Tonkin+Taylor

Job No: 85442.0300
12 May 2022

Palmerston North City Council
32 The Square
Palmerston North 4410

Attention: Michael Duindam

Dear Michael

Aokautere slope stability: considerations for consenting

1 Introduction

This letter report presents the findings of our geotechnical site assessment for the proposed Aokautere development project. It presents a summary of our site walkover and geo-hazard assessment, the results of slope angle analysis for instability, assessment of areas of potential uncontrolled fill, along with recommended considerations for future development. Geohazards have been assessed with regard to the proposed Structure Plan, in order to inform requirements for future subdivision, including any further investigation and assessment work that may be required for development.

This report builds on our previous work to include a summary of our previous reporting, summarise the slope angle analysis undertaken, provide recommendations on managing slope stability hazards, provide comments on liquefaction, and provide an assessment and discussion on fill materials. It should be read in conjunction with our 2020 report[1].

1.1 Context

1.2 Site location

The proposed development contains approximately 490 ha (4.9 km^2) of land southeast of Palmerston North. The majority of the area comprises farmland pasture.

[1] 2020, Tonkin & Taylor Ltd, Preliminary Site Observations for Proposed Aokautere Redevelopment. Reference 85442.0080.

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Figure 1.1: Aokautere development area site location.

1.3 Geology

The Palmerston North regional area lies on the boundary between the older (late Jurassic/ Early Cretaceous) exposed greywacke basement rocks (Esk Head belt) in the Tararua ranges to the southeast and the younger (Pleistocene and Holocene) alluvial river deposits of gravel, sand and silts to the north west (refer geological plan in Appendix A).

The Esk Head belt (Te) forms the base of the Tararua mountain range which is present on the far south-eastern corner of the Waters property.

To the northwest of the Esk Head belt, towards Turitea, early Pleistocene alluvial river gravels and sands (eQa) have been deposited.

Further northwest, up to the cliffs adjacent to the Manawatu River, are Pleistocene age gravels and sands more representative of marginal marine/ beach deposits (Q5b). Cutting through these beach deposits and river gravels is a prominent flat river cut terrace containing gravels and silts eroded from the Tararua Ranges and deposited in a paleo-channel (Q2a). These geological materials underlie the majority of the site.

Younger Holocene deposits of river silts and sands (Q1a) are found in the many smaller river cut terraces formed from the meandering watercourses which loosely follows the Turitea Stream, formed in the Q2a paleo-channel.

The published geology[2] of the investigation area is shown in Appendix A which indicates the regional surface geology.

1.4 Previous work

Tonkin & Taylor Ltd (T+T) has undertaken previous geotechnical studies for Palmerston North City Council (PNCC) to support planning and development in the Aokautere area and these are summarised in the sections below.

2005 slope stability reporting

In 2005, T+T provided PNCC with general advice on the development of land subject to slope instability[3]. The intention of that advice was to provide guidelines and practical solutions for constraints associated with potential slope instability, to help inform the building consent and subdivision consent process. The report did not include any analysis of specific areas of land. In that report, T+T recommended particular nominal slope angles to delineate the risks associated with slope instability for various classes of land, shown in Figure 1.2.

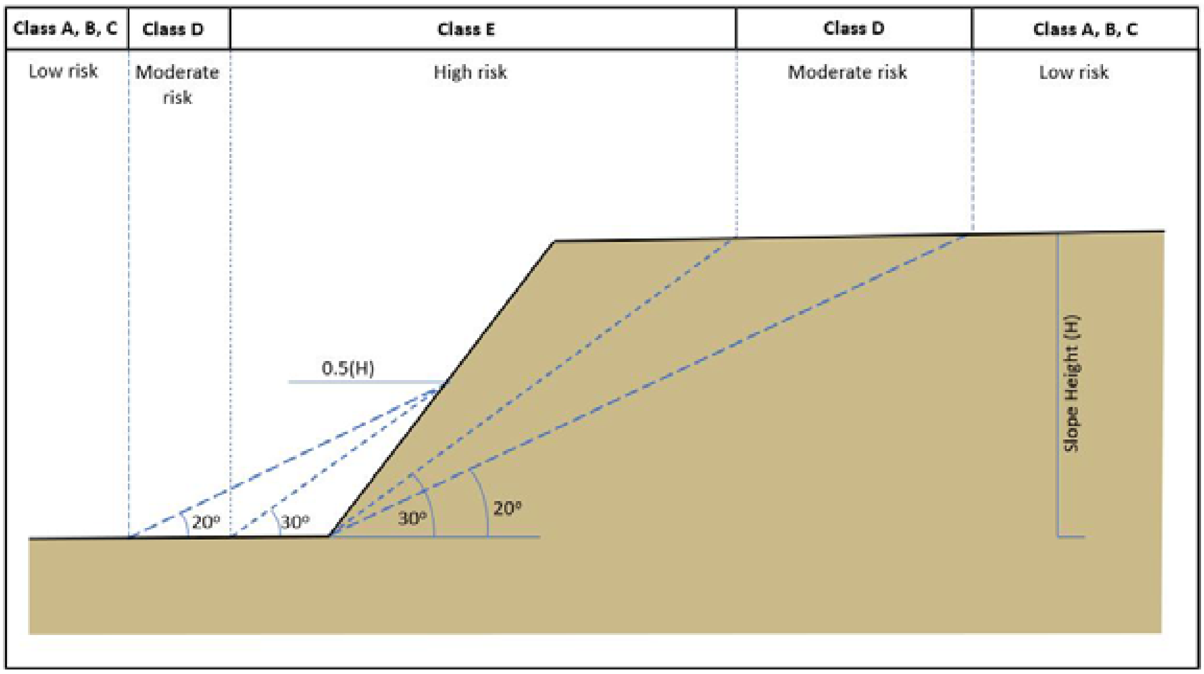

Figure 1.2: Land hazard classes (adapted from T+T, 2005).

These land classes are further explained in Table 1.1, which has been adapted from our 2005 report. In the operative District Plan, land in the existing Aokautere Development Area is divided into two categories: 'Developable' and 'Limited Developable Land'[4]. Classes A, B and C are categorised as 'Developable Land', whilst Classes D and E are categorised as 'Limited Developable Land'.

[2] Lee, J.M., Begg, J.G. (compilers) 2002: *Geology of the Wairarapa area*. Institute of Geological & Nuclear Sciences 1:250,000 geological map 11. 1 sheet + 66 p. Lower Hutt, New Zealand. Institute of Geological & Nuclear Sciences Limited.
[3] 2005, Tonkin + Taylor, Development of land which is, or is likely to be, subject to erosion or slippage: policy document. Reference number 82096.001.
[4] Map 10.1, Palmerston North City Council District Plan.

Table 1.1: Land hazard class descriptions (adapted from T+T, 2005)

Classes A & B (Not at Risk)	This land has an overall slope of less than 11 degrees, does not exhibit any evidence of erosion or shrinkage, and is not likely to be subject to erosion, provided the slope is not subject to river bank erosion.
Class C (Low Risk)	This land has an overall slope of between 11 and 20 degrees, does not exhibit evidence of erosion, or slippage, or inundation from landslip debris, but could be subject to erosion or slippage, if not developed carefully. This land is not likely to be subject to erosion or slippage and is unlikely to be adversely effected by upslope land slippage inundating the site or downslope land slippage removing, or removing support to, the land.
Class D (Moderate Risk)	This land is steep (i.e. steeper than 20 degrees), and/or is either subject to erosion or slippage, or is likely to be subject to erosion or slippage.
Class E (High Risk)	This land is very steep to precipitous (i.e. steeper than 30 degrees) and/or is either subject to erosion or slippage, or is likely to be subject to erosion or slippage.

2020 preliminary geo-hazard assessment

In 2020, T+T carried out a preliminary geotechnical assessment of the Aokautere area for future residential and rural-residential development[5]. This report summarised the geotechnical hazards present throughout the site. The study area was expanded to include a larger area than covered in the Palmerston North City District Plan for the Aokautere Development Area. The study comprised a desktop review of readily available relevant information and a site walkover.

