Hawke's Bay 3D Aquifer Mapping Project:

Delineation of Hydrogeological Basement within the Ruataniwha Plains from SkyTEM-derived resistivity models

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Attention: Simon Harper

Dear Simon,

Hawke's Bay 3D Aquifer Mapping Project: Delineation of hydrogeological basement within the Ruataniwha Plains from SkyTEM-derived resistivity models

1.0 SUMMARY

As part of the Hawke's Bay 3D Aquifer Mapping Project (3DAMP), this report focuses on the mapping of the hydrogeological basement in the Ruataniwha Plains area using SkyTEM-derived resistivity models and supporting datasets.

In this area, the hydrogeological basement was defined as all pre-Quaternary deposits, primarily Mangaheia Group (Pliocene limestone, sandstone and siltstone, including shell beds and shelly conglomerates, deposited in a marine environment) and Tolaga Group (Miocene sandstone, mudstone and limestone). SkyTEM resistivity models, borehole data and surface geology suggest that the hydrogeological basement surface varies from surface outcrop to a depth of ~450 m in the Ruataniwha Plains. Overall, the hydrogeological basement is deeper in the northern and central regions of the Ruataniwha Plains.

The gridded surface of the hydrogeological basement boundary provides valuable information on the depth and thickness of the aquifer in the Ruataniwha Plains. This will be utilised within subsequent interpretation and modelling work as part of 3DAMP.

2.0 INTRODUCTION AND INPUT DATA

This report aims at mapping hydrogeological basement in the Ruataniwha Plains area using SkyTEM data and other supporting information (see below input data list). This work was undertaken as part of 3DAMP, a four-year initiative (2019–2023) jointly funded by the Provincial Growth Fund (PGF), Hawke's Bay Regional Council (HBRC) and GNS Science's (GNS) Groundwater Strategic Science Investment Fund (SSIF) research programme.

A thorough review of the geology, hydrogeology, available data and previous models in the Ruataniwha Plains Model area (Figure 2.1) has been provided in Tschritter et al. (2022). The primary datasets utilised for the hydrogeological basement surface interpretation include the following (see Tschritter et al. [2022] and references therein for further details):

1. A digital elevation model down-sampled to 25 m (from Tschritter et al. [2022]).
2. SkyTEM-derived smooth and sharp resistivity models (e.g. Figure 2.1; Rawlinson et al. 2022), as well as ground-based TEM soundings available in the area (Tschritter et al. 2022).
3. Borehole data (Figure 2.2; Tschritter et al. 2022).
4. Seismic data interpretations (Figure 2.1; Tschritter et al. 2022).
5. Surface geological maps (Figure 2.2; Lee et al. 2011; Tschritter et al. 2022).
6. 3D leapfrog geological model boundaries (Tschritter et al. 2022).

