# REMOTE SENSING TECHNIQUES FOR GEOTHERMAL INVESTIGATION AND MONITORING IN NEW ZEALAND

by

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# Abstract

This thesis examines the use of remote sensing techniques for the investigation and monitoring of geothermal areas in the Taupo Volcanic Zone of New Zealand. The research and development of a helicopter-borne video thermal infrared scanner technique and associated computer image processing methods constitutes the major portion of this study. In addition, preliminary results are presented from a related shallow ground temperature study conducted to investigate diurnal, seasonal and meteorological effects on temperatures in active thermal ground and results from a precursory assessment of SPOT-1 satellite multispectral imagery obtained over the Waiotapu Geothermal Field for detecting, identifying and mapping characteristic geothermal surface features are also reported.

The initial conduct of two video thermal IR scanner test surveys, one using an Inframetrics 525 over portions of the Rotorua Geothermal Field, the other using a FLIR 1000A over portions of the Wairakei-Tauhara Geothermal Field, demonstrated that imagery useful for basic geothermal feature mapping could be obtained in the late summer to early autumn period. Surveying during the hours around dusk was shown to be appropriate. Experimentation established instrument operating settings and defined nominal survey parameters. The real-time video imagery format proved useful as an aid to navigation and as a check on proper instrument set-up and operation. The helicopter platform provided valuable manoeuvrability and control. The results obtained from these two initial surveys aided development of survey design and conduct methodology.

The video imagery obtained with both the Inframetrics and FLIR scanners was compatible with New Zealand's PAL standard. Visual TV-VCR inspection of the IR imagery allowed easy identification of a range of natural thermal features. Identification of cultural features aided location of the thermal anomalies. The Inframetrics imagery suffered from serious *banding* and other minor problems. The FLIR imagery was of a generally higher quality, though it exhibited problems.

The fundamental ability to digitize images from the videotapes and apply powerful computer image processing techniques to aid interpretation and analysis was demonstrated. A

methodology for pre-processing and enhancing the digitized Inframetrics and FLIR images was developed. Application of these image processing techniques brought out detail unavailable in the grey-level imagery and greatly increased interpretation ability.

The demonstrated success of the first two test surveys led to the conduct of the first known large-scale video thermal IR scanner surveys of geothermal fields. Most details of the first of these are *confidential* (at the client's request). A complete range of geothermal features was detected and easily recognised and their distribution established, thus providing a much more detailed map of the geothermal activity than was previously available. The successful results attained confirmed the survey design and conduct methodology used.

The second and largest survey covered the entire Rotorua Geothermal Field (18 $km^2$). Imagery was obtained with both the Inframetrics and FLIR IR scanners and a visible wavelength video camera. Extensive ground control measurements were made. This comprehensive survey of geothermal activity established a baseline from which change can be monitored. The survey identified large scale seepage and submerged thermal input into Lake Rotorua which may be the source of known missing chloride. The first geothermal surface feature changes were identified, thus demonstrating the usefulness of the method for monitoring change. Preliminary image temperature calibration results were obtained and a procedure for constructing visible wavelength-thermal IR composite images was developed. The positive results demonstrated by this survey have led to the helicopter-borne video thermal IR technique being adopted for major geothermal feature mapping and monitoring programmes in New Zealand.

Preliminary assessment of the high spatial resolution (20 m) SPOT-1 multispectral imagery of the Waiotapu Geothermal Field showed that the larger geothermal surface features can be detected and identified on a contrast stretched, 3-band colour composite image.

A shallow ($\leq$ 1 m depth) ground temperature measurement site was established in an area extending from very active to near ambient conditions. Preliminary results show that temperature variations ranging from 1-19 °C can occur in the most active ground. These temperature variations exhibit a strong negative correlation with atmospheric pressure changes and can introduce large, unexpected inaccuracies in ground temperature measurements.

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I would be remiss if I did not mention that my geothermal career originated over 10 years ago, as a consequence of my attending the 1981 Geothermal Institute Course at Auckland University. It was here that Associate Professor Manfred Hochstein provided my first knowledge of remote sensing applications to geothermal investigation, and here also, that my supervisor, Associate Professor Ross Cochrane, amplified on these applications, thus whetting my appetite for the present studies.

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