T+T undertook a site walkover during 26-28 September 2018 (Voss property and north) and 17 October 2019 (Water's property). Mapping and site walkover observations (Appendix A: Figures 4a and 4b reproduced from our 2020 report) were collected for the majority of the undeveloped sites marked for future proposed development, where access approval was granted by the landowner. Photographs of areas of interest are provided in Appendix B (reproduced from our 2020 report). A copy of the original geohazard assessment is included in Appendix A.

During the site walkover observations, particular attention was given to hazards associated with ground instability, water flows and soft ground conditions as summarised in Table 1.2. The assessment and management of slope instability and uncontrolled fill hazards are discussed further below.

[5] 2020, Tonkin & Taylor Ltd, Preliminary Site Observations for Proposed Aokautere Redevelopment. Reference 85442.00820.

Table 1.2: Summary of observations and associated hazards

Site observations	Associated hazards
Evidence of landslip, both recent and historic	Potential slope and land instability.
Evidence of land creep	Potential slope and land instability. May indicate future landslip failures.
Slope direction and gradients	Provides land fall direction indicating areas of water runoff catchments.
Watercourses, both current and ephemeral	Potential for erosion of land along with erosion induced landslips. Path of water runoff may indicate areas of saturated ground. Potential for flood inundation.
Saturated ground conditions and swamp land	Settlement of ground and potential for flood inundation.
Groundwater outflows	Potential for instability on slopes, erosion, internal gully erosion.
Uncontrolled fill	Settlement of ground and loss of bearing.

2 Slope stability

T+T have undertaken a slope assessment in the Aokautere area, and this work has been used as the basis for the analysis described below.

2.1 Current slope angle analysis

T+T have carried out preliminary slope angle analysis[6] for the Aokautere area, to map slope stability hazard classes consistent with the approach introduced in the 2005 T+T report. The study area is shown in Figure 1. The results of this analysis are included in Appendix C. Two lines have been mapped; a 20° line showing the extent of Class C land, and a 30° line showing the extent of Class D land. Class A, B, and C land has been hatched on the map. It should be noted that this analysis is a high-level screening tool to identify areas where slope instability is more (or less) likely. It does not take into account the specifics of an individual site.

The analysis has been completed by initially generating false 20° and 30° slopes from the base of the gullies and identifying where these intercept the true slope. This method relies on a consistent slope profile and does not take into consideration any mid slope geometry changes/terraces. This method often resulted in the extent of Class C or D land being identified mid-slope, downslope of a steeper slope. An additional secondary analysis was therefore applied, where slope steepness was used to identify slopes 30° or steeper which were then classified as Class D or E land. It is noted that the secondary analysis does not accommodate a 'set back' from the base of the mid-slope features, and that this should be quantified during the site-specific geotechnical assessment through assessment of local site topography. Subsequent analysis was conducted, projecting 20° and 30° lines downslope from the mid-point on the slope, for the terrace on the south side of Pacific Drive. This analysis demonstrated that the current slope baseline is appropriate.

Figure 2.1 below schematically illustrates the analysis we have adopted to provide land class categorisation for the purposes of PNCC's District Planning.

[6] The digital elevation model used for this analysis was derived from the LiDAR survey undertaken between 29/08/2018 and 28/09/18. The accuracy specification for that survey is +/- 0.10m vertical and +/- 0.5m horizontal. The elevation model data is a 1m grid, in NZTM map projection with NZVD16 vertical datum.

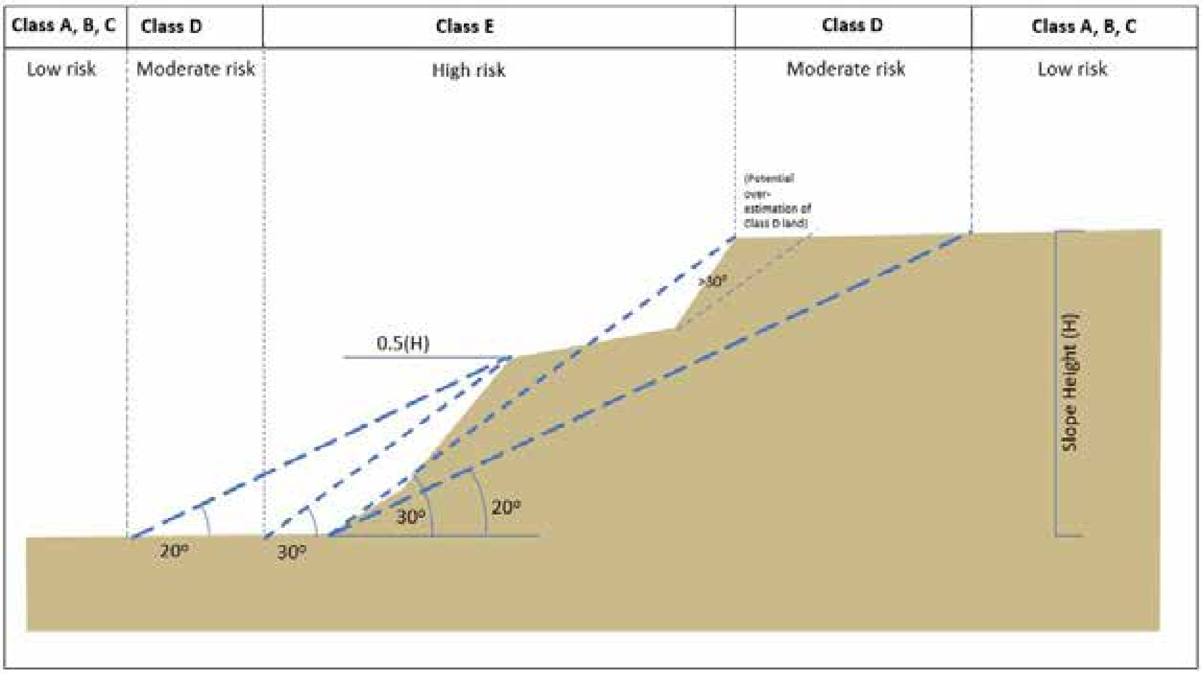

Figure 2.1: Schematic illustration of slope analysis methodology.

2.2 Slope stability- proposed assessment and management

In conjunction with our work carrying out slope angle analysis on the Aokautere area, PNCC requested that we consider whether the operative Palmerston North City Council District Plan approach is appropriate to use for the Aokautere area, covered in our 2020 study. The study area is not currently included in the District Plan map for the Aokautere Development Area.

In the operative District Plan, land in the existing Aokautere Development Area is divided into two categories: 'Developable' and 'Limited Developable Land'. Classes A, B and C are categorised as 'Developable Land', whilst Classes D and E are categorised as 'Limited Developable Land'. For Developable Land, the construction of residential dwellings is a Permitted Activity, whereas for Limited Developable Land, the only Permitted Activities are landscape works, reserves and drainage and water supply works.

In the current District Plan, Class D land (between the 20 and 30° lines) is currently combined with Class E land. However, there is likely to be some land in Class D where development can proceed following geotechnical assessment, and anecdotally we hear from PNCC that this is the case; some land developers with appropriate geotechnical input are developing sites up to 23 degrees. Whereas for Class E land, with slope angles of over 30 degrees, the slope instability hazard is greater, and the land is less likely to be able to be safely or cost-effectively developed.

In our view, it would help to provide better regulatory certainty and clarity on the requirements for geotechnical assessment if the two categories currently in the District Plan were amended to three categories that more precisely reflect the land instability hazard. An additional category to subdivide Class D and E sites could be considered, as summarised below (along with placeholder suggestions for the revised category names):

- **Land that is likely developable:** Class A, B and C land.
- **Land that is possibly developable:** Class D land.
- **Land that is unlikely to be developable:** Class E land.

It should be noted that whether land is 'developable' is a subjective judgment. Even the most steep land can be developed; it just requires significant engineering and stabilisation works, such as re-contouring slopes, retaining earth etc.

The following suggested provisions for each category have been largely adopted from our 2005 report.