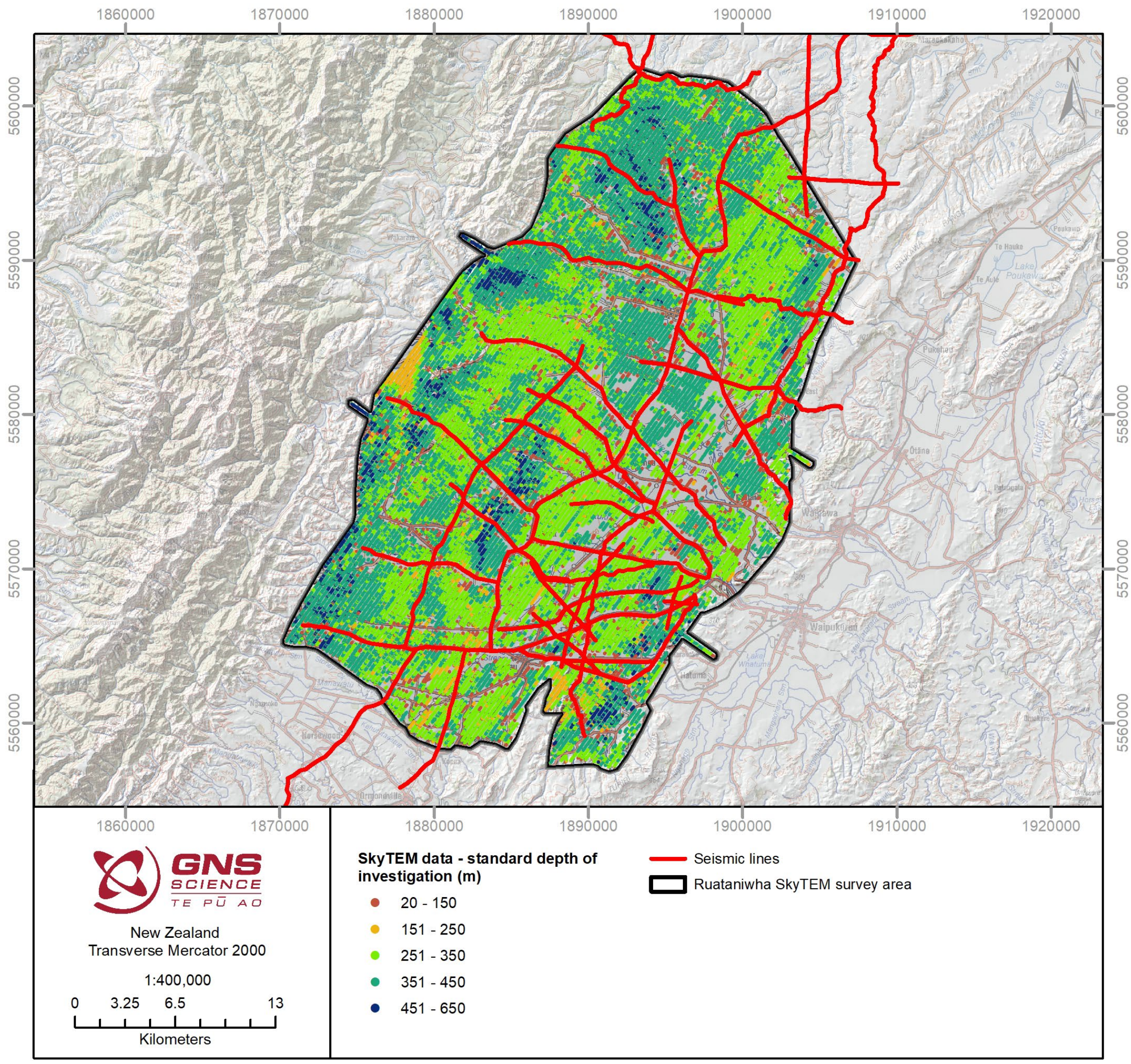

Figure 2.1 Location map of the Ruataniwha Plains showing the extent of the Ruataniwha model area, SkyTEM data coverage and seismic lines. The SkyTEM data locations are coloured based on the smooth resistivity model standard depth of investigation (DOI). Below this DOI depth, the smooth resistivity model is poorly resolved by the SkyTEM data.

