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The importance of a multi-faceted approach to desktop studies

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ABSTRACT

The use of varied desktop reconnaissance tools allows for effective identification of locations that warrant specific attention to enhance field studies. This is illustrated by a mapping project for over 25,000 ha of mixed rural and urban land identified for potential future urban growth within the Kaipara District in Northland. The project commenced with a high-level desktop study identifying focus points across eight study areas. Stereoscopy, published geology maps, historical aerial photographs, subsurface test logs from the New Zealand Geotechnical Database, Google Earth and GIS were all used during the desktop study. Aided by the extensive desktop mapping data, the field study focused on identification and corroboration of geomorphological features and potential geotechnical hazard zones. Land-based mapping and photography, as well as drone photography, was used to gain varying viewpoints of features and wider areas of focus. Project-specific GIS was used to produce slope angle, inferred slope stability, liquefaction potential, consolidation settlement potential, acid sulphate soil potential, on-site effluent disposal potential and combined geohazard maps for the study areas. This holistic approach to desktop studies allows for effective data and risk interpretation which, when presented appropriately, may assist in informing policy, planning and development.

1 INTRODUCTION

The importance of a robust, multi-faceted approach to desktop studies prior to embarking on a field mapping exercise for large areas was illustrated during a mapping project for over 25,000 ha of mixed rural and urban zoned land identified for potential future urban growth within the Kaipara District in Northland. The study was commissioned by Kaipara District Council (KDC) to provide a high-level understanding of the geotechnical constraints to future land development within the Kaipara District, to inform planning strategy and consent application reviews within Council.

The project commenced with a high-level desktop study of eight “Indicative Growth Areas” (IGAs), which were defined by KDC. The desktop study was used to identify key locations (focus areas) that warrant further attention to characterise the land in terms of geotechnical risk, and these were flagged for ground-truthing and further specific background research.

Stereoscopic aerial photographs, published geology maps, historical aerial photographs, borehole records, Google Earth and GIS were all used during the desktop study to develop a broad geological model and to identify focus areas. The field investigation was secondary to the desktop study, and concentrated on identification and corroboration of geomorphological features and other potential geohazards within the IGAs. Land-based mapping and photography, as well as specifically targeted oblique angle drone photography, were used to gain varying viewpoints of features and areas of focus. The data was collated and GIS was used to produce maps showing slope angle and the inferred slope instability, liquefaction, and consolidation settlement potential resulting in combined geohazard maps for the IGAs; Acid sulphate soil potential and on-site effluent disposal potential were also mapped independently of the combined geohazard map. This multi-faceted approach to desktop studies allows for risk interpretation for large study areas which, when presented appropriately, can assist in informing policy, zoning, planning and development.

2 DESKTOP STUDY

The study commenced with a high-level desktop assessment using a range of methods to assess each of the IGAs and to identify focus areas for the field mapping phase. The preliminary maps developed during the desktop study were used by the field geologists to target the focus areas during the limited available time in the field. The various desktop study tools are summarised in the following sections.

2.1 Geological Maps

The geological settings of the IGAs were established through a review of the Institute of Geological and Nuclear Sciences (GNS) 1:250,000 map (Edbrooke and Brook 2009), and supplemented by a site walkover to observe the landform and outcrops, where accessible. Although the QMAP series are a widely accepted account of the surface expression of geological units across the country, at a regional 1:250,000 scale, the detail and accuracy of unit boundaries and structural features are indicative only. Northland Regional Council 1:100,000 soil and rock type maps (Sutherland et al 1980, Crippen and Markham 1981) are also available for some of the IGAs.

The IGAs are underlain by many different geological formations including Tauranga Group alluvium and Kariotahi Group dunes, Waitemata Group and Te Kuiti Group sedimentary strata, Kerikeri Group volcanics, and the structurally complex Northland Allochthon; all of which exhibit highly variable strength and weathering characteristics, and corresponding geotechnical properties.

The geological maps were integral to the desktop study in that they provided a base map and framework to highlight the areas which may be prone to liquefaction and consolidation settlement, and/or formations that are prone to instability. The geological map of the Omamari IGA is shown in Figure 1.