2.2.1 Land that is likely developable

For Class A and B land, the land is not expected to be at risk of slippage, so should not require geotechnical slope stability assessment for resource or building consent (although for some sites geotechnical input may still be required for other matters, such as soft soils or uncontrolled fill).

For Class C land, the angle from the toe of the slope is 11 to 20 degrees, so erosion or slippage is not considered likely to occur, and no erosion or mass movement is evident. But the land is considered to be sufficiently sensitive that erosion or slippage could occur due to cutting and/or filling and/or site disposal of stormwater and/or effluent waste water.

Accordingly, applications for development of Class C land should be accompanied by a geotechnical report which summarises the results of a walk-over survey and a geological/geomorphological assessment (which describes how the landform has been formed, what it is made up of and what slope processes are, or are likely to be, active) and provides an informed opinion on the suitability of the land for the intended purpose.

The geotechnical assessment of Class C land would be expected to include most or all of the following steps:

1 Walk over inspection of the site and the surrounding land and assessment of local topography.
2 Inspection of aerial photographs taken at various times to provide insight into the local geomorphology and evidence of any previous instability or filling.
3 Review of geological data (maps, bulletins).
4 Enquiry after local information about observed instability or settlement of the ground.
5 Seek existing data about the soil and rock profile (look for nearby exposures) or perform some simple subsurface investigation.
6 Examination of the soil profile to confirm if the soil is in-situ and not colluvium or fill.
7 Examination of the existing survey records for evidence of slippage or erosion.
8 Consideration of any other geotechnical constraints or hazards which could affect the site.
9 An opinion stated by a geotechnical specialist as to the stability and suitability of the land for development, identifying any setbacks if necessary.

2.2.2 Land that is possibly developable

Class D land has an angle from the toe of the slope that is generally steeper than 20 degrees but less than 30 degrees. Accordingly, due to the steepness of the slope(s), applications for subdivision, building or other development (such as excavation, filling, removal of vegetation, disposal of stormwater or domestic wastewater into or over the area) should be supported by a geotechnical report which includes a stability assessment demonstrating that the proposed development will not accelerate, worsen or result in the land being subject to, or likely to be subject to, erosion or slippage, to the satisfaction of Council.

In certain areas, there may be design solutions which allow the land to be developed. Examples include placing engineered fills, constructing retaining walls and re-contouring slopes. The specific design solutions that are appropriate for a given area and proposed activity will not be known until site-specific investigation and analysis is carried out.

A geotechnical assessment on Class D land would be expected to include:

1 Topographic survey (if not already available).
2 A description of the geology and geomorphology of the area.
3 Inspection of aerial photographs taken at various times to provide insight into the local geomorphology and evidence of any previous instability or filling.
4 Enquiry after local information about observed instability or settlement of the ground.
5 Definition of the nature and continuity of the strata over the whole area of land which is proposed to be developed (buildings, access and services) involved and to a depth below which slipping is most unlikely, by means of test pit and/or drilling and/or augering (unless existing exposures are adequate).
6 Assessment of the relative strength and the sensitivity of the soil in each stratum in which, or interface on which, sliding is possible.
7 Assessment of likely groundwater levels and piezometric pressures in the strata during extreme infiltration conditions.
8 Consideration of any other geotechnical constraints or hazards which could affect the site.
9 An opinion stated by a geotechnical specialist as to the stability and suitability of the land for development, including specifying setbacks if required.

2.2.3 Land that is unlikely to be developable

This land exhibits evidence of past or present erosion or slippage, or has a slope gradient over 30 degrees and/or is subject to processes (e.g. removal of toe support), such that erosion or slippage is considered likely to occur in future. Accordingly, development of this land presents an identifiable hazard to property and could also, in some circumstances, threaten life.

On, above and below this land, it is unlikely that subdivision, building or other development (such as excavation, filling, removal of vegetation, disposal of stormwater or wastewater) could be carried out without substantial topographic modification of the existing slopes to ensure stability. As such, Class E land is unlikely to be able to be cost-effectively developed into residential lots.

Any proposed development would require substantial geotechnical engineering input and analysis, significantly more than the requirements listed above for Class D land. The requirements for geotechnical engineering input will vary depending on the proposed development and should be tailored to address the slope stability aspects that are critical for the proposed development.

Where infrastructure such as roads are planned to be located over Class E land, this could be achieved by placing engineered fills, constructing retaining walls and re-contouring slopes as necessary. Such work would require the involvement of a suitably qualified and experienced geotechnical specialist.

2.2.4 Rural-residential areas

The southern portion of the Aokautere area is proposed for lower density, rural-residential development with larger lot sizes (around a hectare). According to our slope analysis, much of this land is Class E land. There is likely to be more potential to develop these lots, as they differ from the higher density residential lots in a couple of ways:

1 The much larger lot sizes offer significantly more flexibility in selecting building locations, and there may be areas of lower slope angles that are not identified in our high-level analysis.
2 The significantly larger lot sizes provide more area and flexibility to carry out earthworks and other work to create stable building platforms (such as the creation of cut and fill platforms and construction of retaining walls).

In addition, this area is a more undulating hilly landscape (as opposed to the elevated, relatively level terraces elsewhere), therefore the simplified analysis methodology that we have conducted may result in a conservative delineation of Class E from other classes of land. Site specific geotechnical assessment is therefore necessary in this area to identify suitable building platforms and specify any other necessary design requirements.

3 Uncontrolled fill

Uncontrolled fill has previously been identified by PNCC within the Aokautere area. Uncontrolled fill poses challenges for development as when additional loads are applied (e.g. by further fill placement or building construction) these ground conditions can produce large total and differential settlements. This has the potential to damage buildings and other infrastructure founded on these materials. In some cases, ongoing creep settlement may occur, even without additional loads being applied. Depending on the nature and content of the fill material, there also may be associated soil contamination.

3.1 Identification of potential areas of uncontrolled fill

Two LiDAR derived Digital Elevation Models (DEM) are available for the area, from 2006 and 2018. Where land has been filled between 2006 and 2018, it has a higher elevation in the 2018 Digital DEM, and where land has been excavated, it has a lower elevation in the 2018 DEM. The DEM for 2006 and 2018 are shown in Figure 3.1, below.

