

REPORT

TAUPO DISTRICT COUNCIL

**Taupo Urban, Commercial and
Industrial Structure Plan:
Geotechnical and Geo-
environmental Hazards, Rev 1**

Report prepared for:

TAUPO DISTRICT COUNCIL

Report prepared by:

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1 Introduction

Taupo District Council (TDC) is looking to establish more land for commercial and industrial activities. A number of parcels of rural land totalling approximately 500 hectares have been identified in Taupo District 2050 (TD2050) as potentially commercial or industrial. A structure plan is therefore required to determine the suitability of this land to support such activities. It is envisaged that preparation of the structure plan will be the first step towards re-zoning the land from its current 'Rural' status to a zoning that would allow commercial/industrial use. To effect this change TDC requires information regarding a number of different aspects of the proposed industrial areas.

TDC has engaged Tonkin & Taylor Ltd to carry out a geotechnical and geo-environmental assessment of the proposed industrial areas. In particular we have been asked to investigate the following:

- Fault lines;
- Flood hazard areas;
- Hot ground hazard areas;
- Known contaminated or potentially contaminated sites;
- Areas of land instability (landsliding and tomos);
- Erosion hazard areas; and
- Areas of regional subsidence.

2 Site Description

The proposed industrial sites are located to the east, west and south of Taupo Township. For the purposes of this study the proposed industrial sites have been broken down into ten areas. These areas are shown in Figure 1.

The geology underlying the general Taupo Area comprises various ignimbrites, volcanic airfall deposits and lake sediments. The main geological units that are likely to underlie the proposed industrial areas are:

- Lacustrine and fluvial deposits of the Huka Formation (300 to 26.5 ka);
- Primary Oruanui Ignimbrite (26.5 ka);
- Reworked Oruanui Ignimbrite;
- A lava dome buried beneath younger deposits in Area 4;
- Many airfall and flow deposits, including the Wamihia Ignimbrite, with many paleosols (old, buried, organic soil horizons), thin reworked pumice deposits and loess (26.5 to 1.8 ka);
- Taupo Ignimbrite and associated airfall deposits (1.8 ka);
- Fluvial sediments reworked from the 1.8 ka Taupo deposits.

A detailed description of each of these units is beyond the scope of this report, but:

- Huka Group sediments generally comprise well bedded lacustrine siltstone and diatomite as well as fluvial sandstone, conglomerate and pumice deposits;
- The ignimbrite and reworked ignimbrite deposits are likely to comprise unwelded pumiceous gravelly sand deposits that are loose to dense;

- The buried lava dome may comprise andesitic or dacitic rock associated with the Tauhara dacite; and
- Airfall deposits mostly comprise sand and gravel deposits that are loose to medium dense. Paleosols are present between many airfall deposits.

3 Methodology

3.1 Geotechnical methodology

The work involved a desk study, site walkover and geological and geomorphic mapping. In particular the study included the following:

- Review of available geotechnical data from neighbouring sites and the Eastern Taupo Arterial (ETA) project;
- Review of published geological maps of the area, as well as recently completed in-house maps and cross-sections;
- Review of historical and stereographic aerial photography to identify potentially contaminated sites, possible landslips, areas of instability (including tomo formation), flood hazard zones, areas of erosion and faults. Aerial photographs were supplied by TDC;
- Manipulate topographic contours using GIS software to identify land prone to instability, erosion and flooding. Topographic data does not exist for all of the proposed industrial areas. In areas without topographic information field mapping was relied upon. Topographic data was supplied by TDC;
- Review of survey data and subsidence modelling from Contact Energy in order to identify areas potentially susceptible to long-term geothermally-induced subsidence;
- Undertake a site walkover inspection of areas 1 to 9 and geological/geomorphic mapping to identify possible areas of instability and tomo formation, poor drainage, hot ground and erosion. (N.B. A walkover has not been carried out for Area 10); and
- A review of Area 10 using contour data and the 2008 aerial photographs.

3.2 Geo-environmental methodology

To assess the potential for historic or current land use activities to have resulted in hazardous substances being greater than background levels the following scope of works was undertaken:

- Review of the Taupo District Plan, in regard to known contaminated sites;
- Liaison with Environment Waikato (EW) regarding properties on their Selected Land Use List (SLUL) being known or potentially contaminated sites;
- Review of historical aerial photographs;
- Discussion with the Landcorp Farm Manager, regarding historic and current land use practices;
- A site visit to proof the information collected and visually assess the study area (N.B. a walkover was not carried out for Area 10); and
- A review of Area 10 using the 2008 aerial photographs.

The data gathered from the geotechnical and geo-environmental assessments is presented in Figures 2 to 7 in Appendix A. This data is available in Transverse Mercator 2000 (TM2000) coordinates for inclusion into TDC's GIS database. The geotechnical and geo-environmental hazards associated with each area are summarised in Appendix B.

4 Geotechnical Hazards

4.1 Faulting

The Taupo Volcanic Zone is an area of high active faulting although the thin crust limits maximum earthquake magnitudes¹. Deposits of young volcanic and fluvial material often mask the surface expression of many faults in the Taupo area. No new faults were identified during our walkover, but various faults have been mapped that intersect with, or are proximal to the proposed industrial areas^{1,2}. These are shown in Figures 3 to 5. The geothermal activity in the Broadlands and Crown Road reserves is associated with the Rotokawa Fault Zone³. A mapped splay of the recently active Aratiatia Fault also passes through one of the proposed industrial areas¹.

Mapped faults are located in or close to areas 3, 4, 6, 7 and 10. The eastern splay of the Aratiatia Fault runs through Area 10 and runs close to areas 3 and 4. A gully that runs through area 5 may also represent the extension of a fault mapped to the northeast⁴.

4.2 Flood Hazard Zones

The pumiceous deposits that are underlying the proposed industrial sites are usually highly permeable and any water that falls onto, or flows over them generally percolates away quickly. Zones of flood hazard have been identified in a number of places and comprise the floors of 'box' gully systems that dissect ground surface. These areas are usually dry, but are potential overland flow paths and as such are considered flood hazard zones. These gully systems are thought to have formed by erosion immediately after the deposition of the Taupo ignimbrite. They are dry, but are much lower than the surrounding countryside. Incised 'box' gullies are located in areas 1, 4, 7, and 8 (see Figures 3, 4 and 5). Potential flood hazard zones are also present in area 5 and 6 where shallow incised gullies are present.

A significant flood hazard has been identified in Area 10 by TDC. This relates to stormwater runoff from the industrial area and roads to the east. Incised gullies are also present in to the north and west of Area 10 which are potential flood hazards.

Numerous dry shallow stream channels can be observed in all of the areas studied. They are often of limited extent as any water flowing in them soaks away into the ground. These shallow channels are not considered to comprise a high flood risk, however, some of these channels were observed to contain freshly deposited material indicating recent overland water flow. They should be taken into account during development and appropriate drainage measures implemented.

¹ McVerry et al. (2005) Estimation of spectra for Waikato River Bridge, East Taupo Bypass. Report by GNS Science to Opus International Consultants.