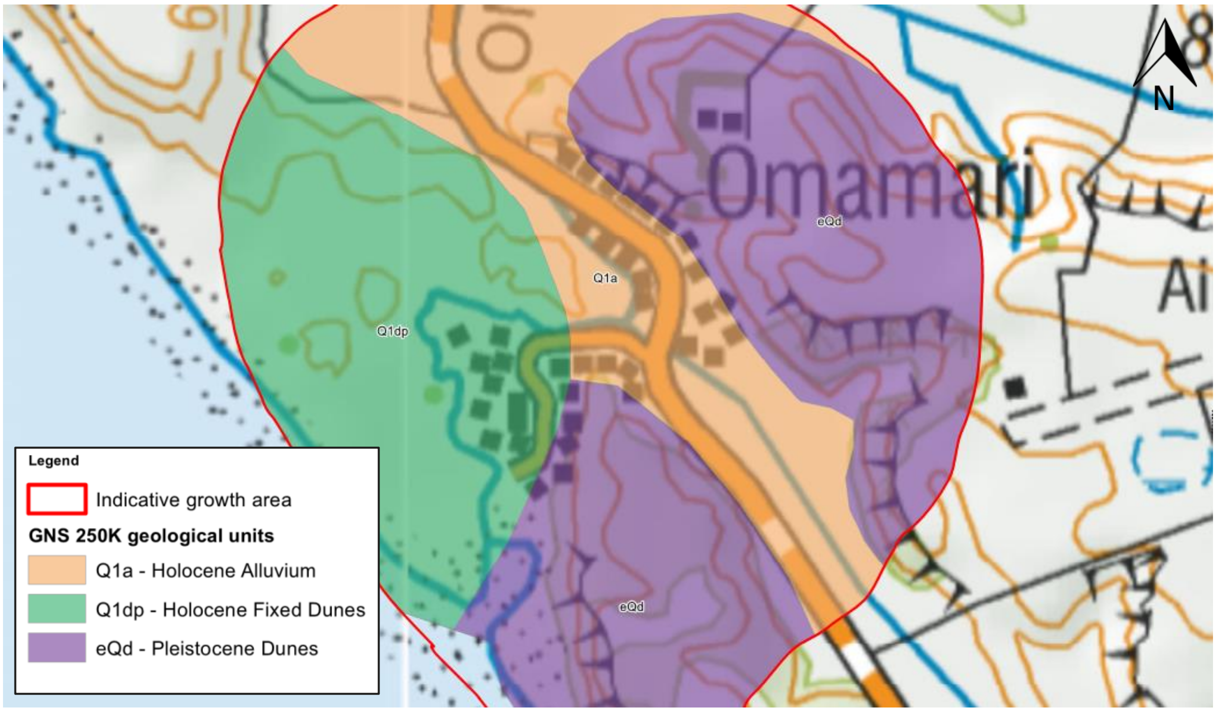

Figure 1: Geology Map for the Omamari IGA.

2.2 Aerial Photography

Historical aerial photographs sourced from Retrolens New Zealand dating back to 1940, stereo-paired aerial photos and Google Earth imagery were reviewed as part of the desktop study. The photographs were viewed under the context of identifying general changes to the landform and development within the IGAs, and to refine the geological mapping based on the topography. Aerial photographs were useful for studying large areas, however were limited by a lack of georeferencing within the Retrolens historical aerial photographs and the physical stereopairs. It was therefore sometimes difficult to locate specific features of interest.

For the stereoscopy, a mid-range scale of 1:25,000 was selected to provide project coverage. Images were assessed to identify geomorphic features such as headscarps, hummocky and irregular-shaped landscapes, displaced blocks and debris lobes that may be indicative of recent or historic landslide activity. Approximate extents of alluvium and colluvium deposits in hillside gullies and valley areas were also mapped, as they are more likely to be susceptible to liquefaction and consolidation settlement.

Google Earth allowed for interactive observations and assessments of the wider IGAs. By using a combination of exaggerated elevation, three-dimensional terrain and oblique angled navigation it was possible to identify and target areas with potential geohazards and geomorphological features to focus on during the field study.

2.3 Survey Data

LiDAR and LINZ Topo50 20 m contours were used to form the base for many of the GIS map outputs and allowed for widespread slope modelling.

At the time of undertaking this study the LiDAR data for the IGAs was limited in quality and extent, and so the LINZ Topo50 20 m contours data was used to create the primary map base. The LINZ data has a vertical accuracy of ≤ 10 m so is useful for high-level studies such as this where the intention is to broadly characterise areas based on a number of contributing datasets. The data is not of sufficient resolution to be valuable for a site-specific assessment where a detailed land survey would be appropriate.

