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A 3-D model of the Rotorua Geothermal Field, data inventory and data validation

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EXECUTIVE SUMMARY

Bay of Plenty Regional Council (BOPRC) contracted GNS Science (GNS) to build a 3-D geological model of the Rotorua Geothermal Field. This project involves gathering and compiling geoscientific datasets available for the Rotorua area, focussing on key geological, structural and hydrological information. Following validation, these datasets are used to build a 3-D geological model of Rotorua as a 3-D base platform for future complementary studies on the Rotorua geothermal reservoir. 3-D modelling software Leapfrog Geothermal 2.7.1 is used to visualise and model the data.

This report presents results from the first stage of the project, namely data compilation and validation. A second report (Alcaraz, 2014) will address and discuss the geological context of the Rotorua Geothermal Field and the method followed to build the 3-D geological model.

BOPRC provided surface data and borehole data from their databases for GNS to compile and complement with additional geoscientific information found internally and externally in the literature. A borehole database that inventories significant well data has been created and is attached to this report for future reference. The methods and processes followed for data validation are detailed in the report. All geological, structural and geophysical datasets have been formatted and prepared to be used for subsequent modelling in Leapfrog Geothermal.

Key findings from this study are:

- The surface geology of the Rotorua area is well constrained and has been presented by several authors in various degrees of details;
- There are no clear surface fault traces within the Rotorua caldera. The inferred structures at depth vary between authors;
- 1317 wells have been identified in the Rotorua area. However, it is likely that more exist;
- The Rotorua wells have not been GPS surveyed and locations are commonly approximate. The naming convention used for the well has not always been consistent;
- Most wells are less than 200 m deep. From the wells identified in this study, the maximum drilled depth is 458.8 m in Rotorua City and 503 m in the Tikitere Geothermal Field;
- Little reliable geological information is available for the majority of the wells;
- Drillers logs, where available, cannot be used systematically to establish stratigraphic correlations;
- Geologists working for the Rotorua Monitoring Programme 1982 – 1985 studied possible geological correlation between boreholes. The full database used at the time could not be sourced;
    - The Rotorua Rhyolite dome is well constrained below the Rotorua City;
    - The top of the Mamaku Ignimbrite has been identified in several wells below Rotorua (eastern side);
    - No shallow stratigraphic correlations in the highly heterogeneous sediments have been done;
- No drillholes in the Rotorua City drilled deep enough to reach the base of the Mamaku Ignimbrite, however wells north and north-east of the project area of interest have reached underlying formations. These provide constraints on the thickness of various formations at depth;
- Geophysical studies providing some insights on deep structures include seismic, magnetotelluric and gravity data.

1.0 INTRODUCTION

Bay of Plenty Regional Council (BOPRC) contracted GNS Science (GNS) to initiate the build of a comprehensive 3-D model of the Rotorua Geothermal Field that incorporates surface and subsurface geological and hydrogeological information. Numerous studies have been conducted in the Rotorua area over the years, traditionally using 2-D techniques (i.e., maps, cross-sections, slices). In 2004, the first 3-D model of the Rotorua area was built as part of a project assessing the groundwater hydrology of the Lake Rotorua catchment (White *et al.*, 2007). This present study has a deeper focus, including information on the geothermal system beneath Rotorua city. The resulting 3-D model of the Rotorua Geothermal Field aims to provide a new and dynamic interface to better understand the geological setting and geothermal reservoir behaviour and response to utilisation. This will provide BOPRC a new tool for reservoir assessment and management, therefore assisting with the long-term sustainability of the resource.

This project involves gathering and compiling geoscientific datasets available for the Rotorua area, focussing initially on key geological, structural and hydrological information. It is a compilation of all previous work, and does not involve acquisition of any new information. Following validation, the datasets are used to build a 3-D geological model of the Rotorua area to use as a base platform for future complementary studies on the geothermal reservoir. For the model build, Leapfrog Geothermal 2.7.1 software is used. While the focus of the study is the Rotorua Geothermal Field, data encompassing the wider Rotorua area are included.

This report presents results from the first stage of the project, which includes data compilation and validation. BOPRC provided both surface and borehole data for GNS to compile and complement with additional geoscientific information obtained through a literature review of the district. The data compilation and validation was conducted collaboratively with BOPRC. A borehole database has been built to manage the data and is provided on the DVD attached to this report. Details on the methods used to transform and/or process the data are given in the report for future reference.

All layers mentioned in the report are named in a blue-coloured font as they appear in the database and 3-D model with their exact extension. Where appropriate a prefix has been added to the layer names to document the data source (a company, a product or an author). Specific data management tools used to prepare and validate the data are italicised.

Key stratigraphic formations in the Rotorua district mentioned in this study are; the Pokai Formation, the Mamaku Plateau Formation (also known as the Mamaku Ignimbrite), the Rotorua Rhyolite and the Rotorua Basin Sediments. Details on the nature of these formations will be given in a following report accompanying the 3-D model (Alcaraz *et al.*, 2014).

2.0 LOCATION AND METHOD

The primary area of interest for this study is the Rotorua Geothermal Field, which is located between Lake Rotorua and the southern topographic margin of the Rotorua caldera (Figure 1). The surface extent of the geothermal field covers an area of ~ 18 km^2 (Bibby *et al.,* 1992). The 3-D model is designed to help understand the characteristics of the geothermal field in its regional geographical and geological context. The area of interest (AOI) constraining data input and model extent was consequently defined to capture key geological features likely to influence the geothermal reservoir (i.e., the Rotorua caldera). The AOI boundary was created in ArcGIS and saved as GNS_RotoruaModel_AOI.shp.

Data gathered for this project is mostly geospatial. It is either directly georeferenced with specific coordinates that can be used to display in 2-D or 3-D, or it is related to features that can be georeferenced. Most data is either in GIS (Geographical Information System) or tabulated formats. GNS used a combination of software to import and manipulate the data, including: Microsoft Excel and Microsoft Access for handling tabulated information; ArcGIS for GIS vector and raster data; and Leapfrog Geothermal for 3-D visualisation and modelling of these datasets.

BOPRC and GNS agreed to build the model using the New Zealand Transverse Mercator coordinate system (NZTM, datum NZGD 2000). Thus all geospatial datasets in New Zealand Map Grid (NZMG, datum NZGD 1949) have been converted to NZTM.

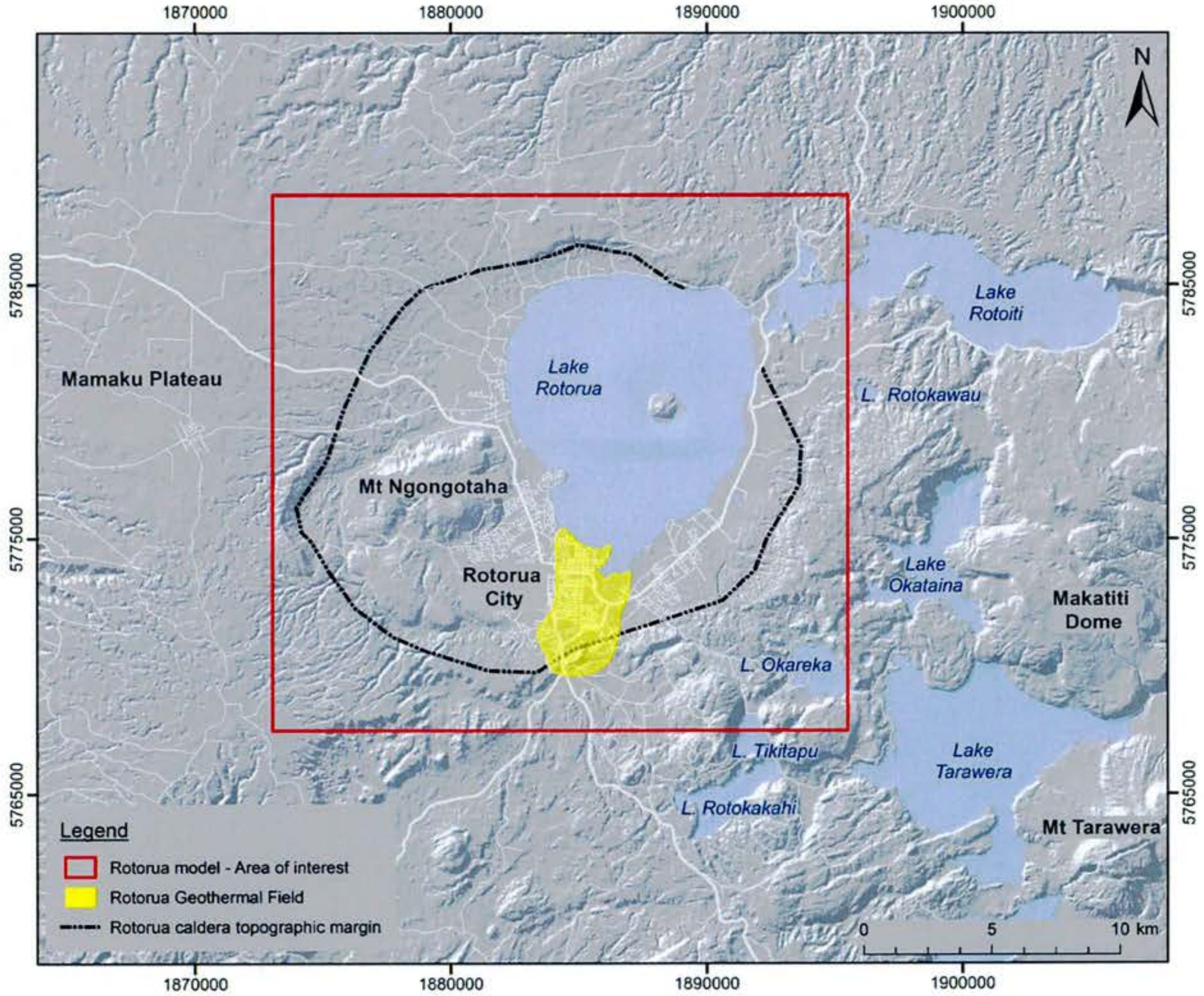

Figure 1. Location map showing the extent of the Rotorua Geothermal Field and wider boundary defined as the area of interest. The caldera topographic margin is from Leonard *et al.,* (2010).