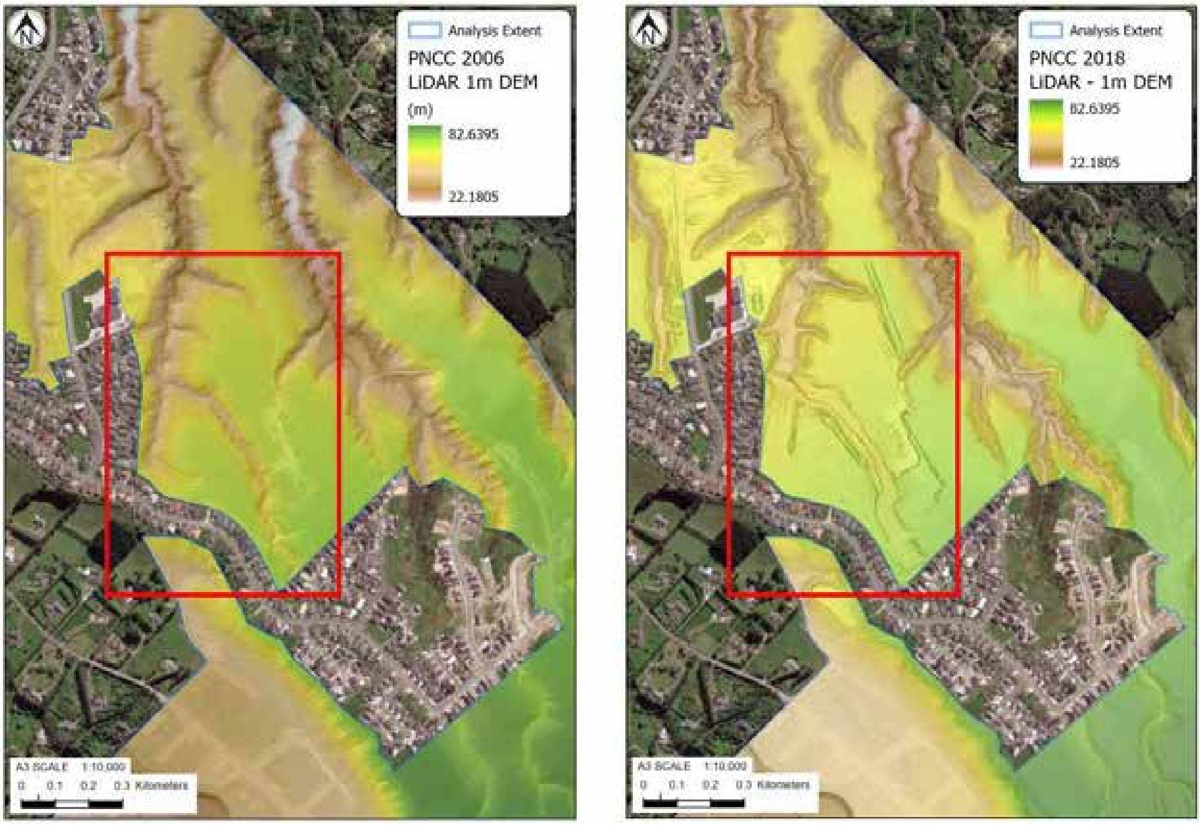

Figure 3.1: Digital elevation models: Left hand image shows 2006 topography, right hand image shows 2018 topography. The red boxes show the focus area.

We have carried out an exercise to identify areas likely to contain fill by subtracting the 2006 DEM from the 2018 DEM. Where the resulting values are negative, the land levels have been reduced by the resultant value by excavation and removal of land, and where the resulting values are positive, the land levels have been raised by that value. The results of this analysis are shown in Figure 3.2. A detailed version of this map is reproduced in Appendix D.

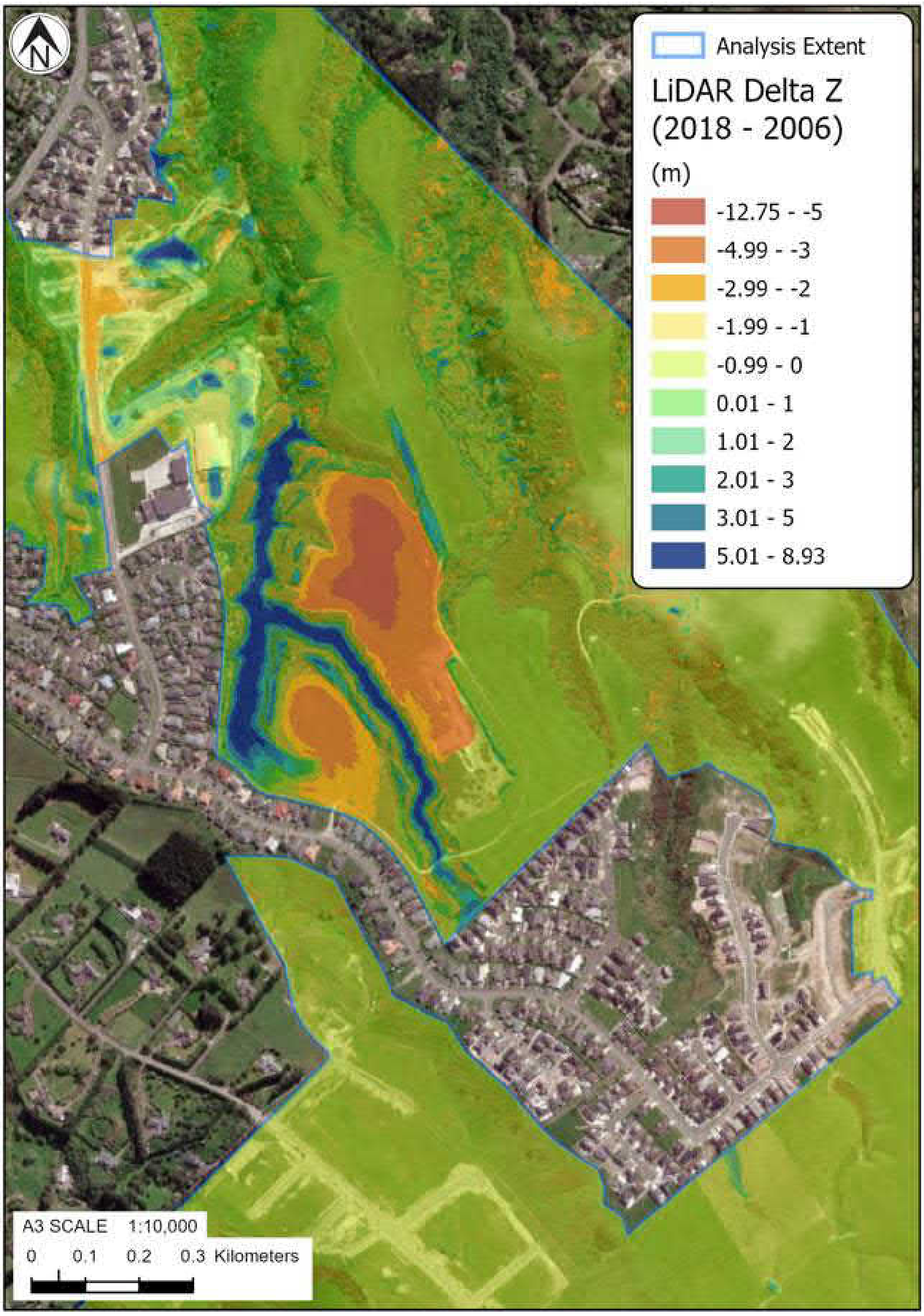

Figure 3.2: Image showing the difference between the 2018 DEM and the 2006 DEM. Positive values indicated land levels that have been raised by filling, negative values indicate land that has been lowered by excavation.

3.1.1 Proposed assessment and management of uncontrolled fill

Where earth fills are present, the soil supporting residential foundations cannot be assumed to be 'good ground' in accordance with NZS3604: 2011[7]. This does not apply where a certificate of suitability for earth fill for residential development has been issued in accordance with NZS4431[8], i.e.

[7] Standards New Zealand. NZS3604: 2011. Timber-framed buildings. Section 3.1.3.
[8] Standards New Zealand. NZS4431: 1989. Code of practice for earth fill for residential development.

where the fill has been placed with appropriate engineering controls and records. NZS3604:2011 is the standard used for the construction of the majority of residential dwellings in New Zealand. Therefore, where there is uncontrolled fill, NZS3604:2011 cannot be used and any residential construction will require specific engineering design, and the involvement of suitably qualified geotechnical professionals.

We have not carried out any geotechnical assessment of the filled land.

Where uncontrolled fill is present, prior to any development it should be characterised. This is likely to require a combination of site investigations and review of historic information. Options are available for developing filled land such as preloading, ground improvement or piling. The feasibility of appropriate options would be determined following geotechnical assessment of the filled land.

A geotechnical assessment on land with uncontrolled would be expected to include:

1. A description of the geology and geomorphology of the area. Review of historic information such as aerial photos, anecdotal reports or other records.
2. Definition of the nature and continuity of the strata over the whole area of land which is proposed to be developed (buildings, access and services). The depth, spatial extent, strength, variability, and material/s should all be identified and where possible, quantified. Fill materials should be assessed by means of test pit and/or drilling and/or augering.
3. Assessment of the relative strength of the fill material and the underlying stratum by means of borehole standard penetration tests, cone penetration tests or scala penetrometers (for shallow soil profiles).
4. Assessment of likely groundwater levels and the effects of fluctuating or changing groundwater.
5. An opinion stated by a geotechnical specialist as to the suitability of the land for development, along with recommendations on any mitigation work or foundations that are required.
6. Consideration of any other geotechnical constraints or hazards which could affect the site.

Although the assessment of contamination is not within the scope of geotechnical assessment, T+T have provided PNCC a Ground Contamination Desk Top Study report[9]. This report notes that uncontrolled fill has a possibility of containing contaminants. Therefore, particular attention should be paid to identifying fill materials and in some cases assessment of possible contaminants may be necessary.