² Grindley, G.W. (1961) Geological Map of New Zealand, 1:63,360, Sheet 8 – Taupo, New Zealand Geological Survey.

³ Fulton Hogan (2008) Taupo District Council Contract No. TDC 678 East Taupo Arterial. Tender Submission Report

⁴ Terrane Consultants (2008) Taupo Retail Holdings, Broadlands Road Geotechnical Peer Review Report.

4.3 Hot Ground Hazard Areas

The Tauhara Geothermal Field is located to the east of Taupo Township and is associated with the Rotokawa Fault Zone. Active surface expressions of the geothermal field are located at the Broadlands Road and Crown Road reserves. Surface geothermal features and areas of hot ground hazard are shown in Figures 3 and 4. Patches of hot and barren ground were observed outside these reserves in areas 4, 5 and 6. Hot ground hazards are also noted in the Taupo District Plan beneath areas 5, 9 and 10⁵. Warm or hot ground and water has also been noted in boreholes drilled for the ETA in areas 3, 5 and 6⁶.

In addition to the hot ground hazards, geothermal gases can be corrosive to construction materials and hazardous to human health. The effects of soil and airborne geothermal gases should be considered during construction of the industrial buildings and appropriate mitigation measures taken.

Hydrothermal eruptions are also associated with geothermal areas. The timing and location of hydrothermal eruptions are unpredictable, but two such events occurred in Broadlands Road in 1974 and 1981⁷. The 20 June event resulted in a 1640 m² crater and distributed debris over some 800 m.

4.4 Land Instability

4.4.1 Tomos/Piping

Tomos are collapse structures (sink-holes) that form above underground cavities. In the Taupo area tomos form within the pumiceous deposits due to ground water movement or geothermal activity.

Tomos in Taupo most commonly form by collapse of the ground surface into subterranean cavities formed by the entrainment of fine particles by groundwater. This process is called piping. Piping is thought most likely to occur where influxes of rainwater percolating through the soil encounter impermeable soils. The water is then forced to flow laterally and may flow fast enough to induce internal erosion of the soils⁸. Piping can also be generated by concentration of rainwater at man-made drainage structures. Man-made tomos have been documented in the Taupo area, particularly beneath unlined stormwater detention ponds² and in areas of overland flow paths.

Piping often occurs in the Taupo Ignimbrite, especially where it is underlain by an impermeable paleosol (buried soil horizon). Piping has also been documented in other deposits, but it is most commonly associated with the Taupo Ignimbrite⁹.

Geothermal tomos occur in areas of current or previous hot ground as a result of fluids or gases escaping to the surface. The ground can also be weakened due to alteration by geothermal fluids thereby increasing the chance of subsurface erosion.

⁵ Taupo District Council (2007) Taupo District Plan.

⁶ Opus (2007) East Taupo Arterial. Geotechnical Assessment Report. Report to Taupo District Council.

⁷ Scott, B.J. and Cody A.D. (1982) The 20 June 1981 hydrothermal explosion at Tauhara geothermal field, New Zealand Geological Survey

⁸ Foster, M. and Fell, R. (1999) A framework for estimating the probability of failure of embankment dams by internal erosion and piping using event tree methods: Sydney, Australia. School of Civil and Environmental Engineering, University of New South Wales.

⁹ Manville, V., Reeves, R. (2006) Acacia Heights CMP – Geology and Geomorphology. GNS Science Consultancy Report 2006/228.

The occurrence of tomos created by piping is often unpredictable. Taupo Pumice is present beneath all of the areas studied and is usually underlain by a paleosol. The paleosol is undulatory which may control the direction of ground water flow. There is potential for tomos to form under all of the proposed industrial sites, but there are a number of areas in which their probability is high. Areas which contain deeply incised gully systems, for example, are likely to be more susceptible to piping induced tomos. Such systems are present in areas 4, 7 and 8 and to the north of Area 10. Tomos and irregular ground were observed in areas 4, 7 and 8 during the site walkover.

Geothermal ground conditions are present beneath a number of the sites visited. The geothermal areas have been highlighted as high risk of tomo formation. This risk is well illustrated in the contours for the southern part of Area 6. The ground surface adjacent to Raywood Crescent is highly irregular as is characteristic of geothermal areas. This irregular surface extended beneath Raywood Crescent and Claret Ash Drive prior to industrial development. Steam vents installed adjacent to Raywood Crescent indicate that the geothermal field is still active in this area. Other areas at risk from geothermally induced tomos include 3, 4 and 5.

4.4.2 Landsliding

Landslides are induced through excess porewater pressures and oversteepened slopes. They may also be caused by human activities where excavations create excessively steep or high slopes and where construction imparts excessive loads on nearby slopes.

No groundwater seepages were observed during the walkover and the water table is generally quite deep suggesting excess porewater pressures do not occur in the study area. In addition most of the proposed industrial areas are either flat or undulating and landsliding is not perceived to be a major problem. Landsliding may be an issue, however, on steep slopes in areas with incised gully systems, particularly during earthquakes. Landsliding may also be an issue on the southern slopes of a buried lava dome in Area 4, especially if the slope is excavated during development.

Locations that have a landslide hazard are located in areas 4, 5, 7, 8 and 10. Landsliding issues may also be associated with some less incised gullies, but they are unlikely to be large scale. Some set back should be maintained from any incised gully systems

4.5 Subsidence

4.5.1 Regional Subsidence

Regional subsidence has been examined by Contact Energy¹⁰. It is associated with pressure decline in the geothermal system due to the extraction of geothermal fluids for electricity generation. The Tauhara Geothermal Field underlies the north and east of the Taupo Township and is hydrologically linked with the Wairakei Geothermal Field. Fluid flow from the Tauhara Geothermal Field to the Wairakei field has lead to subsidence in these areas. It has also lead to the generation of shallow steam zones and further hot ground in the Tauhara Geothermal Field.

The magnitude and rate of future subsidence will be dependent on the extraction rates of geothermal fluids from Wairakei and Tauhara geothermal fields. Subsidence rates of between 0 and 45 mm/year have been calculated in the study area. The greatest

¹⁰ Contact Energy (2007) Ground level change study.

subsidence may be expected in Area 3. Subsidence may also be expected in areas 2, 4, 5, 6, 7 and 10. This subsidence may lead to significant settlement of industrial structures during their design lives. Differential settlements beneath any proposed structures and associated services should be accounted for during design. Horizontal displacements may accompany the subsidence. These may be up to 30% of the vertical displacement.

Further information regarding the subsidence associated with geothermal fluid extraction is available from Taupo District Council.

4.5.2 Local Subsidence/Settlement

Local subsidence and settlement has not been specifically examined as part of this project. There is, however, an area of known fill in Area 6. This has been highlighted as an area of known contamination and it is unlikely to have been engineered. Any structures built on this material are likely to undergo greater settlement than would be experienced if they were built on natural ground. The amount of settlement that the structures may experience will need to be assessed by site specific ground investigations.