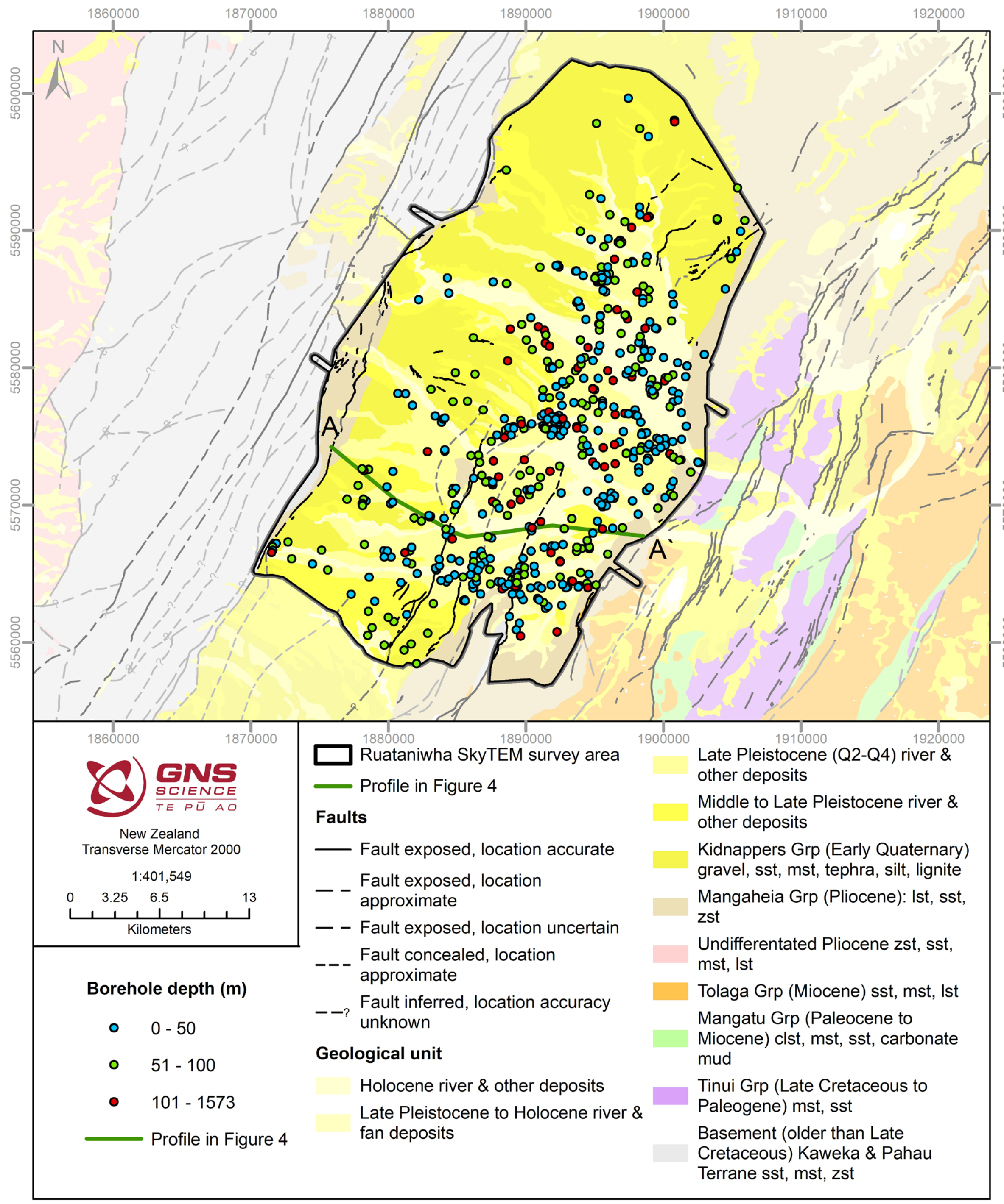

Figure 2.2 1:250,000-scale geological map of New Zealand for the wider survey area (Heron 2020) overlain by boreholes. Active faults are shown in darker colours and inactive faults in lighter grey. The following abbreviations have been used in the legend: sst – sandstone, zst – siltstone, mst – mudstone, clst – claystone, Grp – Group. The location of the cross-section in Figure 4.1 is shown as the green line between A and A'.

3.0 METHOD

3.1 Conceptual Interpretation Model

Initial assessments of the SkyTEM resistivity models and geology of the area suggested that a manual interpretation is required to map the top of the hydrogeological basement in the Ruataniwha Plains area. Following the details described within Tschritter et al. (2022) and Harper (2018), the hydrogeological basement (Basement) was defined as the top of semi-consolidated to consolidated pre-Quaternary units. All pre-Quaternary deposits, primarily Mangaheia Group (Pliocene limestone, sandstone and siltstone, including shell beds and shelly conglomerates, deposited in a marine environment) and Tolaga Group (Miocene sandstone, mudstone and limestone) are generally consolidated or semi-consolidated sediments in this study area. Due to a lack of widespread continuous geological units within the unconsolidated sediments above the hydrogeological basement horizon, it is difficult to map a more refined layer-based interpretation within the unconsolidated sediments. This assessment was confirmed by a parallel study that reviewed 15 boreholes in the basin with detailed geological logs and accompanying geophysical data (Kellett et al., forthcoming 2023).

