 Geological Field Mapping

Field geological mapping within the district is severely limited due to the lack of outcrop, dense vegetation cover and limited access. However, the standard practice of geological mapping has been undertaken where conditions permit. Field mapping was carried out directly onto the 1:4000 map sheets, using the CMA orthophoto (contours superimposed onto a dyeline black and white photograph) sheets to assist field positioning.

5.3 Inference

In areas where no field mapping and/or no borehole data was available the positions of geological boundaries have been inferred on the basis of either previous mapping by other workers and/or topography shown on the 1:4000 sheets.

5.4 Mapping of areas of Land Instability

The areas of land instability were based on the reports supplied by various sources such as the Wollongong City Council, the State Rail Authority, the Roads and Traffic Authority, the work of Pitsis (1992), private geotechnical consulting firms and private landowners. Reference to events and investigations were also found from newspaper reports (notably the local daily Illawarra Mercury). Reference was also made to photographs and accompanying descriptions in the technical literature including university theses. Field mapping was also facilitated by the availability of some aerial stereo pair photographs. Interpretation of such stereo pairs was useful and was helped by knowledge of the local area and its recent history.

The maps completed using the techniques outlined above have been designated the Geotechnical Landscape Map Series. This series comprises thirty three 1:4000 map sheets which together combine to cover the northern suburbs of the greater Wollongong area. Figure 4 shows a GIS plotted reduced scale copy of Map G11, one of these thirty three map sheets.

CONCLUSIONS

The paper highlights the importance of a valid geological model, including the extent and accuracy of the information on which it is based. Information used in generating the geological model is limited by the extent to which major investigations have been carried out and the availability of the information.

A reliable and accurate geological framework has been developed and an up-to-date land instability database has been compiled. The borehole and land instability databases can be adjusted and corrected, and additional data can be added when it becomes available. This will increase the accuracy and reliability of the computer model and of the related maps as and when further updating is carried out in the future.

The project can now move forward to the development and validation of a risk assessment procedure for land instability. Validation will generally involve steps to ground-test predictions or assessments on the base maps.

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