4.6 Erosion Hazard Areas

Erosion hazards are associated with moderately steep terrace slopes and steep gully sides. Debris was observed at the base of the terrace in Area 9 and is suspected to be present at the base of the terrace in Area 1. The steep gully sides are also considered susceptible to erosion due to overland water flow during heavy rainfall and due to seasonal processes. Zones of erosion hazard on the gully sides are generally coincident with areas also at risk of landsliding. These are located in areas 1, 4, 6, 7, 8, 9 and 10 (see Figures 2, 3, 4, 5 and 6).

It should also be noted that pumice deposits are susceptible to significant and rapid erosion on even gently dipping slopes, particularly if the surface cover is removed. Such erosion potentially affects all of the areas studied. Development of the proposed areas should avoid creating areas of bare ground. Surface stormwater control should also be designed to avoid the concentration of overland flow at any particular point and thereby minimise the risk of erosion.

5 Geo-environmental Hazards

The definition of a contaminated site as defined in the Waikato Regional Plan is 'land where any hazardous substances has been added at above background levels as a result of human activity'. This definition is similar to that outlined in the Taupo District Plan as a site 'where the concentration of hazardous substances exists at greater quantities than the naturally occurring background levels'.

Under the RMA 1991, both the Regional and Territorial Authorities share the function of controlling the use of land in order to prevent or mitigate any adverse effects of hazardous substances. The territorial authority is responsible for controlling land use on contaminated sites, which means in terms of the district plan and building consent applications the suitability of the site, in regard to the potential effects of hazardous substances on the building and/or people in the building, given the degree and effects of the contamination. The Regional Council is responsible for the management of the passive and active discharges from contaminated land and therefore the potential effects on the receiving environment.

It is also worthy of note that other organisations such as the Ministry of Health (under the Health Act 1956) and the Department of Labour (under the Health and Safety Act 1992) also have functions that relate to the management of contaminated land. These functions are, however very limited in their scope.

5.1 Taupo District Council and Environment Waikato Database

The TDC has identified known contaminated sites within Schedule 7.0 of the District Plan, these sites are graphically illustrated on the planning maps. Specific sites are not identified in the Waikato Regional Plan, rather EW maintains a register of known contaminated sites within the district, the Specific Land Use List.

In determining whether land is potentially contaminated, when compared to normal background levels, it is important to note that concentrations of some elements, specifically arsenic, mercury etc, associated with geothermal activity, may be naturally elevated within the soil and underlying groundwater for the study area. Comparison of potential contaminants within soil and groundwater therefore need to be treated with caution if comparing to reported guideline levels.

A summary of the information from both the regional and territorial authorities is detailed in Table 5.1 below and shown on the maps in Appendix A:

Table 5.1: Known contaminated sites within the study area

Area	Authority	Legal description	Description
8	TDC and EW	Lot 3 DP 306768 Pt Lot 1 DP 306768	TDC (C11) - Old rubbish dump site (now also part of a timber treatment site). TDC (C42) - Sawdust and mill waste (also part of timber treatment site) EW – identified on Selected Land Use List as associated with a former landfill site The former timber treatment site operated from 1954 to 1997. During this period a gully running through the site and extending into the study area was reported to have been infilled with woodwaste. The woodwaste may have contained elevated concentrations of chemicals used in the treatment of processed timber.

5.2 Historical Aerial Photographs

Aerial photographs from 1946, 1962, 1976 and 2008 were reviewed as part of the assessment. It is noted however that not all of the study area is included within the historical aerial photographs.

The 1946 and 1962 aerial photos indicated that the study area was undeveloped, apart from pastoral grazing. No building or structures, i.e. stock yards etc were identified within the study area. The 1976 aerial however shows extensive development around areas 6 and 7 as shown on Figure 1 in Appendix B. These include:

- Area 6 – part of the area is being used by the timber sawmill for the storage of processed timber. The shallow gully, evident on the 1946 aerial photograph has

been infilled, as detailed in Table 5.1. The 2008 aerial photograph shows that the boundary of the sawmill site has moved back and that the neighbouring land is now utilised by the motocross club for tracks and associated amenities.

- Area 7 – residential development has occurred on the western side of Crown Road. The land use is pastoral grazing. The 2008 aerial photograph indicates that a commercial subdivision has been developed in the southern area with the balance still in pasture grazing.

The 2008 aerial photographs show the development of Area 10 as described below:

- Area 10 – A portion of the site is occupied by the Taupo Native Plant Nursery. The nursery includes glasshouses and accessory buildings. At the time of writing it is unclear whether any chemicals were stored on the site and the type of heating used in the glasshouses. There is potential for contamination of near surface soils, from metals and pesticides historically or currently used in the nursery and metals and hydrocarbons associated with heating of the glasshouses.

Also of note is the area of land located immediately to the east of the Taupo Native Plant Nursery. The area appears to have been used for the disposal of woodwaste from the neighbouring timber sawmill.

5.3 Personal Discussions

The Landcorp Farm Manager, Mark Cunningham, was asked about the historic and current land use practices across the Landcorp farms, within the study areas, that may have resulted in potential ground contamination. He noted that to his knowledge there were no sheep dip sites, stock yards, filling or storage areas of hazardous substances that would have resulted in ground contamination.

5.4 Site Walkover Inspection

To confirm the designations proposed by TDC and EW, and to assess any other potentially contaminated sites across the balance of the study area, a site walkover inspection was undertaken by an Environmental Scientist with experience in contaminated land management, investigation and remediation. The following was noted:

- Area 4 – An existing commercial operation is located at about 33 Broadlands Road. The storage of agrichemicals and petroleum products was evident.
- Area 6 - The area of operation of the former timber treatment site appears to have extended past the current fenced boundary. The area is marked on the maps (Appendix B) and is shown on site by contoured land with gravel surface soils. It is possible that some residual contamination of the surface soils in this area may occur from the storage of treated timber and or landfill of wood or industrial waste.

6 Conclusions

A number of risks are present in the proposed industrial areas. These are as follows:

- Faulting associated with volcano-tectonic movements in the Taupo Volcanic Zone. Faults have been mapped in or adjacent to areas 2, 3, 4, 5, 6 and 10;
- Flood hazard areas. These areas are generally confined to the floors of 'box' gully systems located in areas 1, 4, 6, 7 and 8 and adjacent to Area 10. A significant flood

hazard has been identified by TDC in Area 10 which relates to stormwater runoff. Shallow dry stream channels are present in all of the areas studied and these should be taken into account during development;

- Hot ground hazard areas. The Tauhara Geothermal Field underlies significant portions of the study area and surface expressions are located in the Broadlands and Crown Road Geothermal reserves. Hot ground hazards affect areas 3, 4, 5, 6, 7 and 10. The effects of geothermal heat and gases need to be considered during the development of these areas;
- Contaminated land. The TDC and EW have identified an infilled gully, within area 6, as having been infilled with woodwaste and/or used as an industrial landfill. Concentrations of elements may be greater than background or exceed guideline levels for a commercial/industrial site. Further investigation is required to determine the suitability of the site for the intended land use and any necessary remedial and/or remediation measures.

