Interim Report
on
The Geology of The St Andrews Property, Yanchep-Two Rocks District.
by
Logiden Pty Ltd
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THE REPORT

Aims and Karst Focus

This report is the result of geological study carried out in the southern part of the St Andrews Property, during January 2007. The study was to assess risks related to the observed presence of extensive karst landforms.

The study consisted of a field project involving geomorphic analysis and exploration of subsurface conditions by means of test wells and ground-penetrating radar. Later office study involved analysis of field data and integrated to provide the basis of an understanding of the subsurface stratigraphic and geohydrologic environment.

The study has confirmed earlier findings:- that in the case of the St Andrews Property, planning for development should involve comprehensive, integrate geomorphic analysis, exploration drilling and geophysical studies. The broad objectives of such work being the definition of karst domains undesirable as foundations; as against sandy, post-karst domains with stable subsurface conditions.

Karst features including caves and tunnels, troughs, scarps and pinnacle fields and have been of central interest in the present analysis of subsurface features. The study had reveal that the eastern part of the Property contains numerous caves. Analysis of the regional geohydrology also indicates the high probability that there are cave networks beneath the western part. These caves deliver groundwater to the sea.

Karst & Urbanisation

Karst terranes originated through leaching of soluble rocks, such as calcarenite (a variety of limestone) by percolating groundwater. The leaching and related mass loss results in cave development with consequences that includes meter- to hectometer-scale subsidence and foundation instability. In the context of centuries-long urban development there is an enduring risk of foundation failure with a range of probabilities from single, hectometer-scale collapses to sequential subsidence in small-scale events. Sub-surface karst features such as pinnacle fields and caves also are costly impediments to building and infrastructure installation.

Karst terranes also are notoriously prone to groundwater contamination and subsequent rapid transmission of concentrated pollutants to distant sites, via cave networks. This is a concern in that the St Andrews Property lies across westward flow path from the Gnangara Mound. Global experience is that voluminous abstraction for water-supply purposes, accelerates karstification and attendant instability. Decline of groundwater tables is reported in the Yanchep district and there are plans for voluminous abstraction as part of a regional water supply scheme (Davidson, 1994).

THE PROPERTY

Geomorphology

The Property lies within a highly pitted karst plateau that is underlain by a 45m-thick foundation composed of quartzose, sandy limestone. The formation, which has been termed the “Yanchep Calcarenite” consists of weakly lithified limestone composed of sand-size skeletal fragments of marine organisms and significant percentages of quartz grains. The formation It is about 45m–thick and overlies west-sloping unconformity on Cretaceous-age formations that mostly are aquicludes. The karst base is at about -22mAHD under Lot 202 and Lot 203 in the east and is at about -30mAHD at the coast.

The Terrane is characterized by a widespread development of kilometer-scale karst troughs and plateau remnants; sinkholes of various dimensions, caves and pinnacle fields. Areas of this karst terrane are obscured by meter-thick blankets of residual quartz sand while other parts are bare with rock outcrop, sinkholes, pinnacle fields and caves. Mostly remnants of the karst top lies at an elevations between 30mAHD and 40mAHD.

Covered-karst landscapes dominate in the central part of the Property. Here the underlying Calcarenite foundation is obscured by thick blanket of residual sand or and occasionally by younger, 10m-high parabolic dunes and meter-thick sheets of the Holocene, Quindalup Fm. The Calcarenite foundation crops out on some ridges but most high points are Quindalup dune crests at elevations between 30m and 60mAHD. Hectometer-scale karst troughs and karst stopes are at 10m to 15mAHD. In the central area of there are a number of hectometer- to kilometer- scale, sub-circular closed basins with floors at some 10m to 15m below the general level. These large basins are suspect cover-collapse- or cover-subsidence sinkholes that may reflect presence of cavernous voids in the underlying limestone.

Bare-karst landscapes are characterized by rocky surfaces with irregular soil veneers, abundant sinkholes and occasional dolines. The largest bare-karst area occurs in a 3km-wide zone west of Lot 202, in the Lot 203 reserve and in the Yanchep National Park. Bare-karst areas also are common in various coastal localities where there are steep descents to the shore.

Geohydrology and Caves

There are abundant caves in the area east of the Property and analysis of the regional geohydrology indicates the high probability that there also are caves beneath the western part.

The Yanchep Calcarenite functions as a conduit for flow of pressurized groundwater from the Gnangara Mound to the sea. The overall head is about 40m. There are reports of fresh-water discharge in offshore areas, which if correct, indicate voluminous outflow from seafloor caverns that are sourced in the Property (Davidson, 1996).

The Gnangara groundwater mostly enters the Calcarenite along a NNW–trending, 3km-wide intake zone that lies east of the bare-karst outcrop zone. The intake contains in southward sequence:- the western side of the Lot 201/202 depression, Loch McNess, Yonderup Lake, Pipidinny Swamp, the Mindarie and Carabooda and Nowergup Lakes. Water levels in the intake area descend from 16mAHD at Nowergup to about 7m AHD in Loch McNess. The situation is one where there is high potential for extensive occurrence of karst features and for on-going karstification in the area downslope.