3.0 SURFACE DATA

3.1 DIGITAL TERRAIN MODEL

3.1.1 Datasets

The Digital Terrain Model (DTM) used for the 3-D model has been compiled from various sources provided by BOPRC. For the purposes of this project, all BOPRC datasets (sent as e-mail attachments from Victoria Fergusson to S. Alcaraz, 02/05/2014) were saved on the GNS server. These datasets are:

- A 2 metre (m) resolution DTM of the Rotorua region;
- High resolution Lidar data covering the Rotorua Geothermal Field area. Lidar data was provided as 74 LAS files, which are an industry-standard binary format representing 3-D point cloud data;
- Bathymetry contours of Lake Rotorua as GIS vectors representing various elevations at irregular intervals, though a majority represent 5 m interval contours. From this dataset, the lake surface elevation is at 280.3 m.

3.1.2 Method To Create A Single DTM

For modelling topography, Leapfrog Geothermal uses a single DTM file. In the case of Rotorua, several data files overlap and have different resolutions, so they need to be merged into a single file. Several lakes are included in the model area but bathymetry data is only available for Lake Rotorua. For consistency, the bathymetry was not used as an input to generate the model topography file. Instead it was used to model the lake bottom surface.

The following method was used to combine Lidar data with the 2 m regional DTM:

1. A new LAS dataset was created to access the LAS file in ArcGIS, and then converted to a raster using the *LAS Dataset to Raster* conversion tool. A binning interpolation method was used, where the raster value is obtained from the points falling in the extent of the cell. If several points are within one cell, the average value option was selected. Where no points are within the cells, a linear triangulation method was used to determine the cell value from surrounding cells. The final raster cell-size was set to 2 m, to limit the size of the output raster and facilitate correlation with the regional DTM. The new raster was then converted to an ascii file format for visualisation in Leapfrog Geothermal, BOPRC_DTM_LAS.asc.
2. The 2 m regional DTM is in a grid format and saved as BOPRC_DTM_RotoruaArea_2m.tif.
3. A new raster dataset at 2 m resolution and 32 bit float pixel type (supporting decimals) was created in a *File Database*. The two layers (Lidar and regional DTM) were then combined using the *Mosaic Tool*. In overlapping areas, the first layer is used. In this case, Lidar data precedes the regional DTM.
4. The new raster was then exported as a standalone tiff file and loaded into Leapfrog Geothermal (Topography.tif, 1.4GB) as input for defining the Topography. On importation, Leapfrog Geothermal down-samples the file resolution to minimise processing requirements.

3.2 AERIAL PHOTOGRAPHY AND TOPOGRAPHIC MAPS

BOPRC provided two high resolution aerial photographs of the Rotorua area (BOPLASS Limited, 2011). To save processing capacity each image needed to be compressed from ~4 GB to ~250 MB prior to uploading into Leapfrog Geothermal (Aerial_2k_2011_44052_1.tif and Aerial_2k_2011_44053_1.tif).

Standard topographic maps have been imported into the model, including the 1:250,000 map (TopoMap250k.jpg; LINZ a) and the 1:50,000 map (TopoMap50k.jpg, LINZ b).

3.3 GEOTHERMAL SURFACE DATA

BOPRC provided several GIS datasets and tabulated files representing various surface features in the Rotorua Geothermal Field. These include:

1. The Rotorua Geothermal Field estimated extent (BOPRC_Geothermal Rotorua_resistivity.shp): A polygon representing the inferred extent of the Rotorua Geothermal Field based on the electrical resistivity signature of the area.
2. A geothermal vegetation map (BOPRC_GeothermalExtentsBOP2010_ vegetation.shp): Polygons representing the extent and distribution of typical geothermal vegetation growing in Rotorua geothermal areas. The attribute table (i.e., data attributed to each feature in a GIS format) includes information for each feature about the type of environment and its national or local significance.
3. A Geothermal surface feature inventory (GeothermalInventory_SurfaceFeatures.xls): A location file of geothermal surface features within the Rotorua area, including attached information on location and feature characteristics (e.g., type, status, uses). This database has been reformatted as part of the BOPRC Geothermal Feature Database project that was undertaken by GNS (contract 2013 0233). It also uses a new surface feature naming convention. GNS and BOPRC agreed that the new database is to be used in the 3-D model (GeothermalInventory_Surface Features.shp). It contains 1838 features, 1582 of which are within the AOI.
4. Surface features from the monitoring programme (NERMmonitoringProgramme.shp): This database contains the location of 88 geothermal features that are monitored regularly. This file is a subset of the geothermal surface feature inventory and does not include any results from the monitoring programme.
5. Springs location (BOPRC_SpringLocations_Rotorua01052014.shp): Locations of 75 springs in the Rotorua area, classified by type as cold, hot or unknown.
6. Exclusion zone (BOPRC_WaterAllocation_GeothermalExclusionZone.shp): the 1.5 km radius zone around Pohutu geyser where geothermal bore mass extraction is excluded.

3.4 GEOLOGICAL MAP AND SURFACE STRUCTURES

This section summarises the work by several authors over the last 50 years on the geology of the Rotorua area that provided various interpretations of the district surface geology and structures (Figure 2 and Figure 3).

The geology of the Rotorua district was mapped at 1:250,000 scale by Healy *et al.,* (1964) (Figure 2A) and later by Leonard *et al.,* (2010) (QMAP series; Figure 2B).

Based on Healy *et al.,* (1964), Thompson (1974) provides greater detail on the geometry of various lithological deposits and includes the Rotorua caldera boundary (Figure 2C). Wood (1992) presents a simplified geological map, using the same caldera boundary (Figure 2D).

Milner (2002) presents a surface geological map with a structural interpretation that differs from previous authors. The caldera boundary is redefined, especially to the north-west, the Tikitere graben is clearly constrained by two bordering faults, and there are inferred NW-SE structures cross-cutting the intra-caldera rhyolite domes (Figure 2E). Building on Milner's (2002) interpretation Ashwell *et al.,* (2013) inferred numerous additional faults from a combination of inherited basement and rift related structures (Figure 2F).

Intra-caldera structures are also presented by Wood (1984a, 1992), who introduced the Inner Caldera Boundary Fault (ICBF, Figure 3A), which is based on the morphology of the Mamaku Ignimbrite at depth. Finally, Lloyd (1975) mapped in detail the surface geology in the Whakarewarewa geothermal area and inferred some faults from the linear alignment of springs and geysers (Figure 3B).

All these interpretations have been considered during the 3-D model build of Rotorua and key features that have been digitised for importation into the model (further discussed in Alcaraz, 2014) are:

- Lloyd (1975) faults in the Whakarewarewa area have been digitised and imported as Lloyd1975_Faults_Whakarewarewa.shp
- Wood (1992) ICBF structure has been digitised and imported as Wood1992_Faults.shp
- Milner (2002) faults have been digitised and imported as several layers: Milner2002_Rotorua_Caldera.shp, Tikitere_Graben_S.shp, Tikitere_Graben_N.shp and Milner2002_Other_Faults.shp
- The original QMAP image has also been imported for reference (QMAP_Rotorua.tif).

QMAP layers are also available in a GIS vector format and can be used as inputs to constrain the model surface geology. These files have been converted to the NZTM coordinate system and imported in Leapfrog Geothermal:

- Geology polygons (QMAP_2010_Geology.shp)
- Geology arcs (QMAP_2010_GeologyArc.shp)
- Active faults (QMAP_2010_ActiveFaults.shp)
- Inactive faults (QMAP_2010_InactiveFaults.shp)
- Calderas topographic margin (QMAP_2010_Calderas.shp).