From the assessment undertaken, potential contamination of surface soils in Area 10 could occur for the Taupo Native Plant Nursery, associated with the historic and current land use practices. No other known or potentially contaminated sites were evident across the balance of the study area.

- Land instability - tomos. The formation of tomos is largely unpredictable, but virtually all of the study area is underlain by Taupo Pumice deposits which are susceptible to erosion and potentially to tomo formation. Areas considered to be at high risk of tomo formation are those with incised gully systems. Tomos may also form due to geothermal activity;
- Land instability – Landsliding. Landslide hazard areas are largely confined to the sides of incised gully systems. Such systems are located in areas 4, 6, 7 and 8 and adjacent to Area 10. Landsliding may also be an issue on the southern flank of a buried lava dome in Area 4, particularly if the slope is excavated for construction;
- Regional subsidence. Regional subsidence is associated with the extraction of geothermal fluids for electricity generation. This subsidence may lead to significant settlement during the lives of the proposed buildings. It may also be associated with horizontal displacements. The maximum rate of settlement calculated by Contact Energy in the study area is 45 mm/year. It affects areas 3, 4, 5, 6, 7 and 10;
- There is an area of non-engineered fill in Area 6 that may undergo greater settlement than other parts of the study area. This will need to be investigated during development;
- Erosion hazards. Erosion hazards are mostly coincident with landslide hazard areas on the flanks of incised gully systems. They are also associated with moderately steep terrace edges. Erosion hazards are present in areas 1, 4, 6, 7, 8, 9 and 10.
- Significant and rapid erosion can also occur in pumice soils on gently inclined slopes, particularly where the surface cover has been removed. This will need to be taken into account during design and construction of the proposed industrial areas.

7 Applicability & Limitation

This report has been prepared for the benefit of Taupo District Council with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

The assessment of geotechnical and geo-environmental hazards within the plan change area has been undertaken based on the information provided and a site visit. Every effort has been made to assess and characterise the potential hazards across the plan change area, however it must be appreciated that hazards may exist that have not been identified during this assessment. This may be in regard to unsuitable ground conditions e.g. subterranean cavities or the use of agrichemicals such as DDT to control grass grub or the disposal of waste, including asbestos, within gully or geothermal areas. This assessment is not intended to replace site specific geotechnical and geo-environmental investigations that would normally be required for any commercial/industrial development.


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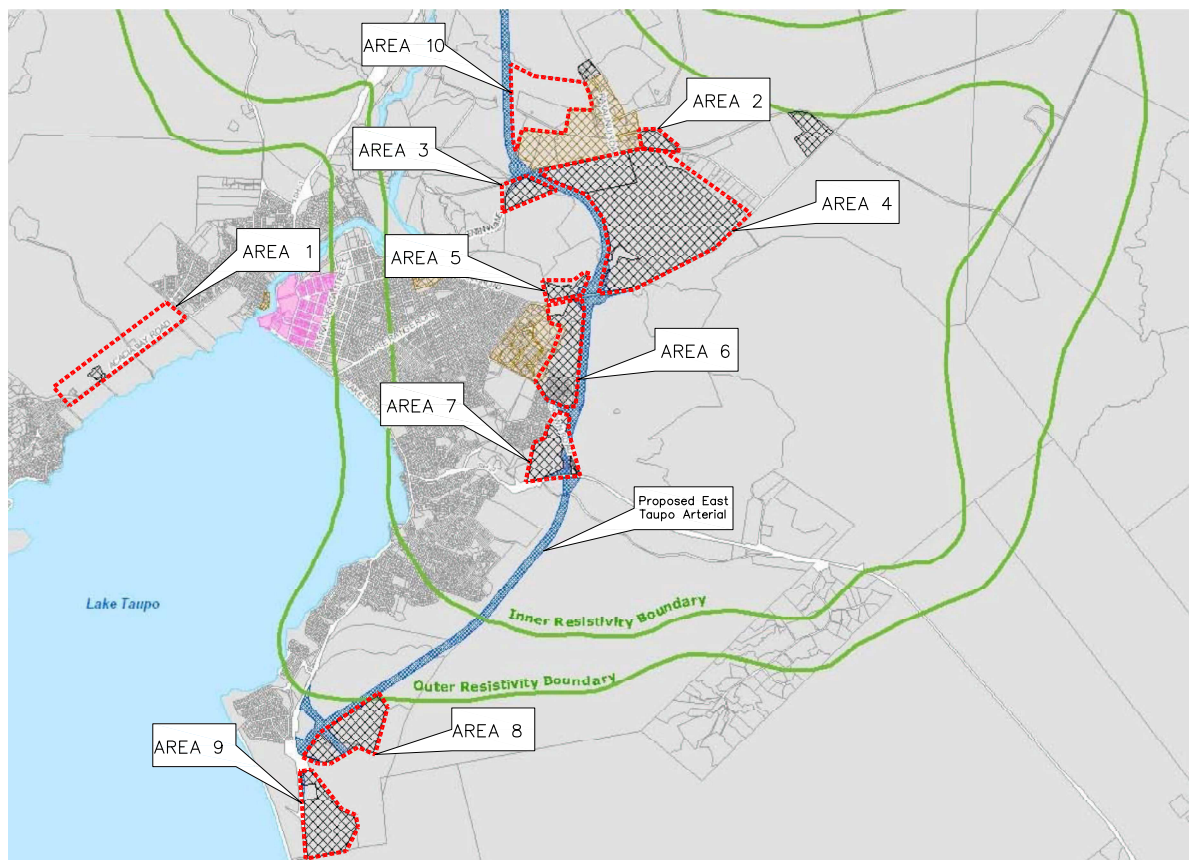
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Appendix A: Figures



- NOTES:
1. Base plan taken from Taupo District Council, TD2050.
 2. Resistivity Boundary refers to limits of geothermal field defined by electrical resistivity measurements.

 Tonkin & Taylor Environmental & Engineering Consultants ■ Tauranga ■ Auckland ■ Christchurch □ Hamilton □ Wellington □ Whangarei	DRAWN: smtb Aug.08 DRAFTING CHECKED: DMMM Nov.08 APPROVED: DAB Nov.08 SCALE: 85 1127 - Fig 1.dwg SCALES (AT A3 SIZE) NOT TO SCALE PROJECT No.: 85 1127
	TAUPŌ DISTRICT COUNCIL TAUPŌ URBAN, COMMERCIAL & INDUSTRIAL STRUCTURE PLAN Location Plan
	FIG. No. Figure 1
	REV. 2

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LEGEND

Existing TDC Planning Data	New T&T Planning Data
Contaminated sites	Flooding hazard zone
East Taupo Arterial	Erosion/landslide hazard zone
Flood hazards	Contaminated land zone
Subsidence	Possible contaminated land zone
Tomos	Landsliding hazard zone
Asbestos sites	Surface geothermal features
Geological sites	Fault lines
Geothermal wells	Proposed industrial area boundary
Hot springs	
Sawmills	
Active faults	
Hot ground hazard area	

NOTES:
 1. Aerial photograph and contours provided by Taupo District Council.
 2. Hazard zones include those identified on the TDC District Plan and those identified during this study.