3.2 Manual Delineation of Boundary and Creation of Boundary Grid

Using GeoScene3D software, resistivity models and supporting data were visualised together in cross-section profiles along flight lines. A maximum distance of 200 m was applied for the projection of boreholes onto the cross-sections. Resistivity models were displayed with a range of 0–200 ohm.m to highlight the resistivity contrasts identified on preliminary inspections of the data. The smooth resistivity model was primarily used for boundary mapping, as it provides finer-detailed discrimination of sediments compared to the sharp resistivity model. The sharp resistivity model was used as a supporting reference and to assist with mapping hydrogeological boundaries with reduced uncertainty, particularly in areas of increased ambiguity and thin sediments.

Manual interpretation points were placed where the resistivity models show contrasts between unconsolidated and consolidated sediments. This interpretation was consistent with the input data such as boreholes and seismic interpretations, where available, and surface geological maps.

The method followed to delineate the hydrogeological basement surface within Geoscene3D software is detailed more thoroughly within Sahoo et al. (2023). Namely:

- Seed points (manually placed interpretation points; Figure 3.1) were placed at ~100 m intervals in the cross-sections where sharp resistivity contrasts were observed.
- Seed points were gridded using a kriging algorithm (ordinary kriging, octant search = 6, search ellipsis = 2000 m, node spacing = 50 m) to develop a 3D surface.
- The gridded 3D surface was reviewed, and additional seed points were added where needed to ensure boundary consistency with information such as structural geology, surface geology (Heron 2020) and borehole lithology (particularly in areas with gaps in the resistivity data or shallow depths of investigation).
- The 3D surface was exported from Geoscene3D and re-sampled to a 25 m grid. It was extended over the entire survey area and clipped to conform to any outcrop hydrogeological basement boundaries (Figure 3.1).