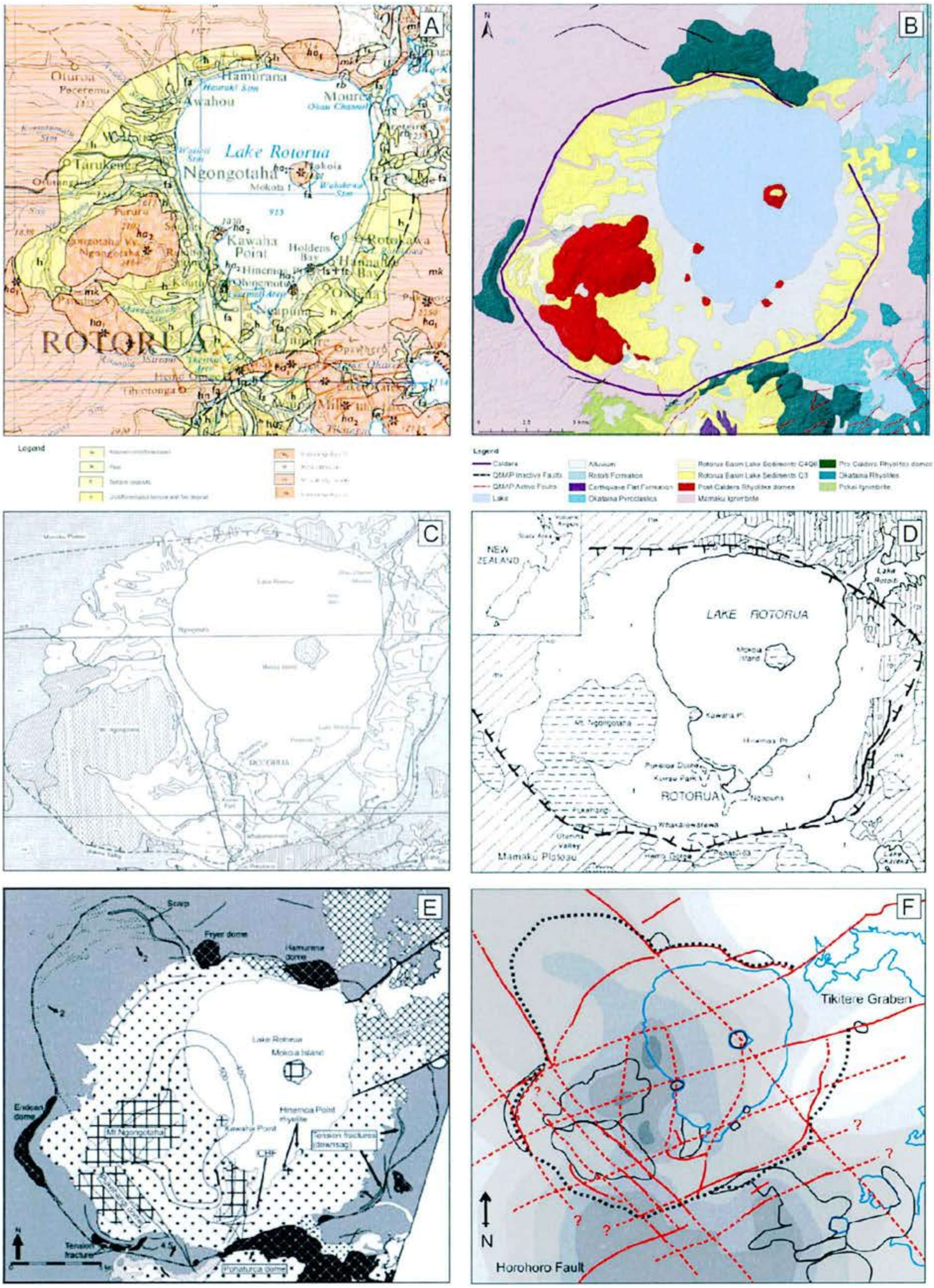

Figure 2. Geological maps and inferred structures of the Rotorua caldera, A: Healy *et al.*, (1964) 1:250,000 geological map. B: Leonard *et al.*, (2010) 1:250,000 geological map. C: Thompson (1974) geological map of Rotorua district. D: Wood (1992) Rotorua surface geology and caldera boundary. E: Milner (2002) Rotorua surface geology and inferred structures. F: Ashwell *et al.*, (2013) interpreted structures.

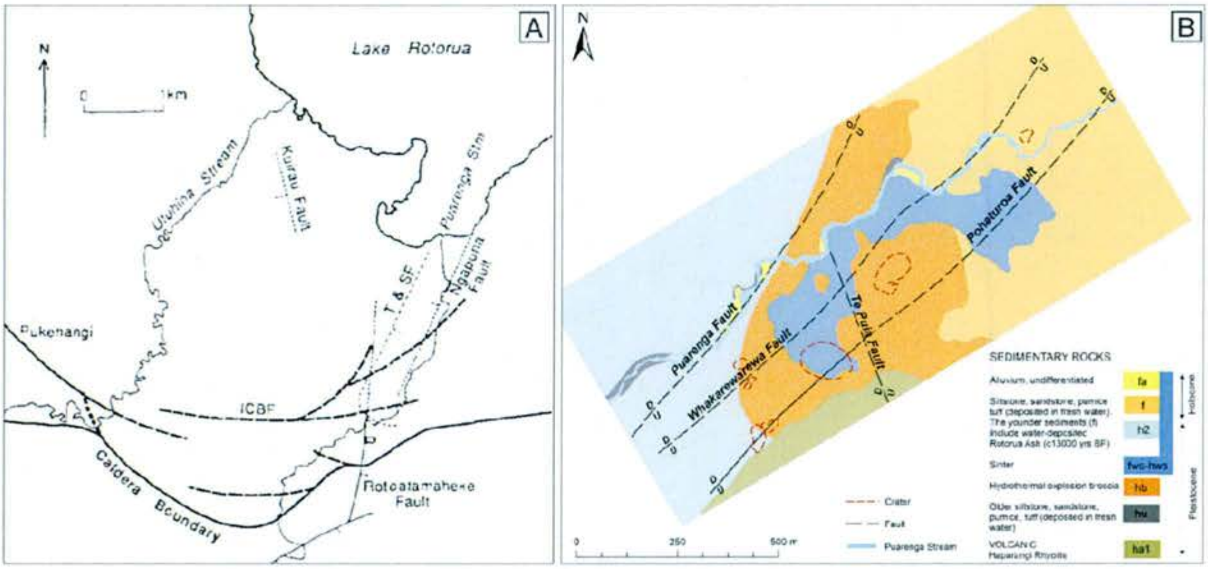

Figure 3. Intra caldera structures and surface geology. A: Wood (1992) inferred the Inner Caldera Boundary Fault (ICBF) structure and other intra caldera faults in the Rotorua Geothermal Field area. B: The Lloyd (1975) geological map with inferred structures at Whakarewarewa.

Finally, the GNS Active Fault database (Jongens and Dellow, 2003) has been imported into the model. It has a better resolution than the QMAP faults and includes complimentary fault characteristic attributes. This layer was clipped to the area of interest and imported in Leapfrog Geothermal as GNS_ActiveFaultsDbse_June2014.shp.

3.5 PETLAB DATA

PETLAB is the National Rock and Geoanalytical Database operated by GNS. The database contains locations and descriptions of rock samples collected in various areas of New Zealand. GNS queried the PETLAB database to retrieve rock information from the Rotorua area.

There are 1083 samples from the area, including surface, drillcore and drillcutting samples. Most of these samples include rock type descriptions, with a few stratigraphic correlations. These samples are used as control points for the model, taking into account any location errors (PETLAB_data_September 2014.csv).

4.0 BOREHOLE DATA INVENTORY

From the data gathered, we identified 1317 unique boreholes in the area of interest, most of them concentrated in the Rotorua Geothermal Field area. Data available on each borehole varies greatly, with some containing no other data than an approximate site location. The borehole naming convention has evolved in time and is a proven issue. Some bores have been renamed, or contrariwise, different bores have been given the same name. This section presents a list of all data gathered and their various sources.

4.1 BOPRC GROUNDWATER DATABASE

BOPRC provided data from their groundwater well database (WellsData.xls, Derek Pirini e-mail 25/03/2014 to S. Alcaraz). It is a compilation in a tabulated format of all consented groundwater wells located in the Rotorua area that contain information (as available) on the well location, drilling information and geological information with miscellaneous comments (Appendix 1:). The original table includes 964 entities (lines) corresponding to 102 unique wells.

In theory, this database is dedicated to wells with water temperature below 30°C, however, some geothermal boreholes are also included. The wells in this database are identified by a unique numeric identifier (e.g., 238), which is not related to the unique alphanumeric identifier of the geothermal borehole data in the geothermal well database that contains a RR prefix (e.g., RR2121).

4.2 BOPRC GEOTHERMAL WELL DATABASE

BOPRC provided data from their geothermal well database (Geothermal Data Conditioning.xls, Derek Pirini e-mail 26/03/2014 to S. Alcaraz). This database only includes wells with a temperature above 30°C. BOPRC considers it to be up-to-date and complete. This file has a similar structure to the Groundwater database. However, the first dataset sent by BOPRC missed a key column containing the unique well name identifier (well ID), as per the geothermal well naming convention with a RR prefix. A request was sent, and a new document provided (GNS_Geothermal_Data_Conditioning_Export 19062014.xlsx, J. Barber email 19/06/2014 to S. Alcaraz). The original table included 351 wells, while the latest included 509 wells (all 351 wells are present in the new table). The new file has a location spreadsheet including data (as available) on the well location and drilling information (Appendix 1:), but also includes more accompanying data in attached spreadsheets with comments, geology, water analysis, ground water table and temperature data. The original file was consequently considered unreliable and completely disregarded.

4.3 BOPRC CONSENT USE

BOPRC provided information on the consented use for groundwater and geothermal water takes and discharges (Derek Pirini email 25/03/2014 to S. Alcaraz). This tabulated information includes the various consent types (e.g., bore permit, discharge permit) with details of their current status and conditions. Ideally, the drilling consent type should be directly related to the two well databases (groundwater and geothermal) using the consent ID number (unique identifier). However, the consent ID numbering system differs between these two tables and cannot be directly related. As a result, GNS and BOPRC agreed (meeting 18/06/2014) that the consent tables should not be included in this model build.

4.4 BOPRC Data for Rotorua Geothermal Bores

BOPRC provided data on the Rotorua Geothermal monitoring bores (Lisa Naysmith email 25/03/2014 to S. Alcaraz), including a location table with temperature and water level profiles, and minimal geological information, for 21 wells. They are known as the M (geothermal monitor bores) and G (groundwater well) monitoring bores, but also have a standard RR number that can be correlated to other databases.

4.5 Other Groundwater Wells

In 2007, Environment Bay Of Plenty (EBOP, now BOPRC) commissioned GNS to assess the groundwater hydrology of the Lake Rotorua catchment. As part of this project, White *et al.,* (2007) created a 3-D geological and groundwater flow model of the Lake Rotorua catchment (using Earth Vision software). The model used surface geology and interpreted geology from mostly geological drilllogs compiled by the well drillers. The datasets used are given as tables in White *et al.,* (2007). Some of the wells in the Earth Vision model are common to the ones provided by BOPRC as part of the present project. The Earth Vision model includes more groundwater wells and fewer geothermal wells. This is likely due to the differences in the defined areas of interest.

4.6 Complementary Borehole Data

Crafar (1974) presented the first geological study of the Rotorua Geothermal Field and attempted correlations of the various logged rock descriptions (mostly done by well drillers) with known stratigraphic units. In the 1980s Wood, as part of the 1982 – 1985 Rotorua Monitoring Programme, assessed the reliability of the Rotorua borehole data and conducted a thorough comparative study of geological well data throughout the area and summarised the geological interpretation and structures at depth. Numerous unpublished DSIR letter and preliminary reports were issued, but major reports from the Rotorua Monitoring Programme include Wood (1984a; 1985a; 1985b) and a publication (Wood, 1992). A few key tables and stratigraphic logs are provided as support to his interpretation in these reports, which only refers to a subset of Wood's (1982 – 1992) data. GNS compared data from some preliminary reports with these major publications and realised that most wells had been revised. Searching and digitising information from the original reports was thus likely to bring erroneous data in the model. These observations prompted a thorough search within GNS for the database or files used at the time to manage the data (a DSIR VAX files system as mentioned in Wood, 1985a), based on the expectation that they would include the final re-interpreted stratigraphic correlations.