SCALE 1:10,000
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 Environmental & Engineering Consultants
 ■ Tauranga ■ Auckland ■ Christchurch
 ■ Hamilton ■ Wellington ■ Whangarei

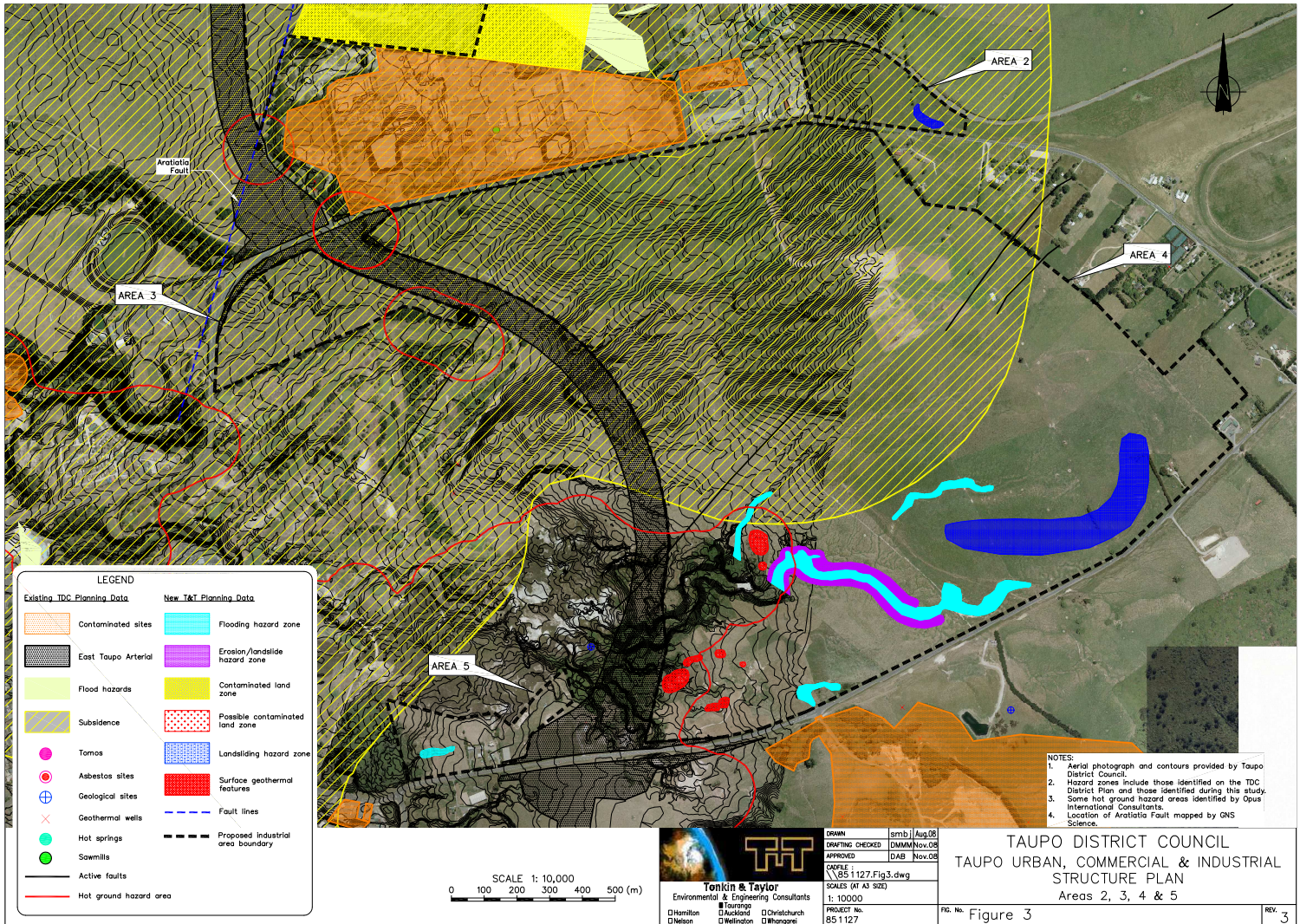
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APPROVED	DAB	Nov.08
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TAUPO DISTRICT COUNCIL
 TAUPO URBAN, COMMERCIAL & INDUSTRIAL
 STRUCTURE PLAN
 Area 1

FIG. No. Figure 2

REV. 2

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LEGEND	
Existing TDC Planning Data	New T&T Planning Data
Contaminated sites	Flooding hazard zone
East Taupo Arterial	Erosion/landslide hazard zone
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Geothermal wells	Proposed industrial area boundary
Hot springs	
Sownills	
Active faults	
Hot ground hazard area	

SCALE 1:10,000
0 100 200 300 400 500 (m)