2.4 Borehole Logs

Borehole data from the KDC groundwater bore database and the NZGD were used to identify location-specific ground conditions, and to derive an indication of representative standing groundwater levels across the IGAs.

The datasets were often limited due to lack of publicly available boreholes. This is likely due to the lower density of development in the Northland region compared to other more populated regions in New Zealand. It also reflects the fact that the NZGD is a relatively young tool and a large amount of historical information has not yet been uploaded.

2.5 Published Data

Publicly available geological and geotechnical data for the wider Northland region was collated from review of journal articles, geotechnical reports, theses, and natural hazard studies. The data studied included geotechnical parameters for soil and rock units assumed in analysis and design, detailed geomorphological mapping studies including assessment of failure mechanisms, and geotechnical considerations for construction and land development in different geological settings.

The data was used to support the development of hazard level criteria when assessing potential for liquefaction, settlement, and slope instability.

3 FIELD STUDY

A review of the available data was undertaken to identify focus areas within each of the IGAs where additional, site-specific data collection would be targeted. The field study phase generally consisted of geomorphological mapping on the ground in those areas where access was possible and use of the drone for more inaccessible areas.

3.1 Land-Based Mapping

The mapping component of the study was not intended to support a detailed geomorphic map of the area, but to ground-truth the preliminary desktop maps and to observe geomorphic features that could not easily be interpreted from aerial photographs. The field mapping was limited by land accessibility. In some cases access to private property was approved for the purpose of observing the landform, but in many cases observations were made from publicly accessible areas including roads and reserves. Geohazard data was gathered at various scales from areas such as road cuttings (Figure 2 - Left) to viewpoints overlooking large areas (Figure 2 – Right).

Figure 2: Left - Road Cutting in Mangawhai, Right – Hummocky Farm Land at Baylys Beach.

3.2 Drone Photography

The use of drone photography and videography allowed for high-level observations of features in wider geographical settings (Figure 3). This enabled observation of areas that were unable to be accessed by land, as well as providing high resolution oblique aerial images which assist in refining the nature and extent of geomorphic features. However, drone surveys were often hindered by high winds in coastal and exposed areas, and require preapproval when operating in a controlled airspace.

Figure 3: Drone Photograph Facing North Over Glinks Gully.

4 REPORTING AND GIS OUTPUTS

The data gathered from the desktop and field studies was analysed and collated to form conclusions on groundwater, slope angles, slope instability, liquefaction, consolidation, volcanic hazards, acid sulphate soils, and on-site effluent and stormwater disposal.

In order to quantify the geotechnical hazard potential for land planning, a broad framework based on a three-level hazard profile was developed. This system defined potential hazards as Low, Medium and High, relative to the level of additional geotechnical assessment that would be expected to meet the requirements of the RMA and Building Act. The hazard level assessment criteria included:

- Geological setting (e.g. likely presence of compressible organic soils), age of formation, and topographic setting for consolidation settlement potential;
- Soil type (e.g. clay soils vs. loose sands), age of formation, topographic setting, and groundwater depth for liquefaction potential;
- Geological setting, geotechnical properties, topographic data (e.g. slope angles) and geomorphological assessment for slope instability potential;
- Published data, geological setting (e.g. likely presence of organic soils) and topographic setting (e.g. low lying areas that may have been influenced by seawater) for acid sulphate soil risk; and
- Soil or rock type (e.g. potential permeability), topography and groundwater depth for on-site effluent disposal potential.

The hazard maps for each IGA were based on a topographical map established using GIS. Due to the limited coverage of LiDAR data over the study area, the LINZ Topo50 20 m contours were used to create digital elevation models, and then slope angle models of the IGAs (as shown in Figure 4).