The files that could be recovered from the Wood (1982 – 1992) datasets and GNS Information Technology (IT) backup system include:

- A list of 943 wells and their locations.
- AutoCAD drawings used to create maps found in some reports, such as structural contours of the Rotorua rhyolite domes (Figure 4), location of the ICBF and depth to the Mamaku Ignimbrite. Rhyolite structural contours were converted from a CAD to a GIS file format and imported into the model as Wood_RotoruaRhyolite_domes_contours.shp.
- DSIR VAX LHN recovery files (IT backup):
    - ZRRWVAX/1.A: index listing all the files supposed to be in the directory. Some files are missing.

- RRDATE.LST: this directory includes an almost continuous list of boreholes drilled at Rotorua from RR1 to RR957 with coordinates and some location information (such as owner's name and address at the time).
- RRWELL.LST: a list of wells with location coordinates, map sheet number and street plan, bore use, casing elevation and depth, drilled depth, , and information regarding the availability or not of chemical (including isotopic) geological, temperature and enthalpy data. This file was last updated 14 December 1993.
- RRTS.DAT: list of petrographic thin sections with their well ID, sample depth, sample type, formation and lithology;
- RHYOLITE.ALL: a list of wells with the elevation of the Rotorua Rhyolite upper surface. It discerns between wells where it is known accurately and those where it is estimated.
- RHYO.SPOT: a list of wells with accurate elevations of the Rotorua Rhyolite upper surface.
- RHYO.EST: a list of wells with estimated elevations of the Rotorua Rhyolite upper surface.
- MAMAKU.DAT: a list of wells that penetrate or likely penetrate the Mamaku Ignimbrite. It includes a comment on the well location relative to the ICBF.
- MAMDEF.DAT: a list of wells that have encountered the Mamaku Ignimbrite.
- MAMAPOS.DAT: a list of wells that have possibly encountered the Mamaku Ignimbrite.
- MAMAKUTEMP.DAT: a list of wells with the depth to the top of the Mamaku Ignimbrite and temperature data.

These files are apparently the results of database queries, not the database itself. It is worth noting that the data presented here does not list all the information available at the time. The depth to the rhyolite upper surface for some wells in Wood (1985a) is not included in these files. The full database is not provided, and could not be retrieved due to lack of information on the system used at the time and compatibility issues with the current IT systems. A table named RRW.GEOL (listed in the index file) apparently provides an inventory of all wells with a reasonably continuous downhole geology log. It could not be sourced.

In summary, this search provided some useful information, but the original database could not be retrieved and some data is likely missing.

The Cody (1998) study focussed on the Kuirau Park area and a structural contour map to the top of the Rotorua rhyolite lava dome beneath the park was presented (Figure 4). Some of the rhyolite depths differ from the Wood (1992) data and Cody includes additional wells implying that either further geological work was done in the area or that the Wood (1992) dataset was incomplete. Details on the data sources in Cody (1998) are lacking and it is difficult to presently assess the reliability of the information without access to the full database used to generate this map.

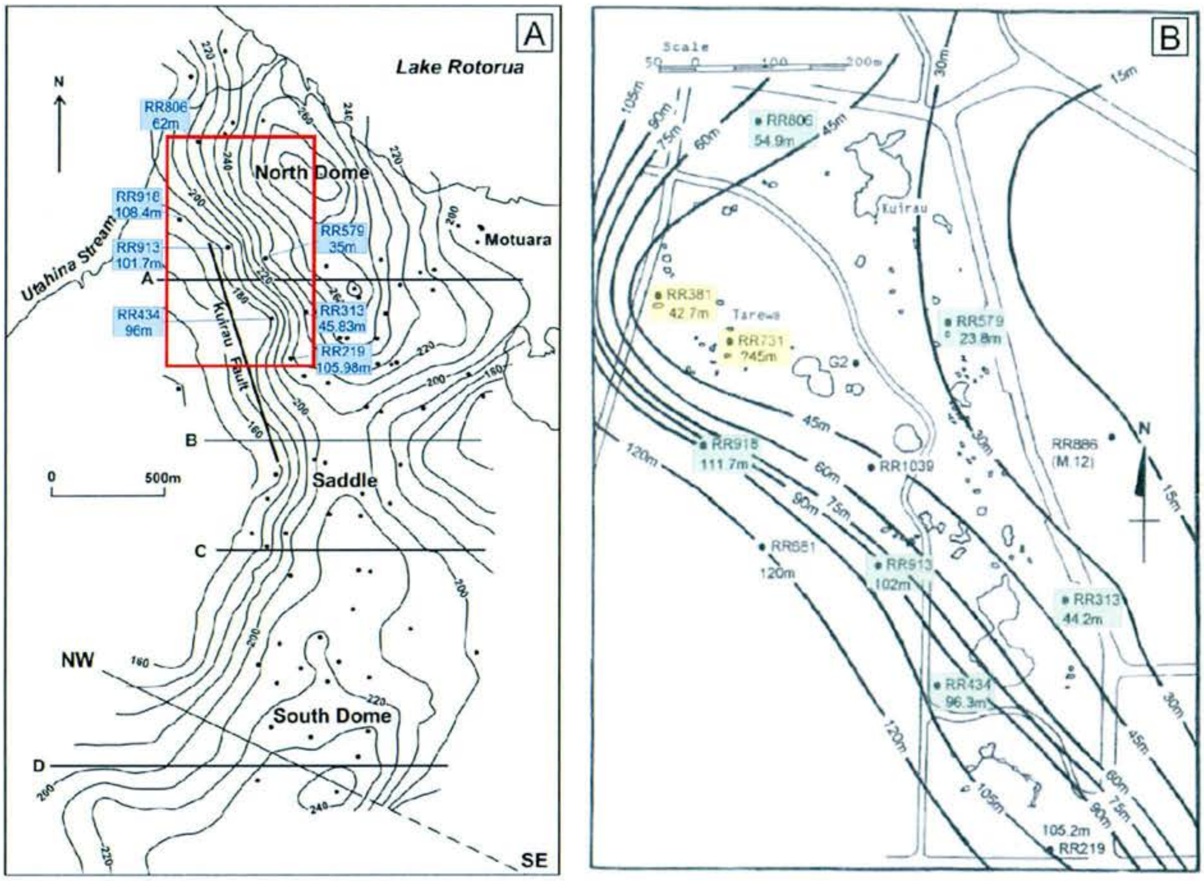

Figure 4. Structural contours to the top of the Rotorua Rhyolite beneath Rotorua city. A. Wood (1992) contours in mRL. Depths to the rhyolite from borehole data in blue rectangles. B. Structural contours of the top of the rhyolite from Cody (1998). Contours are depth to the top of the rhyolite. Wells in green rectangles are present in the Wood (1992) dataset, but the depths differ. Wells in yellow rectangles are not in the Wood (1992) dataset.

Data from wells located outside Rotorua City provide constraints on the subsurface formation thicknesses on the model margins. Useful data include:

- Geological information from wells drilled during development of the Kaituna River hydro scheme (Thompson, 1964): the drillholes are not within the AOI but the deepest wells reached the base of the Mamaku Ignimbrite and provide useful constraints on its thickness in the north-eastern part of the model. A map (Thompson 1964 - Kaituna River hydro schemes Geological map.jpg) and a cross-section (Thompson 1964 - Te Akau tunnel line.png) from the report have been included in the model and data from well AKA18 has been digitised for use in the borehole database.
- The Kaharoa well (Nathan, 1975) located north of the model AOI reached the base of the Mamaku Ignimbrite.
- Tikitere Geothermal Field data for wells RSM1 to RSM7 (Nairn, 1979; Nairn and Msenya, 1980; Nairn, 1981) and TIK43 well (Wood, 1984b) near Rotoiti.

Deep boreholes were recently drilled by Contact Energy Ltd in the Taheke Geothermal Field, located in the northeast corner of the AOI. However, the data from these wells remains proprietorial and was not included in this model.

5.0 GEOPHYSICAL DATA

Several geophysical studies have been conducted in the Rotorua area. Some of these provide complimentary information on the structures and useful constraints on the subsurface geology.

5.1 SEISMIC DATA

Lamarche (1992) did a seismic reflection survey in the south-eastern part of the Rotorua Geothermal Field (Figure 5). Interpreted geological structures are represented along two profiles, including the correlation of seismic reflectors, which are affected by some lithological formations and normal fault structures. Horizon A corresponds to lacustrine sediments. Horizon B is identified as the top surface of the Mamaku Ignimbrite and has been constrained by geological logs from nearby wells (Wood, 1992). Horizon C, with a discontinuous seismic trace, is interpreted to be the contact between the Mamaku Ignimbrite and the underlying Pokai Formation. This lithological boundary remains unconfirmed as it lies below drilled depths. Offsets in the reflector geometries indicate the possible presence of normal faults that crosscutting the inferred ICBF, with vertical displacements on any one fault are no greater than 30 m. Lamarche (1992) interpreted the ICBF to be not a single structure, but a zone comprised of at least four faults. Down-faulting and dip of the surface contributes to an Elevation differences to the top of the Mamaku Ignimbrite from southeast to northwest are ~120 m and implies a thickening of the formation towards the northwest, in agreement with observations from Wood (1992).

The seismic profiles provide valuable information on the geological structures at depth and can be used to constrain the geometry of the Mamaku Ignimbrite. Maps and cross sections that are georeferenced in Leapfrog Geothermal to use as a guide through the modelling process are: Lamarche 1992 - seismic profile map.png; Lamarche 1992 - seismic profile map with pegs and depth.tif; Lamarche 1992 - seismic profile 1.png and Lamarche 1992 - seismic profile 2.png.