 Tonkin & Taylor Environmental & Engineering Consultants Hamilton Tauranga Auckland Christchurch Nelson Wellington Whangarei	DRAWN	sm1b Aug.08
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	APPROVED	DAB Nov.08
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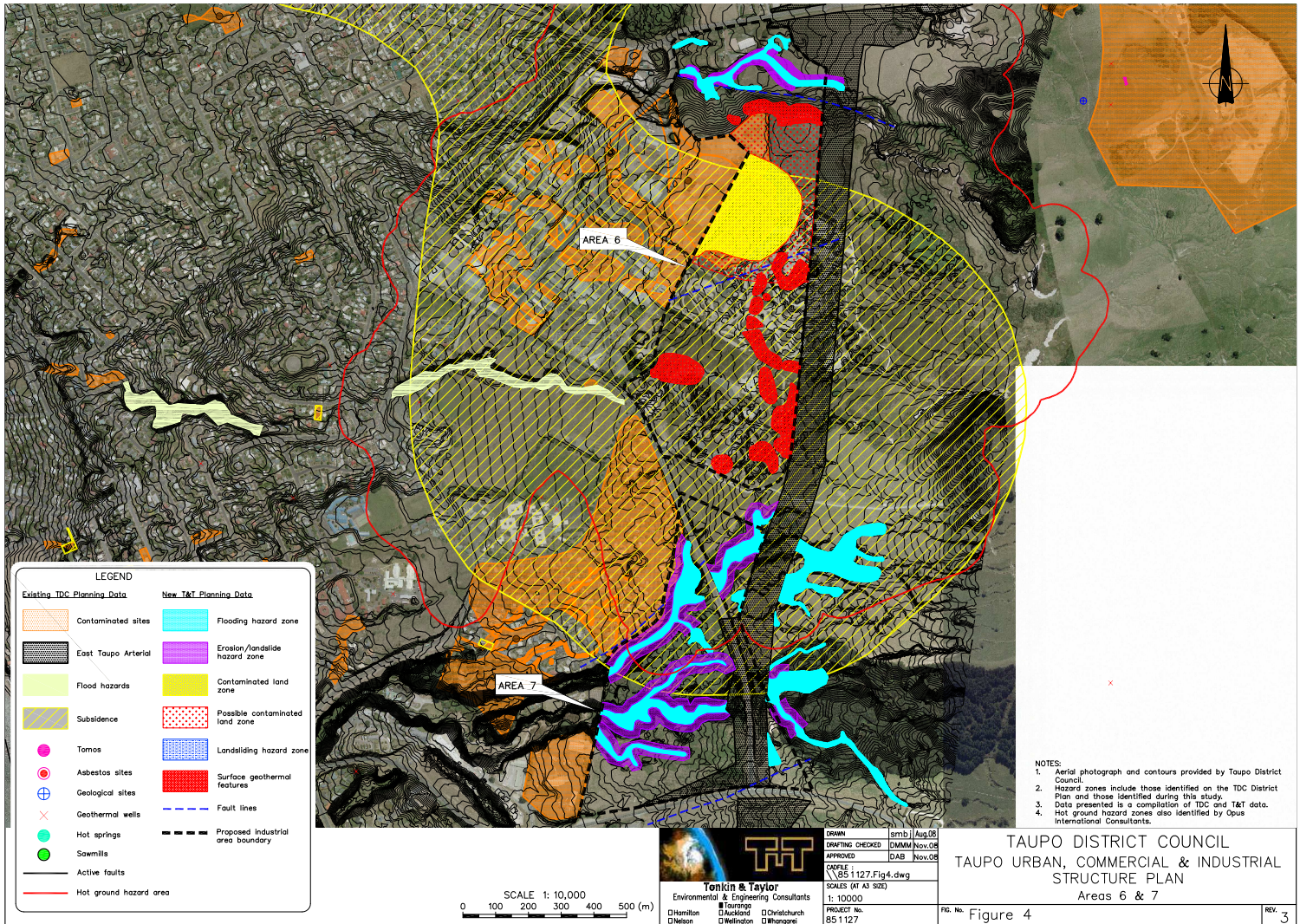
TAUPO DISTRICT COUNCIL
 TAUPO URBAN, COMMERCIAL & INDUSTRIAL
 STRUCTURE PLAN
 Areas 2, 3, 4 & 5

FIG. No. Figure 3

REV. 3

- NOTES:
1. Aerial photograph and contours provided by Taupo District Council.
 2. Hazard zones include those identified in the TDC District Plan and those identified during this study.
 3. Some hot ground hazard areas identified by Opus International Consultants.
 4. Location of Araratia Fault mapped by GNS Science.

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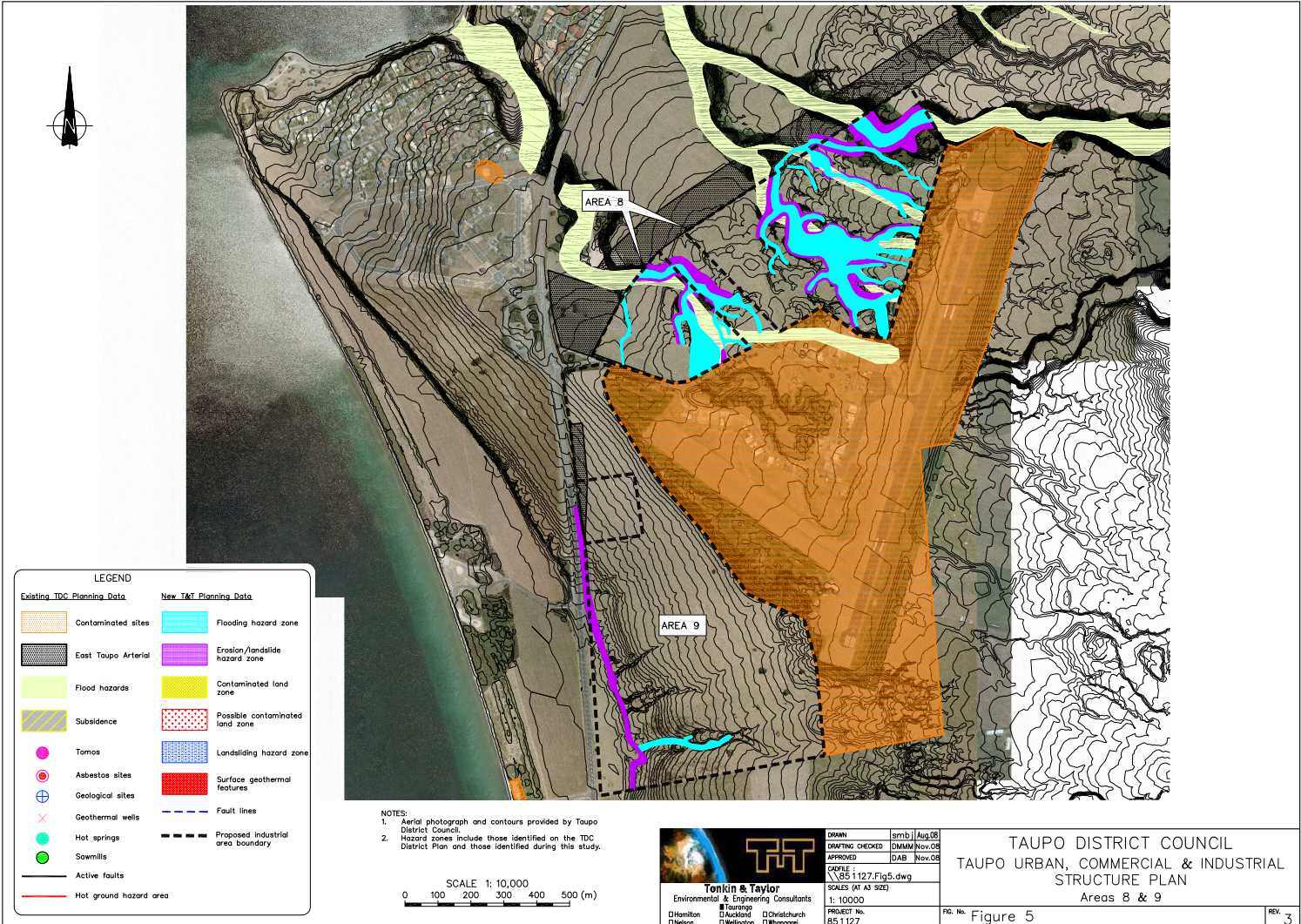
LEGEND	
Existing TDC Planning Data	New T&T Planning Data
Contaminated sites	Flooding hazard zone
East Taupo Arterial	Erosion/landslide hazard zone
Flood hazards	Contaminated land zone
Subsidence	Possible contaminated land zone
Tomos	Landsliding hazard zone
Asbestos sites	Surface geothermal features
Geological sites	Fault lines
Geothermal wells	Proposed industrial area boundary
Hot springs	Active faults
Sawmills	
Active faults	
Hot ground hazard area	

- NOTES:
1. Aerial photograph and contours provided by Taupo District Council.
 2. Hazard zones include those identified on the TDC District Plan and those identified during this study.
 3. Data presented is a compilation of TDC and T&T data.
 4. Hot ground hazard zones also identified by Opus International Consultants.