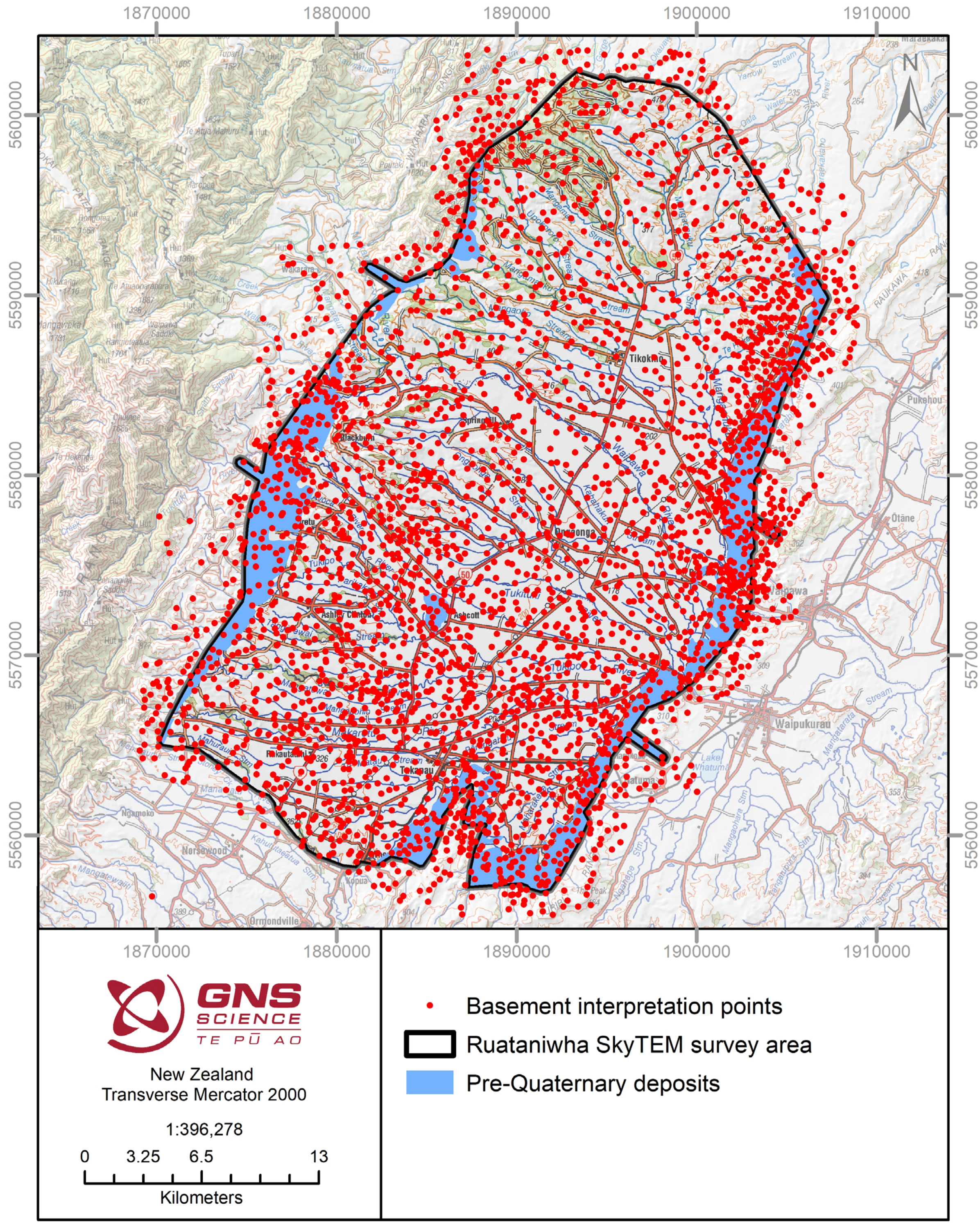

Figure 3.1 Distribution of seed points for hydrogeological basement interpretation. Basement interpretation points picked outside the SkyTEM area are designed to constrain the interpolation of the basement surface. The blue coloured areas showing distribution of pre-Quaternary deposits (outcrop hydrogeological basement boundaries; Heron 2020) have been used to clip the basement surface so that it fits with the outcrop geology.

4.0 RESULTS

The hydrogeological basement horizon represents the base of the gravel-rich units of the Kidnappers Group (e.g. Salisbury Gravel of Brown [2002]) in most of the Ruataniwha Plains and represents the base of the Young Gravel in some of the eastern areas where Salisbury Gravel is not present (consistent with geological cross-sections presented in Francis [2001]). Gravel-poor units of the Kidnappers Group often interfinger with gravel-rich units, and it is difficult to map these individual units based on SkyTEM data alone. However, when some of these gravel-poor units occur as a continuous body below the gravel-rich units, they have then been considered to be part of the hydrogeological basement unit.

In general, gravel-rich units of the Kidnappers Group and Young Gravel show moderate to high resistivities of >30 ohm.m. This resistivity cut-off of 30 ohm.m was used to differentiate these gravels from clay-rich semi-consolidated and consolidated sediments that lie below. However, in the western and eastern areas close to the exposed hydrogeological basement rocks, it is difficult to differentiate these gravels from underlying units based only on SkyTEM resistivity models. In some of the western areas, gravels of Kidnappers Group are underlain by Mangaheia Group sandstone and siltstone, and they often show a similar resistivity character. An integrated analysis of borehole descriptions, previous seismic data interpretation (see details in Tschritter et al. [2022]), geological cross-sections (Francis 2001) and surface geology (Heron 2020) has been done to differentiate these units at some places. In areas where there is a lack of borehole information, the uncertainty in the hydrogeological basement interpretation is high. In some of the eastern areas, the Young Gravel show very high (>100 ohm.m) resistivities similar to the underlying Mangaheia Group limestone units. In these areas, the uncertainty in the hydrogeological basement interpretation is also high.

The differentiation between Salisbury Gravel and the Young Gravel is not clear in all parts of this study area based on the SkyTEM resistivity models. In general, the upper part of the Young Gravel unit shows a distinctive very high resistivity (>100 ohm.m) compared to the Salisbury Gravel (Figure 4.1). In the north, and in parts of the central area, a low to moderate resistivity (~15–40 ohm.m) clay-rich unit separates the Young Gravel from the Salisbury Gravel. However, in other areas, the lower part of the Young Gravel and the top of the Salisbury Gravel show similar lithology and resistivity character (Kellett et al., forthcoming 2023). As described in previous publications (Harper 2018; Rakowski 2021), SkyTEM resistivity models also indicate that this low to moderate resistivity clay-rich unit between the Young Gravel and Salisbury Gravel is thin and discontinuous.