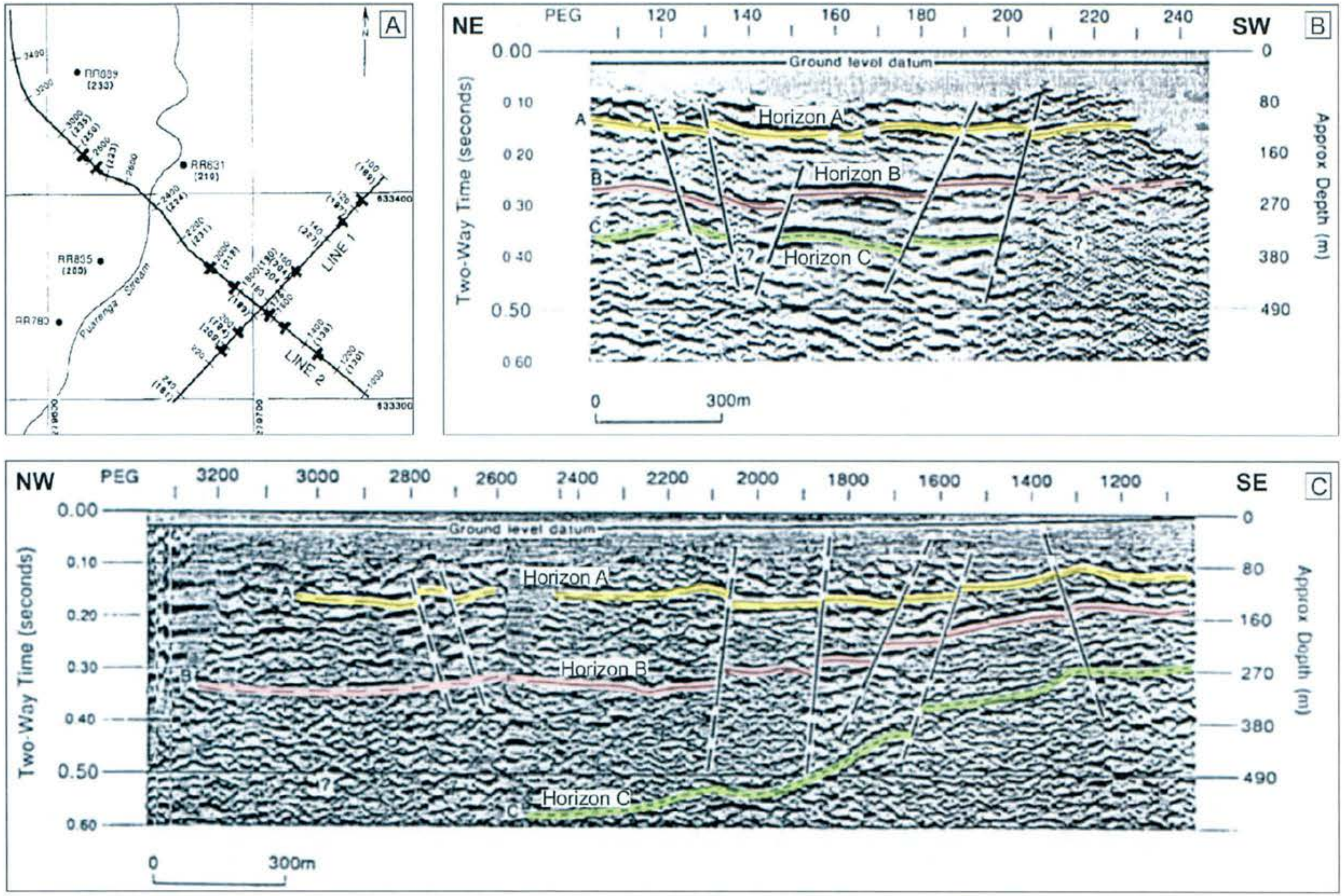

Figure 5. Lamarche (1992) seismic profiles. A: Location map of the seismic profile and pegs, showing the estimated depth to the top of the Mamaku Plateau Formation (bold numbers). B: SW-NE seismic profile along line 1. Horizon A (yellow): lacustrine sediments. Horizon B (pink): top of the Mamaku Plateau Formation. Horizon C (green): contact between Mamaku Plateau Formation and Pokai Formation. C: NW-SE seismic profile along line 2. Coloured lines as for Figure 5B.

5.2 MAGNETOTELLURIC DATA

GNS was contracted by BOPRC to conduct a magnetotelluric (MT) survey of the Rotorua Geothermal Field. This was to provide insights on the extent of the deep-resistivity structure of the geothermal system (Heise *et al.,*, 2013; Caldwell *et al.,* 2014). Key findings relevant to this study are summarised below (Figure 6):

- A deep conductor (i.e., < 15 Ωm) below 4 km depth and southeast of the Rotorua city is thought to represent basement crust with a high percentage of magmatic melt. The vertical conductor (i.e., ~20 – 40 Ωm) extending to shallow depths (`1 – 4 km depth) above the northern edge of the deep conductor may represent the high temperature geothermal upflow.
- The shallow low resistivity layer beneath the Rotorua Geothermal Field is interpreted as being the clay cap overlying the hotter deeper parts of the geothermal system.
- The shallow low resistivity layer northwest of Rotorua, outside the geothermal field, is interpreted as representing old ignimbrites (> ~700,000 year).
- The deep resistor northwest of Rotorua (blue colour) is interpreted as being greywacke basement rocks.
- The steep contact between the zones of low and high resistivity, beneath the Rotorua Geothermal Field may be related to caldera margin structural features.
- The resistor present at the surface west of Rotorua city correlates to the young volcanic materials of Ngongotaha dome.

The MT location map and two 2-D MT profiles from Caldwell *et al.,* (2014) (their profiles 3 and 4) have been georeferenced and imported into Leapfrog Geothermal for reference, respectively as Caldwell 2014 - MT location map.png, Caldwell 2014 - MT profile 3.png and Caldwell 2014 - MT profile 4.png.

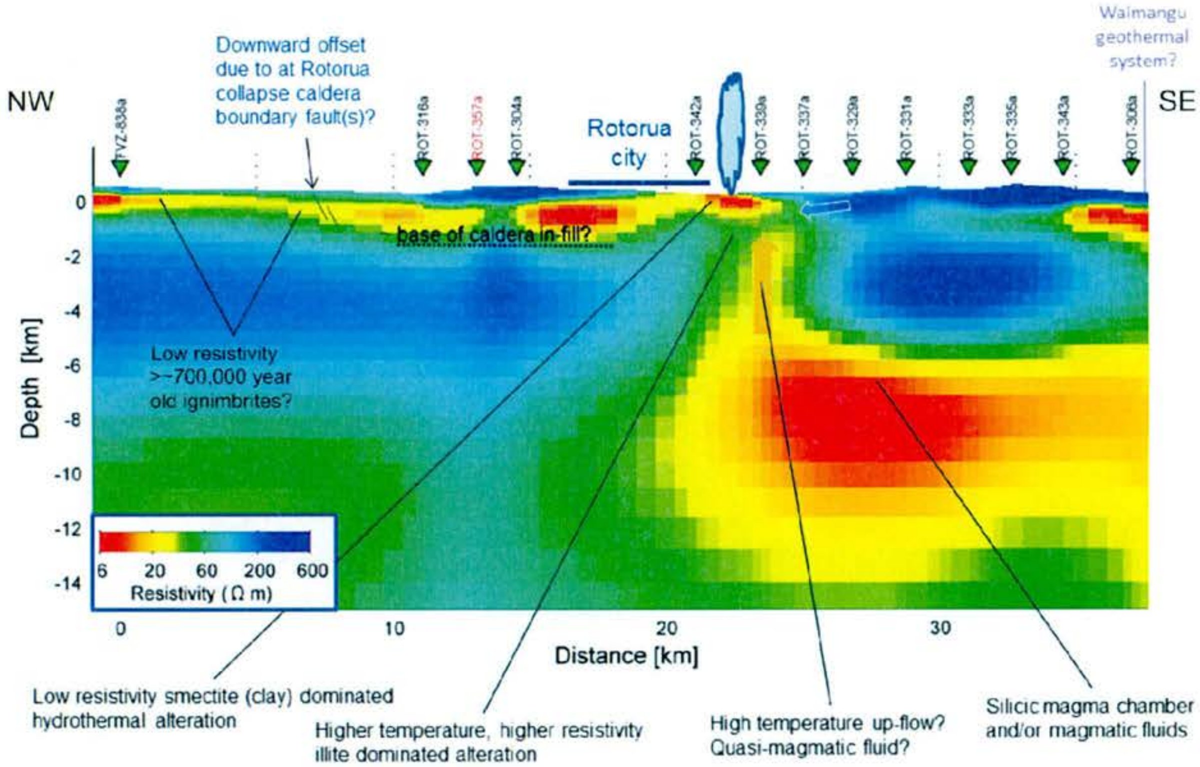

Figure 6. A NW-SE 2-D resistivity model from Caldwell *et al.,* (2014) (their profile 3) with annotated geological interpretations.

5.3 GRAVITY DATA

Hunt (1992) examined gravity data from the Rotorua area. The Rotorua caldera presents a complex and atypical gravity signature compared to other rhyolitic calderas, which usually have a circular negative gravity anomaly (Macdonald, 1974). Hunt (1992) identifies a gravity low west of Lake Rotorua with three minima. Within the city boundary, a gravity low beneath Linton Park is inferred to be related to a considerable thickness (> 1 km) of low-density material, likely to be sediments, but may also include the Mamaku Plateau Formation and Pokai Formation. Hunt suggests that the rhyolite is not present at depth further west than well RR892 (Figure 7).

The Pukerora anomaly (Figure 7) is a gravity high coincident with the buried Rotorua Rhyolite domes beneath Rotorua City (Figure 4A). The gravity contours bulge to the west in places, indicating the rhyolite may extend to the west at depth. This is confirmed in RR892 for the western extension of the northern dome, but no drillholes are deep enough to verify this hypothesis in the southern parts of the dome.