4 Liquefaction

PNCC have requested we consider the potential for liquefaction in the Turitea Stream valley bordering the northeast side of Turitea Road. The geological map for the Aokautere area is available in Appendix A, and the location and topography of the valley adjacent to Turitea Road is shown in Figure 4.1 below. The upper terrace is mapped as late Pleistocene river deposits of gravel and sand. The lower terrace is mapped as Holocene river deposits of gravel, sand, clay and peat. The upper terrace is elevated approximately 8 – 12 m above the lower terrace.

There are not currently any geotechnical investigations available for this valley area in the New Zealand Geotechnical database. It appears there is some residential development taking place on the upper terrace at the southern end of Valley Views, but there is no geotechnical information available.

The depth to groundwater in this area is unknown.

[9] Aokautere Redevelopment – Ground Contamination Desk Study, T+T, June 2020, report ref; 85442.0080v2.

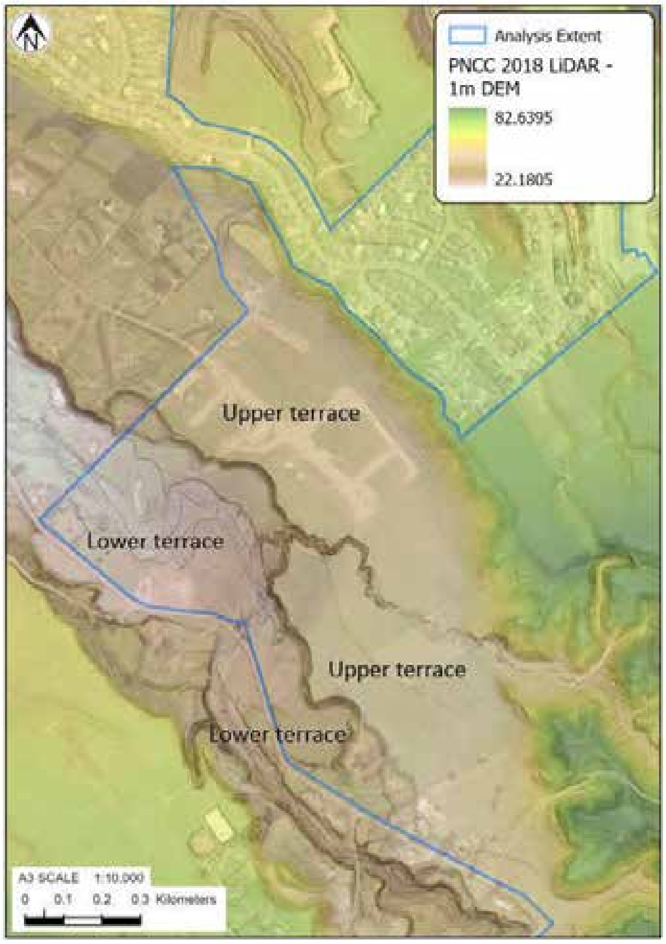

Figure 4.1: Topography of the Turitea Stream valley.

On the basis that there is no geotechnical information or groundwater data for this area, both the upper and lower terrace areas should be classified as **Liquefaction Category is Undetermined** in accordance with the MBIE/MfE Guidance (2017)[10] at this time. Any development in these areas should assess the potential for liquefaction, following the framework laid out in the MBIE/MfE (2017) guidance.

Assigning a category of **Liquefaction Category is Undetermined** is a valid assessment under MfE guidance. The guidance contemplates progressively more detailed assessments of liquefaction, beginning at 'Level A- Basic desktop assessment' through to 'Level D- Site specific Assessment'. At Level A, the three resultant categories are **Liquefaction Category is Undetermined**, **Liquefaction Damage is Unlikely**, and **Liquefaction Category is Undetermined**. The category **Liquefaction Category is Undetermined** is therefore useful as a starting point for identifying where more detailed assessment is required as part of planning or development.

[10] MBIE/MfE. 2017. Planning and engineering guidance for potentially liquefaction-prone land.

5 Applicability

This report has been prepared for the exclusive use of our client Palmerston North City 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, or by any person other than our client, without our prior written agreement.

Tonkin & Taylor Ltd

Environmental and Engineering Consultants

Authorised for Tonkin & Taylor Ltd by:

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Mike Jacka
Technical Director

Report prepared by: Eric Bird, Engineering Geologist

ERBI
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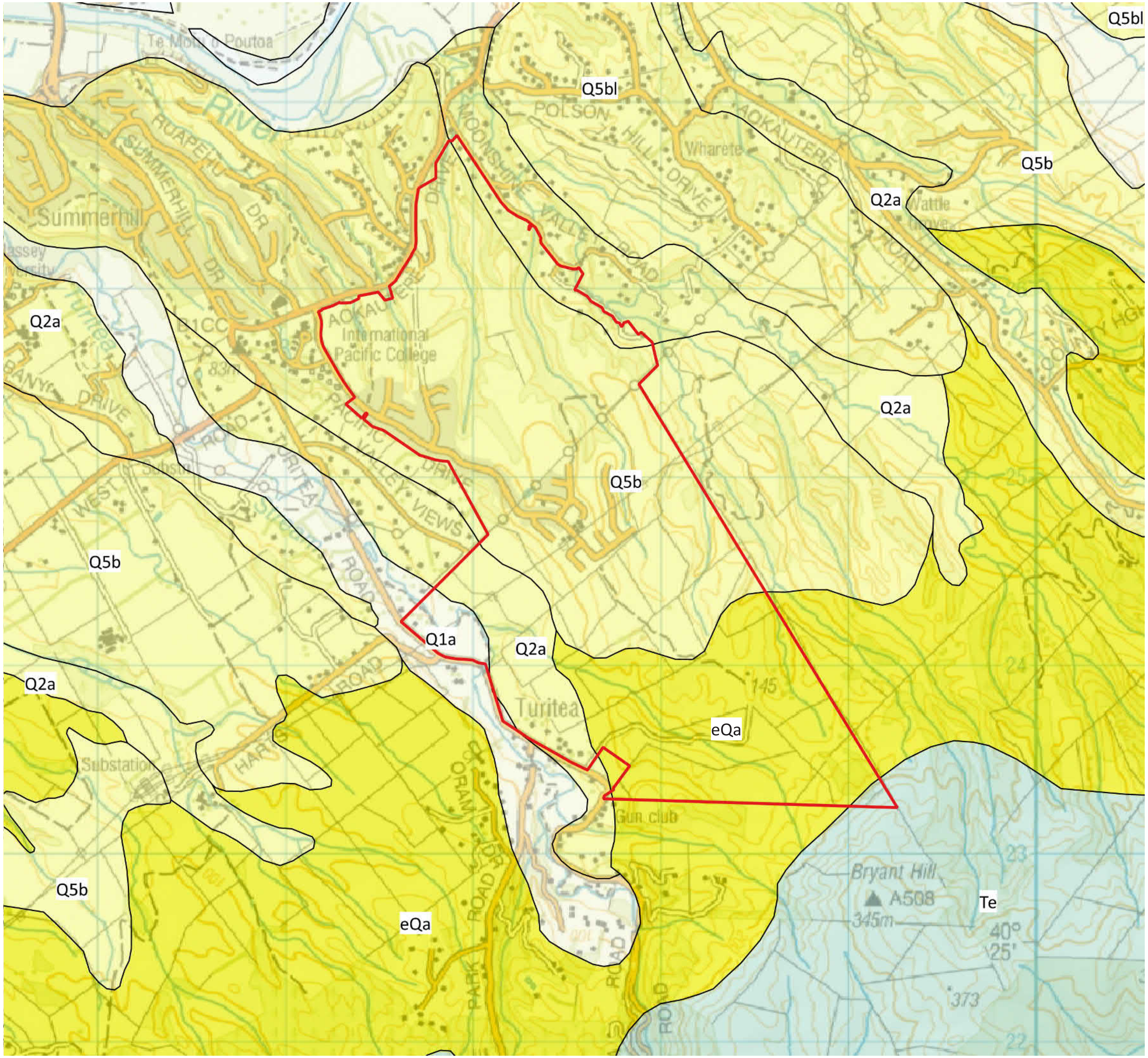
Appendix A: Geological map, site observations and hazard mapping



Legend

Key	Published description (Age)	Site observations
Te	Esk Head Belt: Sandstone and Mudstone (Late Jurassic to early Cretaceous)	Exposed boulders and outcrops
eQa	River deposits of pumiceous sand and gravel (early Pleistocene)	River gravels and silts, trace weathered volcanic gravel.
Q5b / Q5bl	Beach deposits of sand and gravel (late Pleistocene)	Beach sand and marginal marine gravels.
Q2a	River deposits of gravel and sand (late Pleistocene)	River gravels and silts.
Q1a	River deposits of gravel, sand, clay and peat (Holocene)	Silts and swamp.