English *et al* (2000) cite 315 caves in the Yanchep National Park of which 46 contain pools or seeps. These caves are sub-horizontal reflecting dissolution along bedding surfaces in the Calcarenite. They are several meters to a decameter in height and contain speleothems, cave sediments and collapse breccia. Some caves lie in the phreatic zone and some have decimeter-deep water streams while others lie in a meters-thick damp, transitional zone; others lie in the vadose zone. This is a situation reflecting cave genesis in declining water-table conditions and is a natural phenomena related to cave development and consequent acceleration of drainage.

There also are caves in the western part of Lot 202, that apparently direct phreatic drainage westward to the Lot 203 reserve along the northeastern border of the Property. In Lot 202 a cave with a height of 9m and a 2.5m deep pond, at a level of -3.4mAHD. was encountered Several test wells also have revealed cavities up to 1m to 2m high. These features are in the western part of Lot 202 and are in the phreatic zone where the Calcarenite foundation is immersed in the Gnangara aquifer.

Unfortunately the data on caves in the central and western part of the Property is sparse. The recent test drilling and GPR traverses has revealed two 4m-high caves in the central part of the Property. These caves about 2km from the coast and lie in SSW-trending linear depressions that may be partly filled-karst tunnels.

METHODS & RESULTS

Test Wells

Ten test wells were drilled by air-core technique. Average well depth was 45m and the total project meterage was 451m. The wells were logged with attention to presence of cavities, location of the groundwater-table and the depth (sgl) of the karst-formation base.

Ground-Penetrating Radar (GPR)

Ground Penetrating Radar is a means of identification and charting of sub-surface features on a 2D, and possibly 3D basis. A GPR survey of about 10km length was carried out in accessible areas to north and south of the Yanchep Road. GPR charting provides a better than 0.5m-level of precision in respect to sub-surface boundaries. GPR applications require precise control on location and level in respect to survey lines. Spatial control was provided by Fugro Spatial Solutions using differential GPS. The operator, Georadar Research also exerted control on a peg-to-peg basis during traverses. The GPR charts were interpreted by Logiden Pty Ltd.

The maximum penetration depth was about 21m. The charts revealed fine details of sub-surface features including:- i) contacts between the Spearwood Sand (Soil) and underlying Yanchep Calcarenite; ii) profiles of the superficial Quindalup dunes; iii) zones of intense karstification and; iv) possible cave-roof features. Unfortunately a 21m sgl penetration limitation, precluded scans of the Yanchep Calcarenite karst-base zone that has been defined in bore holes as between 25msgl to 45msgl.

Geomorphic Analysis

Geomorphic analysis showing the distribution of landforms and geohydrologic terranes is essential or planning and property development. Unfortunately the database for such analysis in the Yanchep District has been sparse and as a consequence there have been erroneous interpretations in some early publications.

The analysis of the St Andrews Property commenced with a brief desktop study by Logiden (2006) based on historical data from Gozzard, (1982) and CALM (1986). The scope of the analysis has been extended with the recent availability of an ortho-image with a superposed 5m-contour grind. The landform analysis also has benefited from the availability of sub-surface data from the GPR projects t. The outcome has been new insights and understanding of landscape in the Property.

CONCLUSIONS

The present study has confirmed earlier findings and indicate that planning for urban development in the St Andrews Property should involve comprehensive, integrate geomorphic analysis, exploration drilling and geophysical studies since there is a high probability of the occurrence of cave networks. There also are other impediments to development such as extensive pinnacle fields.

In the Property, there also are post-karst areas that are underlain by decameter-thick sections composed of residual quartz sand and thus stable and suitable for urban development. The parameters of the residual sand blanket are poorly defined; observations being from a few boreholes and sand pits. Some sandy domains contain extensive pinnacle fields. Pinnacles are tower or spire-shaped, rock pillars that rear-up meters to decameters through residual sand

above the parent calcarenite foundation. They usually are sub-circular and diameters range widely from a few centimeters to several meters. Pinnacles, between 0.5m and 5m high are common in the terrains where they mostly lie hidden in the overlying residual soil. Characteristically, pinnacles occur in extensive fields. In such fields, pinnacle frequency is between 3000-5000/ha.

Pinnacle fields present impediments to development particularly in respect to installation of sub-surface infrastructure involving trenching and drainage. There also is some question as to their bearing strength is respect to large structures. The question mainly relates to the fact that in areas of advanced decalcification, pinnacles do not descend to the karst foundation but are supported only in sand.

In the context of urbanization the overall questions concerning any locality in the Property are:- i) whether the karst process has advanced to the stage where the foundation is now mostly thick, residual quartz sand and thus suitable for urbanization or, ii) the area is underlain by caverns and residual karst and thus undesirable as a foundation for buildings and infrastructure.

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