The residual gravity anomaly map presented in Figure 7 has been georeferenced and loaded in Leapfrog Geothermal (Hunt 1992 – Residual gravity anomaly map.png) to use as a guide.

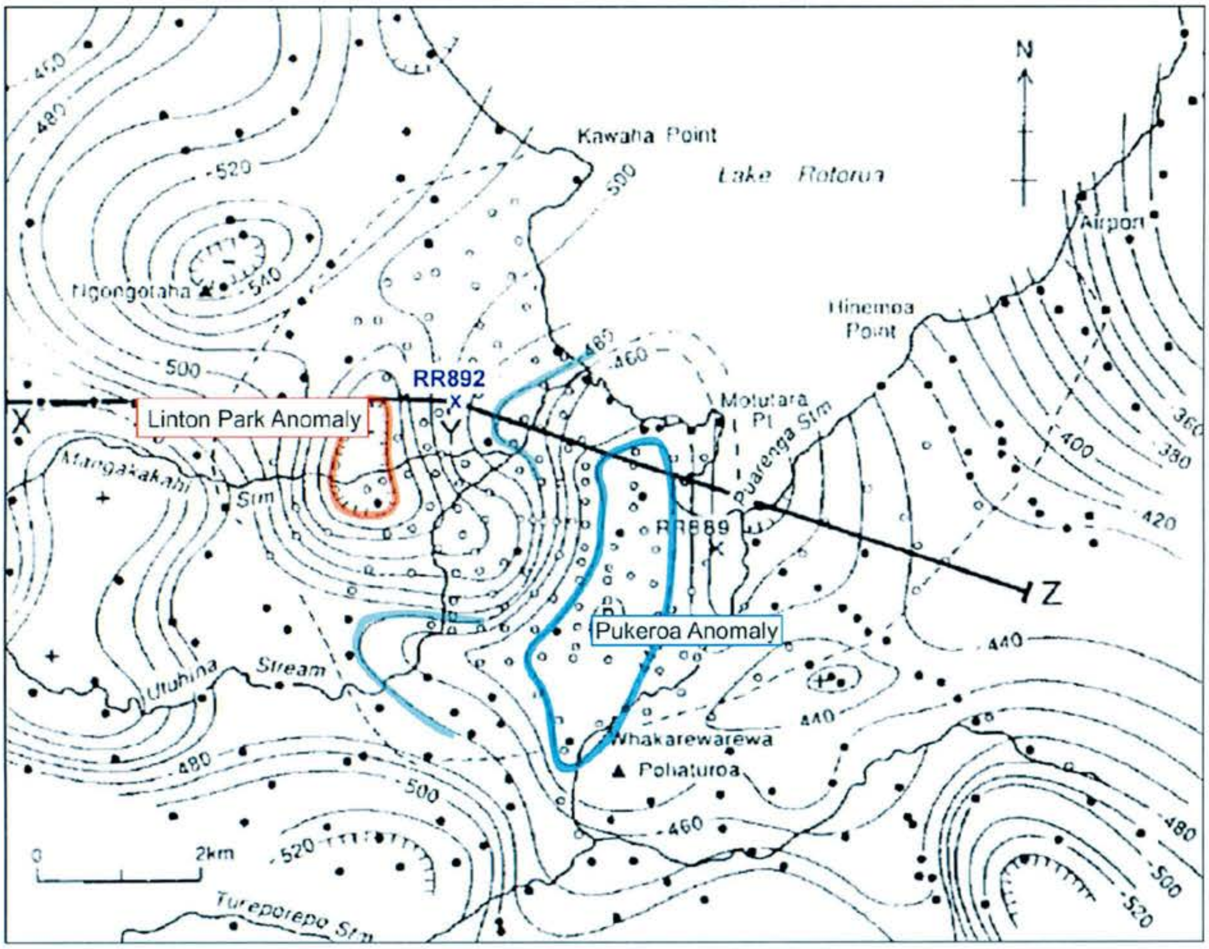

Figure 7. Residual gravity anomaly map of Rotorua City area from Hunt (1992) Contour interval is 10 μN/kg. Anomalies discussed in the text are highlighted.

6.0 BOREHOLE DATA VALIDATION

6.1 LEAPFROG REQUIREMENTS

Leapfrog Geothermal supports borehole data and works similarly to a relational database where the well ID (well name) is key to establishing relationships between borehole tables. A minimum of three tables are necessary:

- **Collar**: includes the well ID, the well coordinates and elevation, well depth and any additional information as chosen by the user. There can be no duplicates in this table and each well corresponds to one entry.
- **Survey**: includes the deviation information to define the geometry of each well in 3-D. The well ID, depth, azimuth and dip information are the parameters given to each well.
- **Interval table**: this table include interval information such as rock type, lithology or any category data or numeric data. Each line in the table includes the well ID, a depth interval (from/to columns) and a category or numeric column at the minimum. It does not have to include data for every single well.

Other measurements/categories observed across intervals or at specific depth can be added as additional interval tables and/or point tables providing they include the well ID, allowing correlation to the Collar and Survey tables for 3-D display.

The borehole data described in section 4.0 of this report had to be reformatted, checked and validated prior to import into the 3-D model. For the purpose of handling tabulated data, a Microsoft Access database was created (copied on the DVD attached to this report).

6.2 COLLAR TABLE

The following methodology was used to process the borehole location files and generate a unique 'Collar' table:

1. Format the individual tables and remove duplicates within each table.
2. Compare wells between sources to identify duplicates.
3. Check and validate the location of duplicates.
4. Merge the data.

6.2.1 Formatting tables

The BOPRC groundwater database was sent as a single table containing 964 entries (lines) with information on bore location, geology and comments. In this table, one bore could have several entries due to multiple geological layers being intersected, or comments being split across several lines. To remove the duplicates, the table was first separated into two spreadsheets, one for the location information, and one for the geology, keeping the well ID as the key identification column to allow relationships to be established. The comments were kept with the location information and compiled into one line per well[1].

[1] A lot of measurements and results are given in the comments, which should be separated in a data spreadsheet. The issue was raised with BOPRC and it was agreed that a data clean-up, other than geological data, should not be part of this project (J. Barber pers. comm., meeting 18/06/2014).

All the duplicates were then removed using Microsoft Excel *Data Validation* tool, resulting in 102 unique wells in the location table. These two tables have been loaded in the Microsoft Access database as BOPRC Groundwater Well Data – Location and BOPRC Groundwater Well Data – Geology.

The BOPRC Geothermal well database was already split between several Excel spreadsheets: well locations, comments, geological logs, water analyses, ground water data and temperatures. The well location table (509 wells) and geology table were checked for duplicates. The unique identifier is the geothermal bore number column (RR number). Each table was then loaded in the database as BOPRC Geothermal Wells – Location, BOPRC Geothermal Wells – Geology, BOPRC Geothermal Wells – Water Analysis, BOPRC Geothermal Wells – Comments, BOPRC Geothermal Wells – Ground Water Data and BOPRC Geothermal Wells – Temperature.

The Rotorua Geothermal monitoring bore table was separated into a location table and a geology table before being loaded in the database as BOPRC Monitoring Geothermal Bore – Location and BOPRC Monitoring Geothermal Bore – Geology respectively. The wells were given their true RR numbers as key identifiers in both the location and geology tables. Eight out of twenty-one wells have missing coordinates.

From the recovered Wood datasets (1982 – 1992), a table listing 943 geothermal wells was created and loaded in the database as PWood_Bore_Location. No duplicates were found, and the coordinates were formatted to the NZMG coordinate system prior to import.

White *et al.,* (2007) data used to build the Earth Vision model is given as tables in the report. All tables were merged, excluding the Wood (1992) data that is included separately in this study, and reformatted to create a location table (White_bore_location) and geology table (White_bore_geology). The location table includes 166 wells.

Finally, a table including other well data found in the literature and not present in any of the previous sources has been compiled as Other_well_from_literature_Location (10 wells). Some of these wells are outside the area of interest but provide value to the model by constraining formation thicknesses. The geological data for these wells is imported in the Geology table (refer to section 6.4).

6.2.2 Comparing data

At this stage, the Microsoft Access database included well location data from six different sources: BOPRC Groundwater database, BOPRC Geothermal database, BOPRC Monitoring data, Wood data (1982, 1992), White at al. (2007) data and other wells from the literature. In order to identify duplicates, the well numbers were compared between tables (without the prefix RR for the geothermal wells when compared to the groundwater wells). Coordinates and location descriptions were then compared between matching well numbers, to identify true duplicates that were then marked in their respective tables. Table 1 summarises the key findings for the principal datasets.

All wells with duplicates had their coordinates compared. Mismatches between the coordinates from wells within the BOPRC databases were sent to BOPRC for verification (S. Alcaraz e-mail 20-06-2014 to J. Barber). Once verified (J. Barber e-mail 29-06-2014 to S. Alcaraz), the coordinates in the Rotorua borehole database were corrected.

Table 1. Number of duplicate wells found between tables, based on the well number, and confirmed as the same well based on their coordinates and/or location description. Comments are added for information. Total number of wells in each dataset are indicated in brackets.

	BOPRC Groundwater database (102)	**BOPRC Geothermal Well database (509)**	**BOPRC Geothermal Monitoring bores (21)**	**P Wood data (943)**	**White *et al.*, (2007) (166)**
BOPRC Groundwater database (102)		**36** Well 238 (groundwater) and well RR238 (geothermal) are not the same	**3** Exact same coordinates	**0** Some wells have the same number but are not related	**21** There are an extra 3 wells with the same numbers but different locations; they have been ignored (2118, 2119 and 2147)
BOPRC Geothermal Well database (509)			**12** Includes 4 wells with minor to significant offset	**354** Coordinates rarely match	**6** Matching wells renamed as RR numbers in the White *et al.*, (2007) table
BOPRC Geothermal Monitoring bores (21)				**12** Coordinates rarely match	**0**
P Wood data (943)					**0** Some well have the same numbers but are unlikely related
White *et al.*, (2007) (166)					

The Wood dataset (1982 – 1992) include 354 wells in common with the BOPRC Geothermal well database. However, most coordinates differ. We applied a ± 25 m filter on both Eastings and Northings to identify the wells furthest apart. The query identified forty wells with the same name, but according to the location coordinates are located more than 25 m apart. Further analysis provided the following conclusions:

- Based on their address and descriptions, twelve wells are the same, even though some have major offsets (from > 800 m up to 2 km away).
- 22 wells are likely the same based on their address.