Simplified Geology

- Indurated sandstone
- Pumiceous sand
- Sand and gravel
- Gravel sand and peat

Proposed Development Boundary

A3 SCALE: 1:20,000

0 210 420 630 840 1,050 (m)

N

1. Geological Boundaries,Inactive Faults,Active Faults GNS Science, Lower Hutt, New Zealand.
2. geotiffs Eagle Technology, LINZ
3. Property Boundary sourced from the LINZ Data Service and licensed for re-use under the Creative Commons Attribution 3.0 New Zealand licence.

Created On:	18/12/2019
Created By:	ELiddle
Approved By:	
TT Proj Ref:	85442.0080
TT Map Ref:	TTMAPREF1433463001.902

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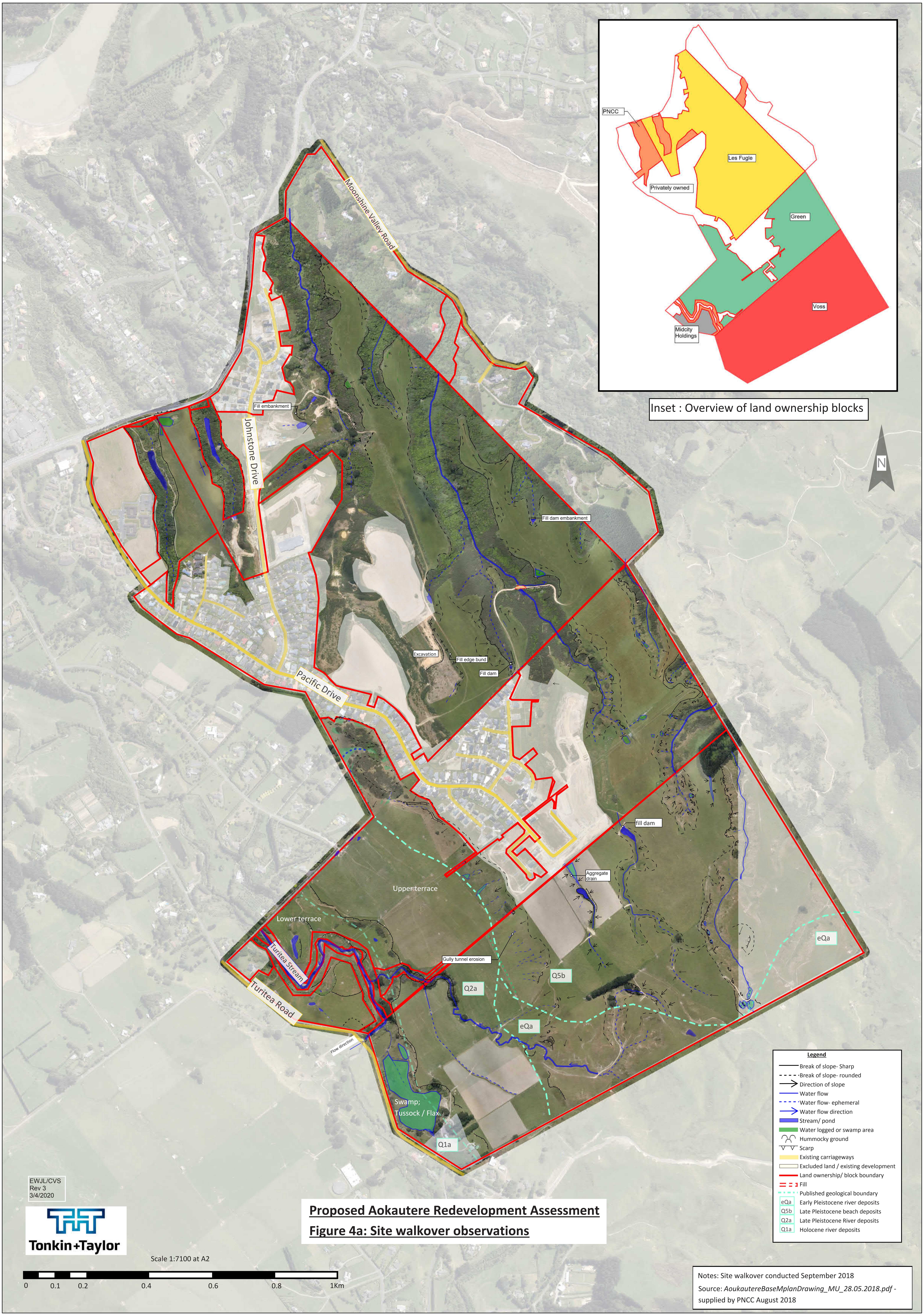
PALMERSTON NORTH CITY COUNCIL