<p>Tonkin & Taylor Environmental & Engineering Consultants</p> <p>Hamilton Tauranga Christchurch Dunedin Auckland Wellington Whangarei</p>	DRAWN: sm1b Aug.08 DRAFTING CHECKED: DMMM Nov.08 APPROVED: DAB Nov.08 CADFILE: 851127.Fig4.dwg SCALES (AT A3 SIZE): 1:10000 PROJECT No.: 851127
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TAUPO DISTRICT COUNCIL TAUPO URBAN, COMMERCIAL & INDUSTRIAL STRUCTURE PLAN Areas 6 & 7		FIG. No. Figure 4 REV. 3
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LEGEND

Existing TDC Planning Data	New T&T Planning Data
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East Taupo Arterial	Erosion/landslide hazard zone
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Geothermal wells	Proposed industrial area boundary
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NOTES:
 1. Aerial photograph and contours provided by Taupo District Council.
 2. Hazard zones include those identified on the TDC District Plan and those identified during this study.

SCALE 1:10,000
 0 100 200 300 400 500 (m)

Tonkin & Taylor
 Environmental & Engineering Consultants

Hamilton Tauranga Christchurch
 Nelson Auckland Wellington Whangarei

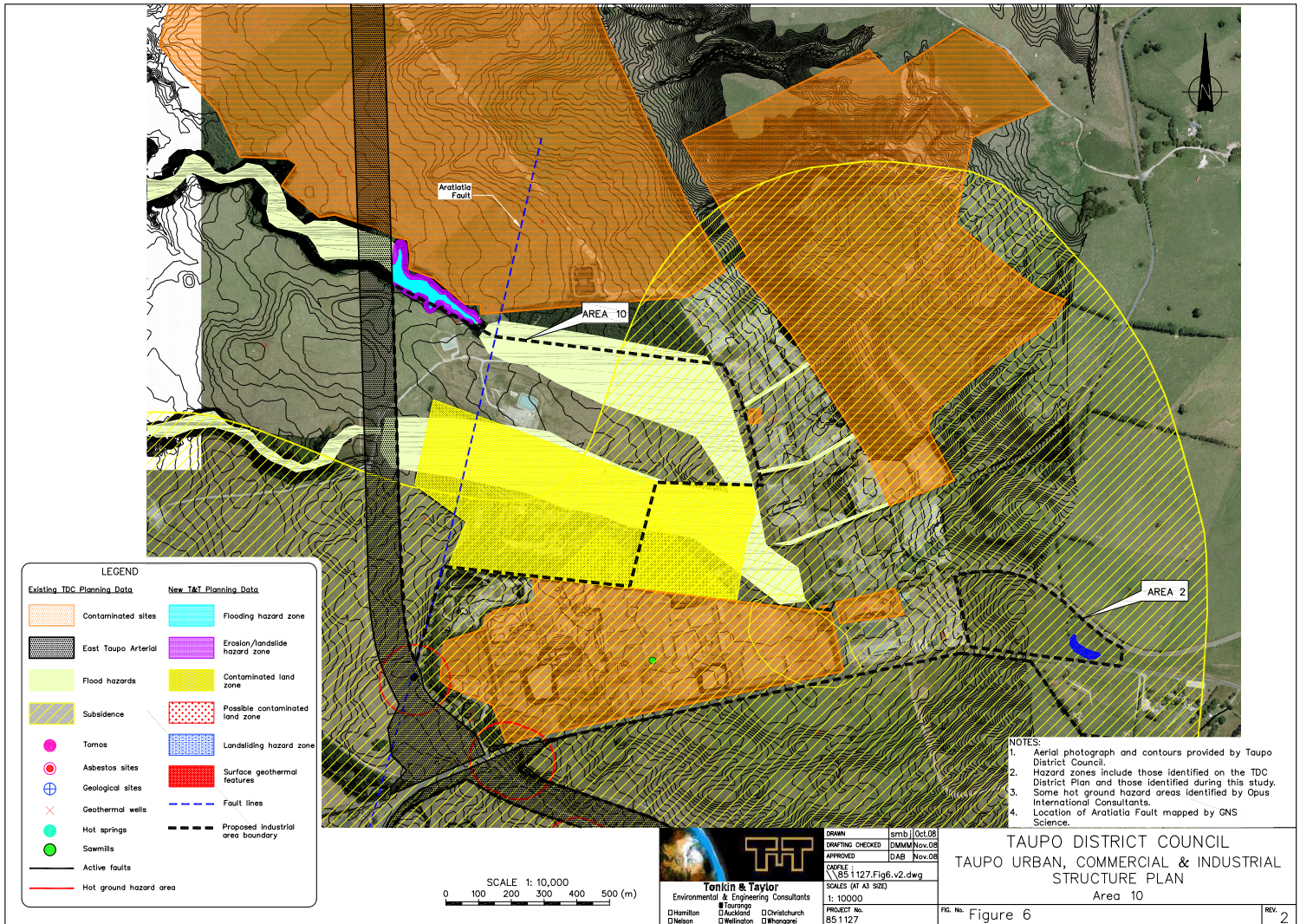
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TAUPO DISTRICT COUNCIL
 TAUPO URBAN, COMMERCIAL & INDUSTRIAL
 STRUCTURE PLAN
 Areas 8 & 9

FIG. No. Figure 5

REV. 3

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Appendix B: Potential Hazards by Area

Area 1 (see Figure 2)

Hazard	Description
Description	Rangitira East Land between Taupo and Acacia Bay. Proposed industrial area gently sloping, undulating land is between Acacia Bay Road and the first lake terrace.
Fault Lines	None identified.
Flood Hazard Areas	<ul style="list-style-type: none">- Flood hazards in incised gully systems.- Numerous shallow dry stream channels will need to be accounted for during drainage design.
Hot Ground Hazard Areas	None identified.
Land Instability - Landsliding	Low risk.
Contaminated or Potentially Contaminated Sites	None identified.
Erosion Hazard	Small erosion hazard along terrace edge.
Subsidence	None identified.

Area 2 (see Figure 3)

Hazard	Description
Description	Small Area between Off Highway Road and Centennial Avenue.
Fault Lines	None identified, but faults of the Rotokawa Fault Zone are mapped approximately 400 m southeast of the site.
Flood Hazard Areas	None identified, but there is a low area that runs along the northeast edge of the site that will need to be drained during development.
Hot Ground Hazard Areas	None identified.
Land Instability - Landsliding	Low risk, but one arcuate shaped landslide structure at the eastern end of the site.
Contaminated or Potentially Contaminated Sites	None identified.
Erosion Hazard	Low risk.
Subsidence	10 to 25 mm per year calculated by Contact Energy.