- Two wells have different addresses but are located close to each other form their coordinates and are considered the same.
- Well RR699 has a different address and major offset. However, it was found that it was RR699A in Wood's file and corresponds to RR699 in BOPRC's file. The original well was thus renamed RR699X and RR699A renamed to RR699. The renaming was cascaded to related tables.
- Two wells have the same address but different owners or vice versa and are likely the same.
- One well could not be recognised as a duplicate or not.

Wood (1982 – 1992) coordinates are likely derived from approximate location and coordinate estimation from street maps. Even though the wells in the BOPRC databases have not been surveyed by GPS, a lot of work was done to locate the wells as best as possible based on current information (including property matching). Until a rigorous GPS survey has been conducted the BOPRC coordinates are considered accurate enough for this model (J. Barber pers. comm.). GNS and BOPRC agreed that the BOPRC coordinates should be used for all duplicated wells where the coordinates do not match.

6.2.3 Merging data

At this stage of the process, the location data from different boreholes have been imported in the master database and obvious duplicates identified. The next step consists of merging the datasets in a unique table to generate the COLLAR table that Leapfrog requires for modelling purposes. The following method was followed:

1. A source column was added to each table and populated accordingly:
    - BOPRC Monitoring Geothermal Bore
    - GNS server - Wood data (1982 – 1992)
    - BOPRC Geothermal wells database
    - BOPRC Groundwater wells database
    - GNS CR2007/220 – White *et al.*, (2007)
    - Exact reference if available
2. The BOPRC Geothermal Wells – Location table was copied and renamed COLLAR. The following columns were kept (additional column can easily be added based on the key column):
    - Well number
    - Well ID (KEY)
    - Monitoring bore name
    - Easting_NZMG
    - Northing_NZMG
    - Bore Depth
    - Source 1
3. All wells from the BOPRC Monitoring Geothermal Bore table not marked as duplicates are appended to COLLAR (7 wells have been added). The 'source 1' is updated for all wells, both individuals and duplicates.
4. All wells from the BOPRC Groundwater Well Data – Location table not marked as duplicates are appended to COLLAR (66 wells have been added). A 'source 2' column is added and updated.

5. All wells from the White_bore_location table not identified as duplicates (or wells being ignored due to location issues, Table 1) are appended to COLLAR. 140 wells have been added. A 'source 3' column is added and updated.
6. All wells from the PWood_Bore_Location table not identified as duplicates are appended to COLLAR. 586 wells have been added. A 'source 4' column is added and updated.
7. A new column 'Sources' is added to COLLAR and populated by merging 'source 1', 'source 2', 'source 3' and 'source 4' into one column.
8. All wells from the Other_well_from_litterature_Location table not identified as duplicates are appended to COLLAR. 10 wells have been added. The 'Sources' column is updated.
9. A final query checking for duplicates was run. None were found. There are 1317 wells in the final COLLAR table.

6.2.4 Coordinates and depth

From the 1317 wells recorded in the COLLAR table, nine wells from the Wood (1982 – 1992) dataset do not have coordinates and were ignored for further processing. They are: RR30, RR47, RR48, RR49, RR157, RR229, RR442, RR443 and RR547A.

The remaining 1298 wells have coordinates in NZMG and were converted to NZTM using the Linz *advanced online coordinate conversion tool* (http://apps.linz.govt.nz/coordinate-conversion/index.aspx?Advanced=1). The coordinates were then updated in the COLLAR table and the columns renamed to 'Easting_NZTM' and 'Northing_NZTM' respectively.

The collar elevation was not always provided in the location files. For consistency, the Z value of each well was extracted from the combined DTM generated for Leapfrog (Topography.tif, section 3.1.2 of this report) using the *Calculate Raster Value to Point tool* in ArcGIS. A new column 'Z_from_DTM' was then added to the COLLAR table in the master database.

Finally, a new column 'Depth_3D' was created and automatically populated with the original 'Bore Depth' values. The bore depth is a mandatory field in Leapfrog and null values generate errors. All wells without data on the depth were arbitrarily set a depth of 5 m. The depth values were then compared with the depth intervals from the geological datasets (described in section 6.4). All bores with geological descriptions or samples taken at depth greater than the maximum depth given in the Collar table have been adjusted to honour the geological data.

6.3 SURVEY TABLE

A SURVEY table was created listing all the wells with their depth. Then, a column 'azimuth' and a column 'dip' were added as per the format required in Leapfrog Geothermal. All the Rotorua wells are vertical and therefore these two columns were automatically populated with 0° azimuth and 90° dip. One line per well provides enough information to create a vertical well trace in the 3-D interface.

6.4 GEOLOGY TABLE

Most wells drilled in the Rotorua area are less than 150 m deep (Figure 8), with only twenty-one wells deeper than 250 m. The maximum depth in the Rotorua City area is 458.8 m for RR892. In Tikitere, well RSM4 was drilled to ~503 m.

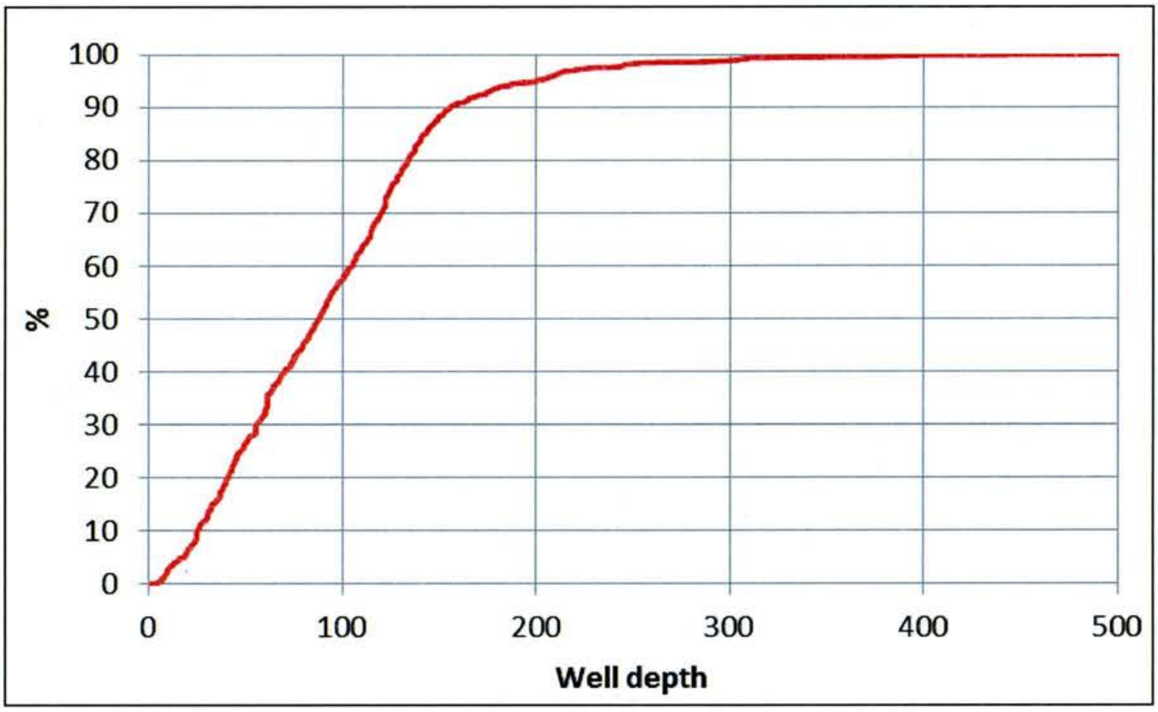

Figure 8. Cumulative distribution plot of the well depth (only for wells with known depth).

Before 1978, drill cuttings were not examined systematically and little reliable geological information is available for the majority of these wells (Wood, 1984a). Geological information available in the BOPRC databases are mostly descriptions and logs compiled by the well drillers, which are rarely correlatable with known stratigraphic units.

Here are some examples of descriptions from the well driller logs:

- Soft organic brown material with clay layers
- Brown mud
- Firm hard to very hard rock
- Hard and rough
- Soft rock

These descriptions do not provide enough information to establish the exact nature of the rock type, let alone a stratigraphic correlation. However, in some cases the descriptions may provide indirect indications of the likely formation they represent. For example:

- Soft pink rhyolite: A unit of the Mamaku Ignimbrite is known for its distinctive pink colour. If depths from constrained wells match, this formation could likely be attributed to the Mamaku Ignimbrite.
- Diatomaceous: this is a characteristic of a lacustrine environment and can be related to the Rotorua Basin Sediments.

Comparing some driller logs with geological descriptions done by professional geologists on the same wells (Table 2), we confirmed that correlation of the driller logs with stratigraphic units is typically unreliable, unless the cuttings have been reviewed by a geologist familiar with the district.

Table 2. Comparison between a driller logs (*BOPRC Geothermal and Groundwater Wells database – Geology) and the stratigraphic log from a geologist (** Kilgour, 2009) for well RR11532.

	Driller log*			Geologist log**		
Well Name	**From**	**To**	**Description**	**From**	**To**	**Geology**
RR11532	0	10	Soil, pumice, sand. Good penetration	0	6	Surficial Deposits
RR11532	10	30	Sands, mudstone, clay. Good penetration	6	30	Oruanui Formation
RR11532	30	60	Mudstone, clays			
RR11532	60	78	Grey mudstone, clays, good penetration.	30	75	Rotorua City Rhyolite Domes

As mentioned in section 4.6, Wood (1982 – 1992) final data compilation could not be located and the descriptions given in publications only represent a data subset that focusses on identifying both the top of the Rotorua rhyolite and Mamaku Ignimbrite. There are only seven graphical logs in Wood (1992), and no details on the shallow sedimentary correlations.