PRELIMINARY SITE ASSESSMENT

PROPOSED AOKAUTERE REDEVELOPMENT

GEOLOGICAL MAP

FIGURE No.
3

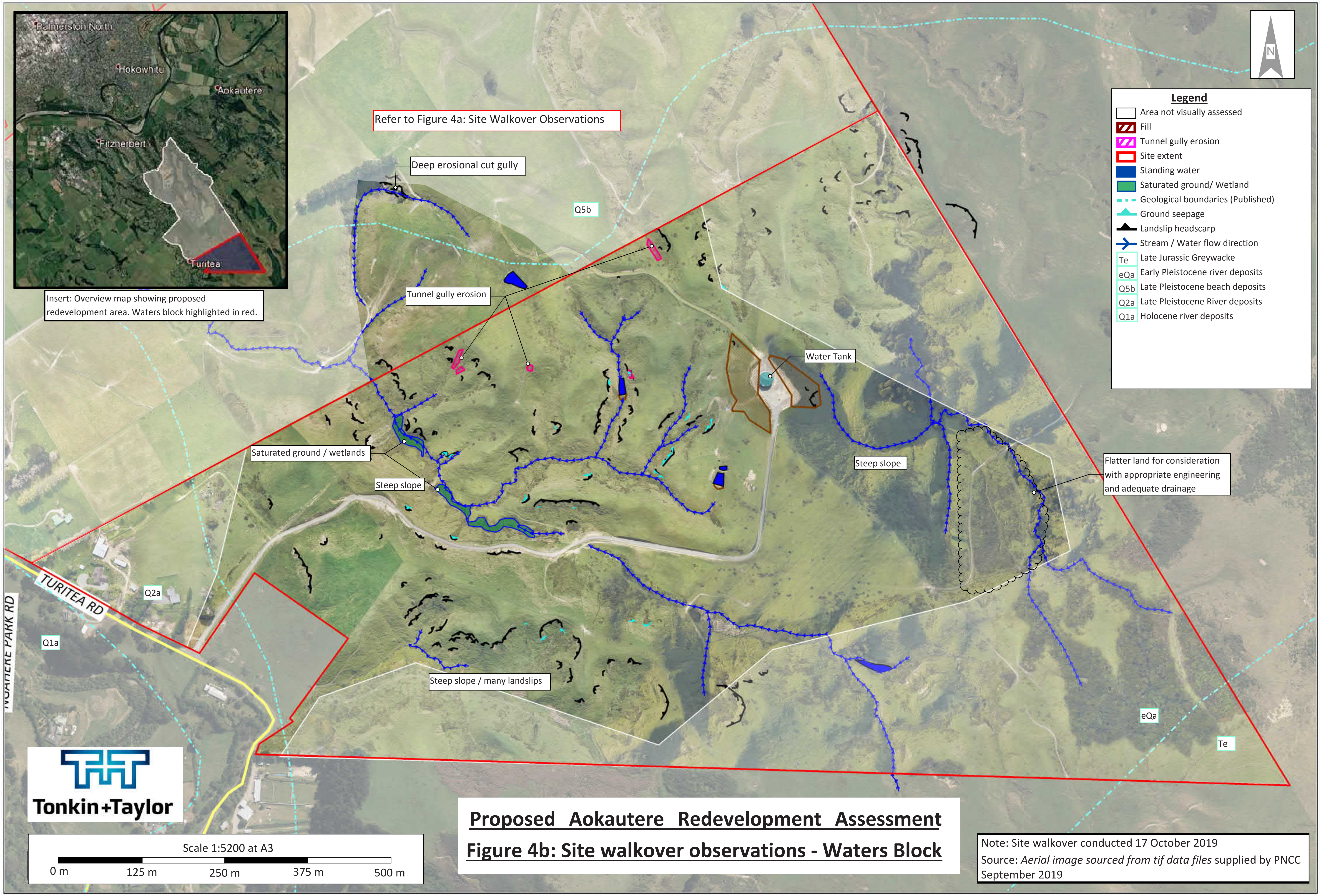


Proposed Aokautere Redevelopment Assessment

Figure 4a: Site walkover observations

Notes: Site walkover conducted September 2018

Source: *AoukautereBaseMplanDrawing_MU_28.05.2018.pdf* - supplied by PNCC August 2018



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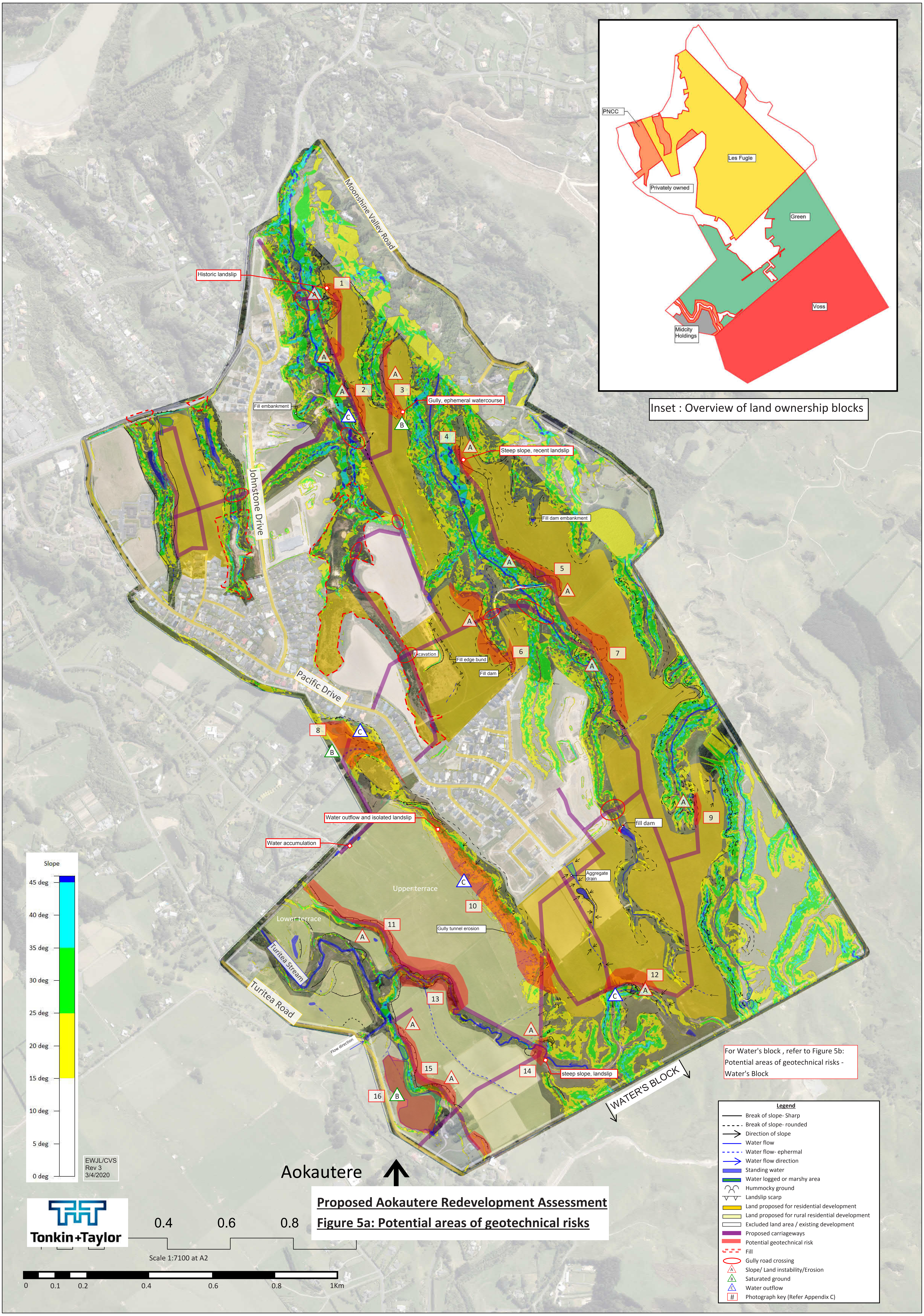
Proposed Aokautere Redevelopment Assessment

Figure 4b: Site walkover observations - Waters Block

Note: Site walkover conducted 17 October 2019

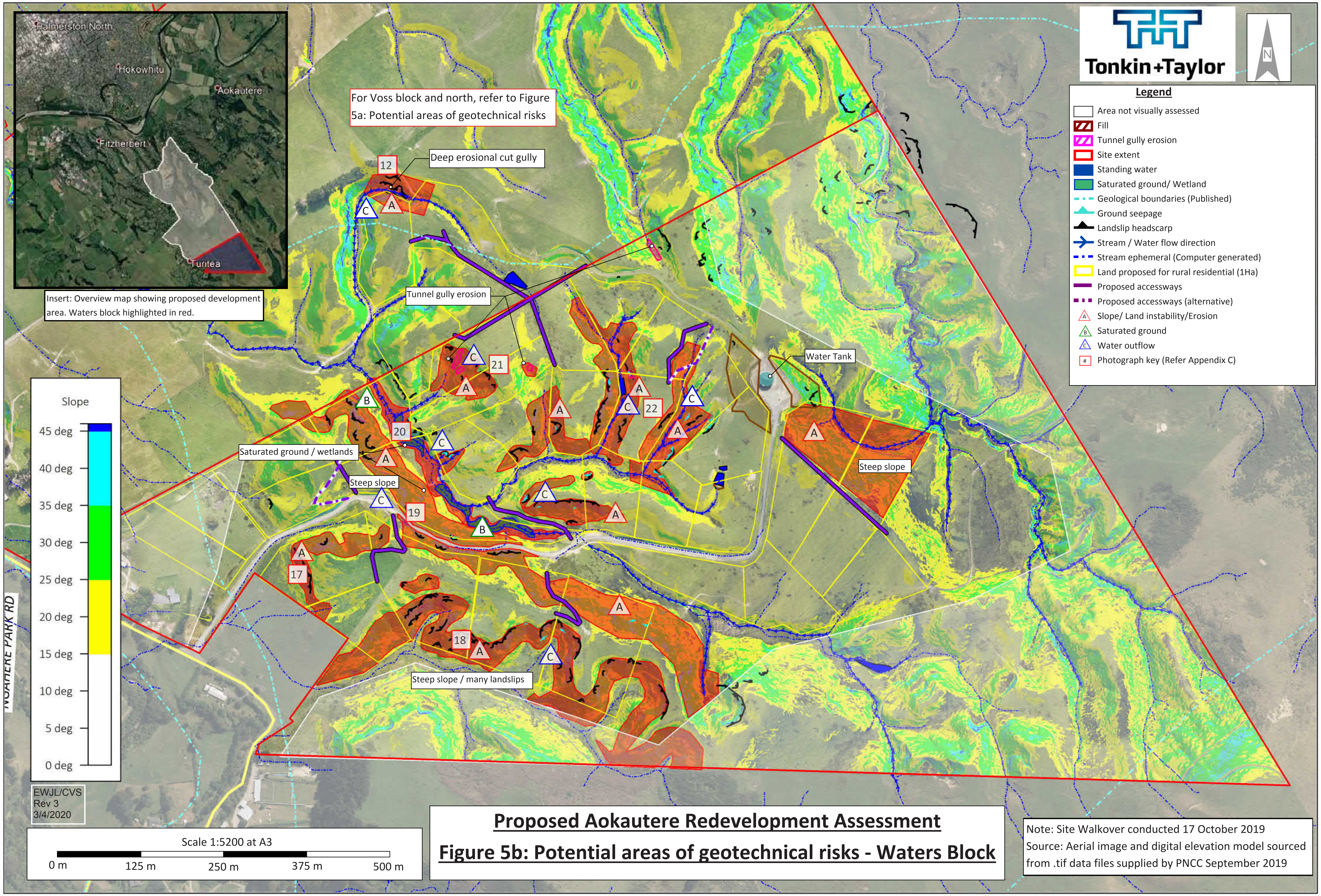
Source: *Aerial image sourced from tif data files* supplied by PNCC September 2019