Area 3 (see Figure 3)

Hazard	Description
Description	Small area to the north of the golf course. Currently owned by Landcorp. It will be southwest of the interchange between Centennial Ave and the ETA.
Fault Lines	None identified within the area. However, Aratiatia East Fault runs close to the western and northwestern boundary.
Flood Hazard Areas	None identified.
Hot Ground Hazard Areas	In a geothermal hazard zone identified by Taupo District Council. Hot spring identified by Opus Consultants at eastern end of site. Hot ground identified at quite shallow levels in ETA boreholes in vicinity of the site.
Land Instability	Low risk.
Contaminated or Potentially Contaminated Sites	None identified.
Erosion Hazard	Low risk.
Subsidence	25 to 55 mm per year predicted by Contact Energy.

Area 4 (see Figure 3)

Hazard	Description
Description	A large area between Broadlands Road and Centennial Avenue. The land mostly slopes to the west. A low lava dome present in the eastern part of this site dominates the topography. This land is currently owned by Broadlands and is being intensively investigated by Contact Energy for geothermal resources.
Fault Lines	Four faults of the Rotokawa Fault zone are shown in the area on published maps. The Broadlands Geothermal Reserve in the southern part of the area is also associated with the Rotokawa Fault Zone.
Flood Hazard Areas	<ul style="list-style-type: none"> - Some deeply incised dry streams in southern part of the area are flood hazards. - Numerous shallow dry stream channels cross this area. These may need to be considered when designing drainage in the area.
Hot Ground Hazard Areas	Surface expressions of the Tauhara Geothermal Field are present in the southern portion of the site.
Land Instability - Landsliding	<ul style="list-style-type: none"> - Steep slope on the southern flank of the buried lava dome. - Steep, low slopes also located along the edge of the dry, incised stream channel in the southern part of the area.
Contaminated or Potentially Contaminated Sites	Existing commercial operation, on Broadlands Road, includes the storage of agrichemicals and petroleum.
Erosion Hazard	Erosion hazard adjacent to incised stream in southern part of the area.
Subsidence	0 to 30 mm per year estimated by Contact Energy.

Area 5 (see Figure 3)

Hazard	Description
Description	Small area north of Broadlands Road. It will be northwest of the interchange between Broadlands Road and the ETA.
Fault Lines	None identified, but the site is proximal to the Broadlands reserve. The geothermal field activity in this area is associated with the Rotokawa Fault Zone. TA gully that runs through Area 5 has been identified as the possible extension of a fault mapped nearby ⁴ .
Flood Hazard Areas	Gully at western end of site may be a flood hazard. Pumice deposits at the head of this gully indicate recent overland water flow. A minor dry stream channel to the north of the site may also require drainage during development.
Hot Ground Hazard Areas	Area is within a hot ground hazard area identified by Taupo District Council. It is adjacent to the Broadlands Reserve in which geothermal features are present at the ground surface.
Land Instability - Landsliding	Low risk.
Contaminated or Potentially Contaminated Sites	None identified.
Erosion Hazard	Low risk.
Subsidence	0 to 10 mm per year calculated by Contact Energy.

Area 6 (see Figure 4)

Hazard	Description
Description	Long thin area to the east of Ashwood Business Park. Commercial development has already commenced in this area with the construction of Raywood Crescent and Claret Ash Drive.
Fault Lines	One fault shown on published maps. Area 8 is underlain by the Crown Road Geothermal Reserve. The geothermal activity in this area is associated with the Rotokawa Fault Zone.
Flood Hazard Areas	Some incised dry 'box' gully systems in the north of Area 8 are flood hazard areas.
Hot Ground Hazard Areas	Area 8 is within an area of hot ground hazard identified by TDC. Numerous surface geothermal features are present.
Land Instability - Landsliding	Some risk of landsliding adjacent to incised streams in the northern and southern parts of this area.
Contaminated or Potentially Contaminated Sites	Former sawmill operation, including the infilling of a gully with wood and industrial waste and the contouring of land for the storage of processed timber. Potential contamination from waste disposal within infilled gully and storage of treated timber on surface soils.
Erosion Hazard	Some erosion hazard adjacent to incised streams.
Subsidence	5 to 45 mm settlement per year predicted by Contact Energy. Area of known fill that is likely to undergo settlement during development.

Area 7 (see Figure 4)

Hazard	Description
Description	Irregular shaped block between the Napier-Taupo Highway and Crown Road.
Fault Lines	None identified within Area 9, however published geology shows faults mapped immediately to the north and south of the area.
Flood Hazard Areas	Deeply dissected, dry gully systems are present in this area. The bases of these systems are flood hazards.
Hot Ground Hazard Areas	No surface geothermal features present. Northern part of this area is identified as hot ground hazard by TDC.
Land Instability - Landsliding	The incised gullies are steep sided increasing the risk of landsliding.
Contaminated or Potentially Contaminated Sites	None identified.
Erosion Hazard	Erosion hazard present on the steep gully sides.
Subsidence	0 to 5 mm per year calculated by Contact Energy.

Area 8 (see Figure 5)

Hazard	Description
Description	Two areas to the northwest of Taupo Airport.
Fault Lines	None identified.
Flood Hazard Areas	Incised, dry, 'box' gully systems present in this area. Flood hazard present in the bases of these gullies.
Hot Ground Hazard Areas	None identified.
Land Instability - Landsliding	Gullies are generally steep sided and pose a landslide risk. Large gully system at the northern end of this area creates a landslide risk.
Contaminated or Potentially Contaminated Sites	None identified.
Erosion Hazard	Erosion hazard present on the steep gully sides.
Subsidence	None identified.

Area 9 (see Figure 5)

Hazard	Description
Description	Area to the west of Taupo Airport. A low terrace runs northwest – southeast through the southern part of the area.
Fault Lines	None identified.
Flood Hazard Areas	Some potential flood hazard in a moderately incised gully system towards the southern end of the site. This should be controllable with appropriate drainage.
Hot Ground Hazard Areas	None identified.
Land Instability	Low risk.
Contaminated or Potentially Contaminated Sites	None identified.
Erosion Hazard	Spalling of rock material and rubble at the base of the moderately steep terrace indicate that it is an erosion hazard.
Subsidence	None identified.

Area 10 (see Figure 6)

Hazard	Description
Description	Area to the north of Centennial Drive and west of Rakaunui Road.
Fault Lines	East strand of Aratiatia Fault mapped through this area.
Flood Hazard Areas	Potential flood hazard in adjacent incised stream gullies. Significant flood hazard due to runoff from industrial area identified by TDC.
Hot Ground Hazard Areas	Geothermal wells on the site, hot ground hazard in southern end of area noted in TDC database
Land Instability	Mostly low risk, but risk may be increased adjacent to incised gully just beyond the northern area boundary.
Contaminated or Potentially Contaminated Sites	Site of the Taupo native Plant Nursery, which includes glasshouses and accessory buildings. Potential contamination of surface soils from metals and pesticides used in the glasshouse and metals and hydrocarbons associated with heating. Note land area located immediately to the east of the plant nursery appears to have been used for the disposal of woodwaste.
Erosion Hazard	Some erosion hazard adjacent to incised streams.
Subsidence	10 to 25 mm per year calculated by Contact Energy.