Based on these observations, GNS compiled geological data in various tables to load into Leapfrog Geothermal. Unless stated otherwise, the only processing done on these tables is the homogenisation of the names used to describe geological formations.

- A GEOLOGY table: This is the master Geology table Leapfrog needs to generate the borehole object in the 3-D model. The table includes the well name, the depth interval, the lithology, descriptions and a source column. A column 'Geology' summarising the formations to be used in Leapfrog has been added. This table is compiled from observations believed trustworthy and include data from recent GNS reports (Kilgour, 2006; Kilgour, 2007; Kilgour, 2009), database records and publications (e.g., Wood, 1992).
- BOPRC Geothermal Wells – Geology: an interval table including the data from BOPRC. It is not used as direct input in the model but it is used for visualisation and comparison. All intervals missing depth values have been deleted as they cannot be used in the model. Other inconsistencies in the depths intervals have been fixed:
  - Overlapping segments due to typographical errors have been fixed;
  - Invalid intervals (e.g., From: 200 m To: 200 m) have been fixed by adding a decimal to the 'TO' values.
- BOPRC Groundwater Wells - Geology: an interval table including the data from BOPRC. It is not used as direct input in the model but it is used for visualisation and comparison. A column 'Geology_3D' has been added to standardise the formation names to be used in the model. All intervals missing depth values have been deleted as they cannot be used in the model. Other inconsistencies in the depths intervals have been fixed:
  - Overlapping segments due to typographical errors have been fixed;
  - Invalid intervals (To > From) due to typographical errors have been fixed.
- BOPRC Monitoring Geothermal Bore - Geology: an interval table including the data from BOPRC. It is not used as direct input in the model but is used for visualisation and comparison.

- White_bore_geology: an interval table including geology data from White *et al.,* (2007), mainly based on interpretation of driller logs. It is not used as direct input in the model but it is used for visualisation and comparison.

Data from Wood (1984a; 1985a; 1985b) and data recovered from GNS IT backup systems, have been compiled in several tables and imported into the database and model as:

- PWood_Samples: list of well samples and thin sections (sourced from RRTS.DAT). The table includes the well name, depth of the sample, sample type, P number if available (the GNS PETLAB database number), and formation name and lithology description. A column 'Geology_3D' has been added to standardise the formation names to be used in the model. The following adjustment were made for successful import in Leapfrog Geothermal:
    - The ejecta samples ('E' sample type) have been deleted as the depth of the sample is unknown;
    - Leapfrog Geothermal does not accept measurements/observations taken at an exact same location (e.g., several thin sections done on a rock sample). In these instances, the thin sections have either been grouped under one sample, or the depth interval adjusted to avoid duplication (arbitrarily adding a decimal to the depth value).
- PWood_Rhyolite: A list of wells with the elevation of the top of the Rotorua Rhyolite, including wells where it is known accurately and wells where it is estimated (sourced from RHYOLITE.ALL and checked with published data). This file has been loaded in the model as a borehole table (PWood_Rhyolite_Depth.csv) and a point table (PWood_Rhyolite_Depth_Location.csv). The latest is related to a daughter file including accurate measurements only: Pwood_Rhyolite_Precise_measurements.
- Pwood_Mamaku: List of wells that penetrate or likely penetrate Mamaku Ignimbrite (sourced from MAMAKU.DAT and checked with published data) including bore name, elevation of the top of Mamaku Ignimbrite and a column specifying if the measurements are accurate or estimated. Proven intersections are loaded in Leapfrog as the PWood_Mamaku_Proven. Wells that possibly penetrate Mamaku Ignimbrite have been loaded in the model as PWood_Inferred_Mamaku_ Interval_last50m. Based on the bore maximum depth, the last 50 m of each well was set to Mamaku Ignimbrite. This dataset was used to validate the geometry of the Mamaku Ignimbrite, but not as a direct input as the exact interval encountered by Mamaku is unknown.
- PWood_1985_Rhyolite: Depth of the Rhyolite. Some of the data presented here is from Wood (1985a) and is not in any other source.

The PETLAB table required some formatting and processing prior to import in Leapfrog Geothermal. This file includes both surface and drillhole samples. Consequently, it had to be loaded as a x,y,z location file (not a borehole file) with the sample locations clearly defined. The X and Y coordinates are given in PETLAB. A new column for the ground level elevation ('z_groundlevel') at the locations of these samples was created, and calculated from the topography file. For surface samples, the sample elevation ('z_sample') was set equal to ground level. For cores and cuttings from the drillcores, the sample elevation was calculated ('z_groundlevel' minus depth of the sample). In the case of intervals, duplicates of the samples were generated every 5 m for the length of the interval.[2]

[2] The naming convention in PETLAB is not consistent with the Rotorua borehole database. We chose not to modify the well name from the data extracted from PETLAB to facilitate future referencing.

7.0 SUMMARY

This report presents an inventory of the data used to build a 3-D geological model of the Rotorua Geothermal Field focussing on key geological, structural and hydrological information. Surface data comes from GIS layers sourced from BOPRC, GNS databases, and relevant information digitised from unpublished and published literature. Downhole information mostly comes from the BOPRC groundwater and geothermal databases, which were completed with information found internally at GNS.

Data management is an essential step towards building a model. Converting and transforming the data into a format compatible with the software is necessary, however, the most critical step includes control and validation of the data. This report summarises the methods followed to assess the borehole data gathered from various sources. Duplicates were found and a total of 1317 wells were compiled. Uncertainties in the well locations have been addressed and coordinates have been verified from BOPRC records as and when possible. Based on the knowledge acquired throughout this study, it is likely that more boreholes may be discovered in time and it cannot be ruled out that some wells listed in the database may in fact be the same (but with different names). Unfortunately, uncertainties in a lot of the wells locations hinder a search of duplicates based on location only.

A new Rotorua borehole database has been created and includes all the borehole data in this report. The information contained in each table and details on the sources and issues found during data validation will allow this model to be replicated and will facilitate future updates of both the database and the model.

The deepest well in the Rotorua city is 458.8 m, however, the majority are under 200 m. Little reliable geological information is available, as drillcutting and core collection and description was not always systematic, especially in the early days of Rotorua drilling. Geological descriptions, when available, mostly come from logs compiled by the well drillers. Comparing data from these logs with reliable interpretation from professional geologists familiar with the Rotorua geology showed that drillers' descriptions are often inconsistent, untrustworthy, and hence cannot be used systematically to define the lithology and establish stratigraphic correlation. Key stratigraphic surface and subsurface correlations from reliable sources familiar with the Rotorua geology are included in the database and are the only datasets used as direct input into 3-D geological model. The original database from Wood (1982 – 1985), who studied the Rotorua geology as part of the Rotorua Monitoring Programme 1982 – 1985, could not be sourced. Complementary data providing insights on the possible geology and structures at depth include geophysical datasets, in particular seismic profiles, MT profiles and gravity maps.

This report is a first assessment of the data used to build a 3D geological model of the Rotorua Geothermal Field. It is believed that the model will keep evolving as new information becomes available. Details on the geological context of the Rotorua Geothermal Field and the method followed to build the 3-D geological model of the Rotorua Geothermal Field using the data described in this document will be detailed in a following report.

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APPENDICES

APPENDIX 1: BOPRC BOREHOLE DATABASES

BOPRC Groundwater database	BOPRC Geothermal database	BOPRC Rotorua Geothermal Bores
WEL_well_number	Well Number	
	Geothermal bore number	RR No
	Monitoring bore name	BOPRC
	Company Name	
WEL_own_surname	Surname	
WEL_owner_initials	Initials	
WEL_sit_add_1	Situation Address 1	Location
WEL_sit_add_2	Situation Address 2	
WEL_sit_town	Situation Town	
	Valuation Number	
	Mailing Address 1	
	Mailing Address 2	
	Mailing Town	
	NZMS260	
Easting_NZMG	Easting_NZMG	Easting_NZMG
Northing_NZMG	Northing_NZMG	Northing_NZMG
WEL_consent_number	Consent Number	
WEL_temp	Consent Status	
WEL_r_l_of_collar	Reduced Level of Collar	
RLofGround		
GPSCaptureDate		
	Elevation Code	
DCM_drill_cmp	Drilling Company	
	Driller Name	
DMT_drill_method	Drilling Method	
WEL_date_drill_completed	Date Drill Completed	
AllocationZone		
MaxAnnualVolume		
WEL_bore_depth	Bore Depth	Depth
CasingDepth	Casing Depth	
CasingDiameter	Casing Diameter	
	Construction Code	
RiserDiameter		
ScreenDiameter	Screen Diameter 1	
	Screen Diameter 2	
ScreenSetFrom	Screen Set From	
ScreenSetTo	Screen Set To	
ScreenSlotSize	Screen Slot Size	
ScreenType	Screen Type	
	Aquifer Code	

BOPRC Groundwater database	BOPRC Geothermal database	BOPRC Rotorua Geothermal Bores
	Geology Layer	
	Use Status	
	Static Level Prior Pump	
	Artesian Head	
	Static Water Level Date	
	Pump Test Method	
	Pump Depth	
	Test Discharge	
	Drawn Down Level	
	Test Type	
	Duration of Test	
	Potable Water	
	Chemical Analysis	
	DSIR Log Number	
	Author	
	Geophysical Logs	
	Geothermal Bore	
	Cold Water Bore	
	Temperature	
	Isotope Analysis	
	Geologists Log	
	Pump Test Data	
	Water Level Data	
	NERMN Water Level	
	NERMN Chemistry	
	EDS Water Level	
	Date Modified	
	Staff Number	
	Staff Name	
	SpatialObjectID	
	WUS_well_number	
	Well Use 0	
	Well Use 1	
	Well Use 2	
WellComment		