The interval between the DEM and the hydrogeological basement horizon (i.e. the depth to hydrogeological basement) represents the overall thickness of unconsolidated aquifer units in the Ruataniwha area. The depth to the hydrogeological basement map (Figure 4.2) suggests that aquifer units are mainly distributed in the central and northern regions, where the maximum sediment thickness is ~450 m. This map fits well with the depocentre distribution pattern and maximum depth of the hydrogeological basement by Harper (2018). Some of the fault-bounded grabens in the western areas also show the potential for thick aquifer units. These units are considered to be mainly the Salisbury Gravel, based on surface geology and previous publications (Francis 2001; Brown 2002; Harper 2018).

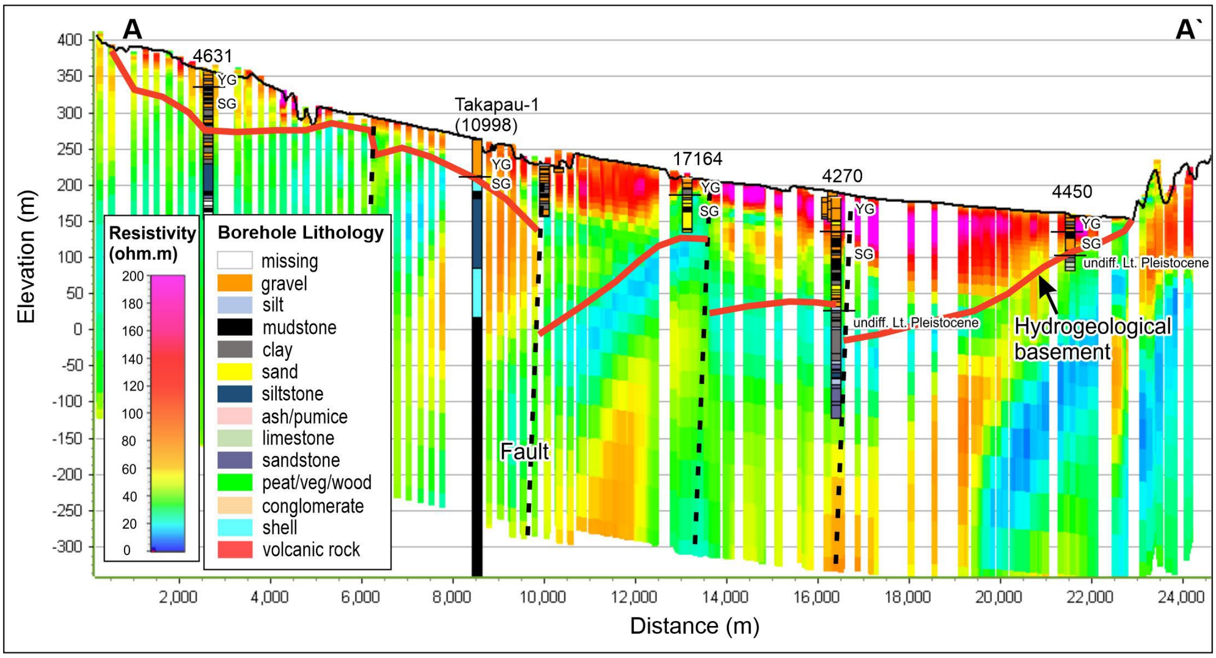

Figure 4.1 Profile AA` (see location in Figure 2.2) showing the smooth SkyTEM model, key boreholes and hydrogeological basement interpretation. The borehole lithological descriptions and representations of Young Gravel (YG) and Salisbury Gravel (SG) are derived from petroleum reports, Brown (2002) and Kellet et al. (forthcoming 2023). The interpreted faults match with the surface geology map (Figure 2.2), with the exception of the fault mapped to the left of Takapau-1 well. This fault is newly interpreted based on the SkyTEM data.