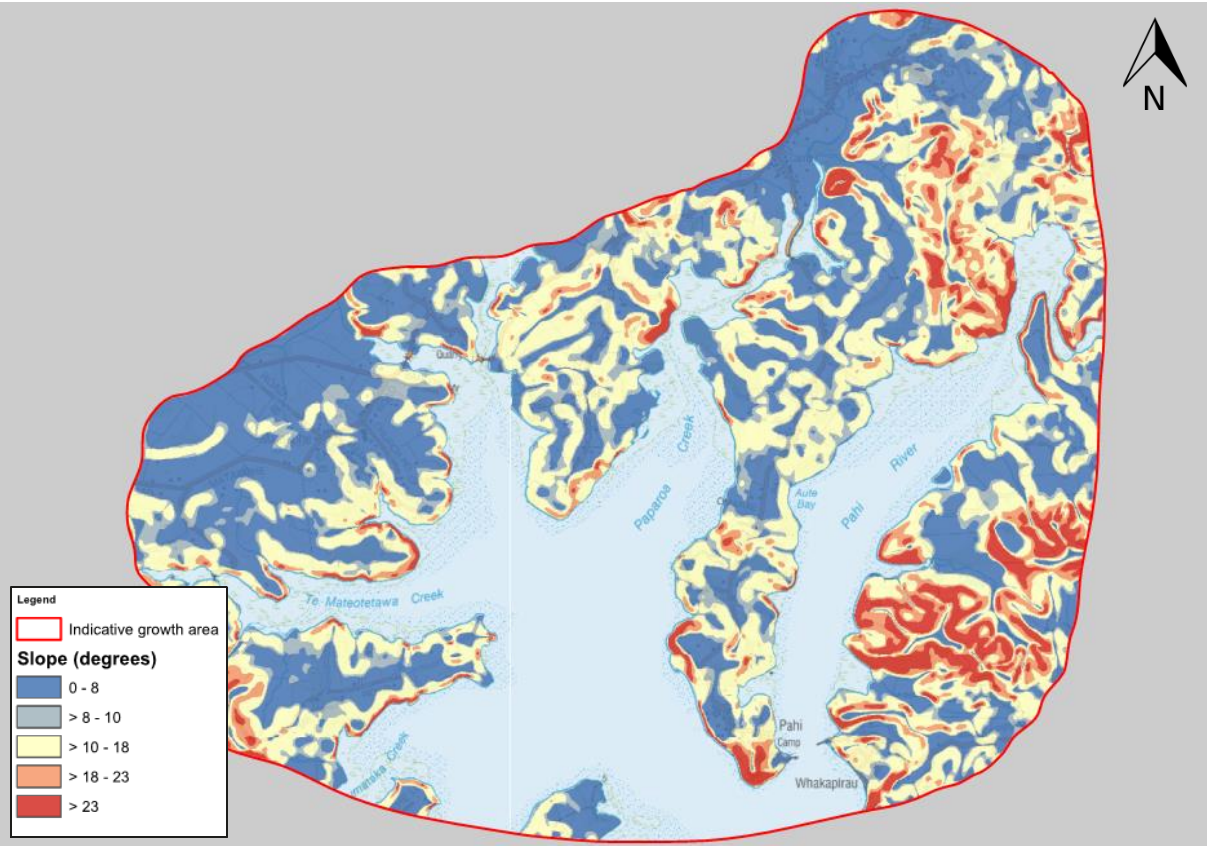

Figure 4: Slope Classification Map of the Matakohe IGA.

The assessed risk ratings for each hazard were then used as GIS inputs to produce various maps for each of the IGAs, including maps for:

- IGA Vicinity - showing the IGA regional location and boundary;
- Geology - showing the geological setting and formations within the IGA (Figure 1);
- Slope Classification - showing the slope angles across the IGA (Figure 5);
- Geomorphological Interpretation – delineating the areas observed to be at greater risk during the desktop study and field mapping exercise (Figure 5);
- Slope Instability Profile - showing the assessed potential for slope instability;
- Settlement Susceptibility - showing the assessed potential for consolidation settlement;
- Liquefaction Hazard - showing the assessed potential for seismically induced liquefaction;
- Acid Sulphate Soils - showing areas considered to have potential for acid sulphate soils;
- On-site Effluent Disposal Potential - showing areas assessed to be potentially suitable for on-site disposal and those that are unlikely to be suitable due to ground conditions and / or geomorphological constraints.

Figure 5: Geomorphological Interpretation Map for the Maungaturoto IGA.

Combined geohazard maps based on a summation of the primary geotechnical constraints considered for each IGA was then produced (Figure 6). These combined geohazard maps were based on the geomorphological interpretation, slope instability and settlement maps and depicted the highest risk level from the attributing data sets for a given area within the IGA.