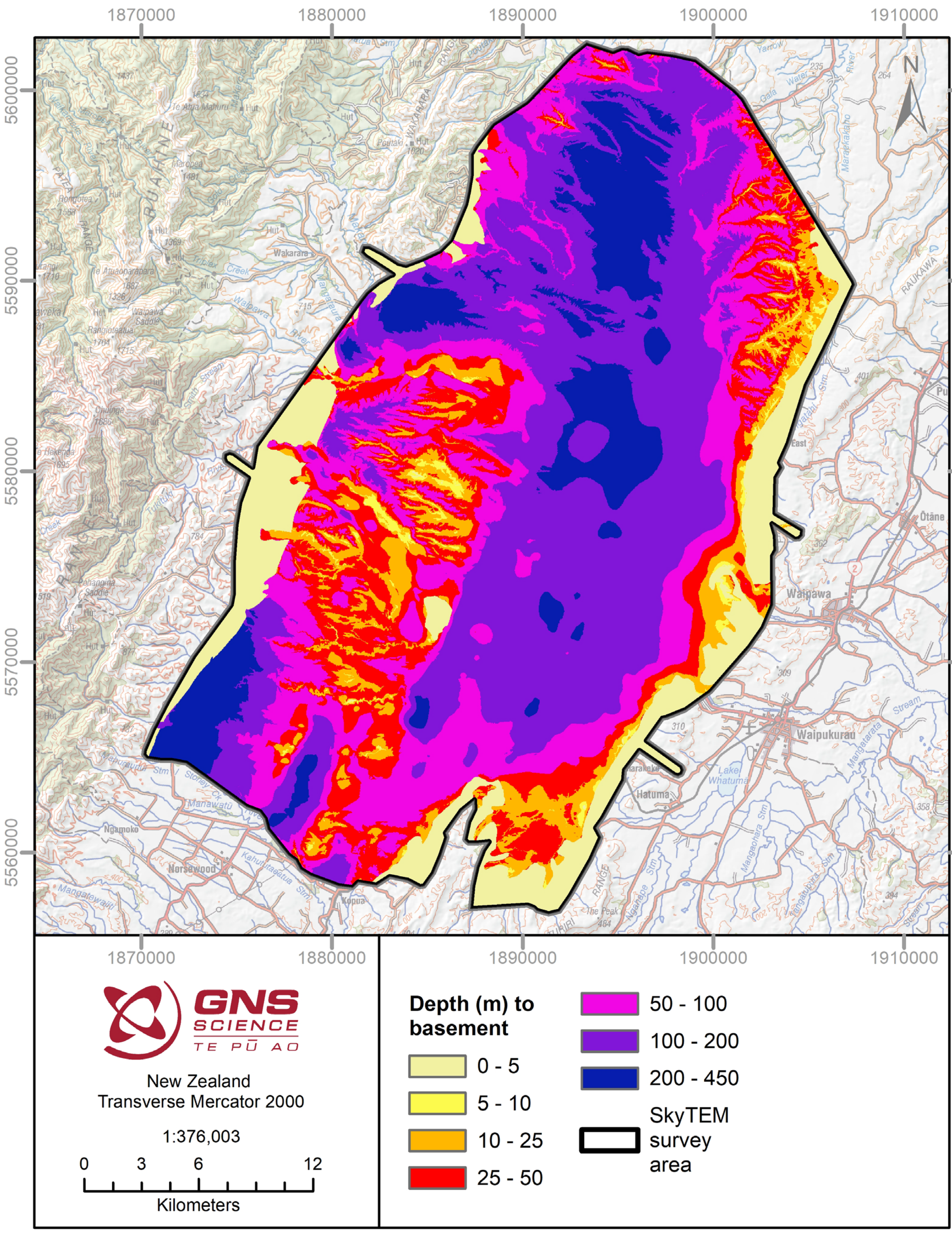

Figure 4.2 Depth to hydrogeological basement surface (equivalent to the thickness of the aquifer unit).

5.0 DELIVERABLES

The primary dataset delivered is the hydrogeological basement boundary surface, which is delivered in the readily accessible ascii grid format (with 25 m resolution):

- *Ruataniwha_Basement_top_V1_2023.asc*

Manual interpretation points that were used to generate the surface are provided as an x,y,z *.csv file:

- *Ruataniwha_Basement_top_points_V1_2023.csv*

Polygons utilised for refinement of the surface at the ground surface are provided as a shapefile:

- *Ruataniwha_GeoMap_Basement_clip.shp*

The utilised 25 m DEM is provided in an ascii grid format:

- *RuataniwhaSkyTEM_DEM2022_25m.asc*

Yours sincerely,

Tusar Sahoo	Zara Rawlinson	Richard Kellett
Geoscientist	Senior Hydro-Geophysicist	Senior Geoscientist

6.0 ACKNOWLEDGEMENTS

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