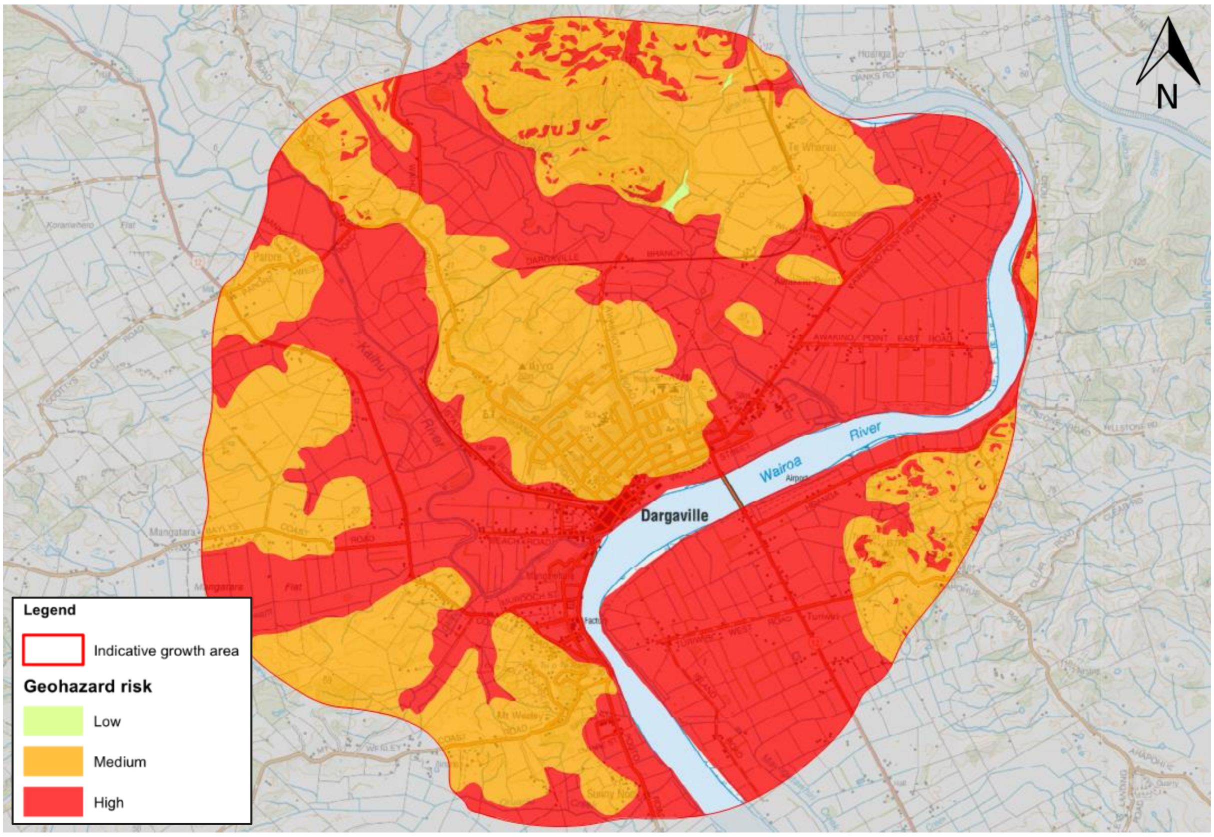

Figure 6: Combined Geohazard Map for the Dargaville IGA.

5 CONCLUSION

The importance of a multi-faceted approach to desktop studies was illustrated during a geotechnical survey and geohazard mapping project which covered approximately 25,000 ha over eight IGAs in Northland, New Zealand.

A robust desktop study was carried out which utilised a variety of tools to formulate a high-level understanding of the geological setting, geomorphological features and potential geohazards within the IGAs, which allowed for focus areas to be identified and preliminary hazard maps to be produced prior to embarking on the field-based component of the investigation. Publicly available aerial photographs (both recent and historical) played an important part in the desktop study as they allowed for a high-level assessment of the wider IGAs and identification of focus areas, with opportunity to identify the changes in landform and land use over time.

The source, level of detail, and limitations of the available data was a key consideration for the project. The small scale of the available geological maps and aerial photographs meant hazard area boundaries were approximate, and only visually ground-truthed where access was available. The limited publicly available borehole data could not be used to support development of a complex geological map for the study, and the LiDAR data was limited in quality and extent.

The combined geohazard maps have been used to support development policy and spatial planning by KDC, and to inform the planning team of the nature of the geohazards that should be addressed by the specialist consultants for land development within the IGAs.

6 ACKNOWLEDGEMENTS

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