EWJL/CVS
Rev 3
3/4/2020



Proposed Aokautere Redevelopment Assessment

Figure 5a: Potential areas of geotechnical risks



Proposed Aokautere Redevelopment Assessment

Figure 5b: Potential areas of geotechnical risks - Waters Block

Appendix B: 2020 Site visit photos

Photograph 1: Les Fugle block; hummocky ground

Photograph 2: Les Fugle block; hummocky ground

Photograph 3: Les Fugle block, top of gully and watercourse with soft ground

Photograph 3b: Les Fugle block, watercourse at base of gully

Photograph 4: Les Fugle block; recent landslip

Photograph 5: Les Fugle block; hummocky ground

Photograph 6: Les Fugle block, standing water created by fill dam.

Photograph 7: Green block; historic landslip scarp

Photograph 8: Green block; saturated hummocky land

Photograph 8b: Green block; saturated hummocky land

Photograph 8c: Green block; saturated soft land and standing water

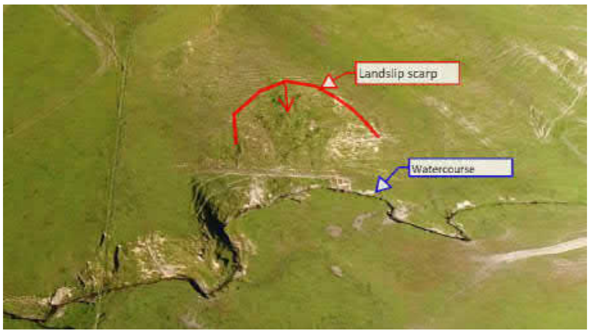
Photograph 9: Voss block; recent landslip scarp and saturated ground

Photograph 9b: Voss block; recent landslips and saturated ground

Photograph 10: Voss block: water induced landslips and watercourses

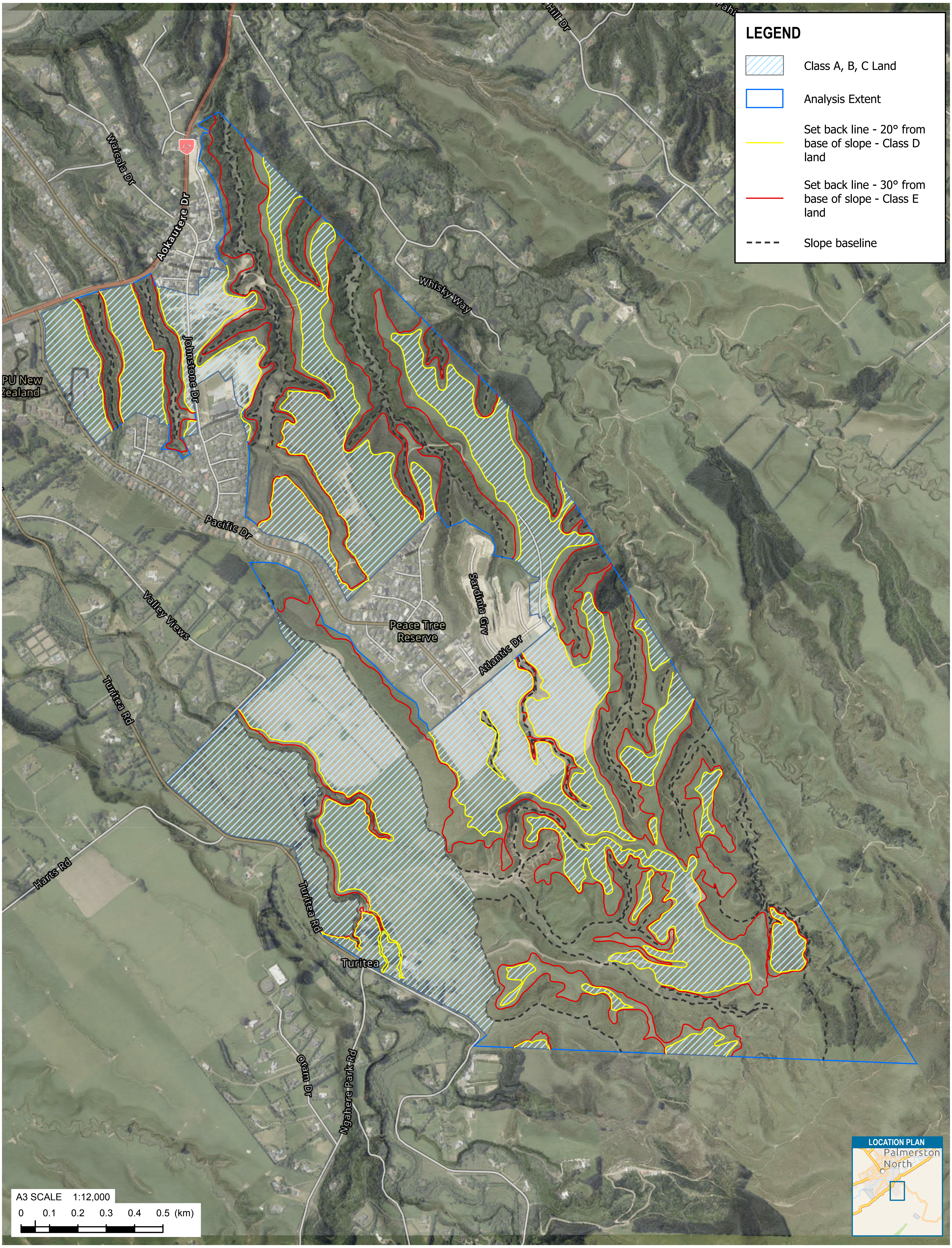
Photograph 11: Voss block; steep hummocky river terrace slope

Photograph 12: Voss block; steep water-cut gully with recent landslips

	
Photograph 13: PNCC block; steep water-cut gully with recent landslips	Photograph 14: Voss block, landslip scarp and watercourse (photograph from UAV footage)
	
Photograph 15: Voss block; steep slope with landslips	Photograph 16: Voss block; saturated ground and swampland
	
Photograph 17: Waters block; Steep slope and landslip headscarps	Photograph 18: Waters block; Steep slopes and multiple landslip headscarps
	
Photograph 19: Waters block; Steep slope, water seepage, multiple landslip headscarps	Photograph 20: Waters block; Streams and saturated surrounding land.

	
Photograph 21: Waters block; Tunnel gully erosion	Photograph 22: Waters block; Steep slopes, landslide headscarps and watercourse

Appendix C: Slope Angle Analysis



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NOTES:

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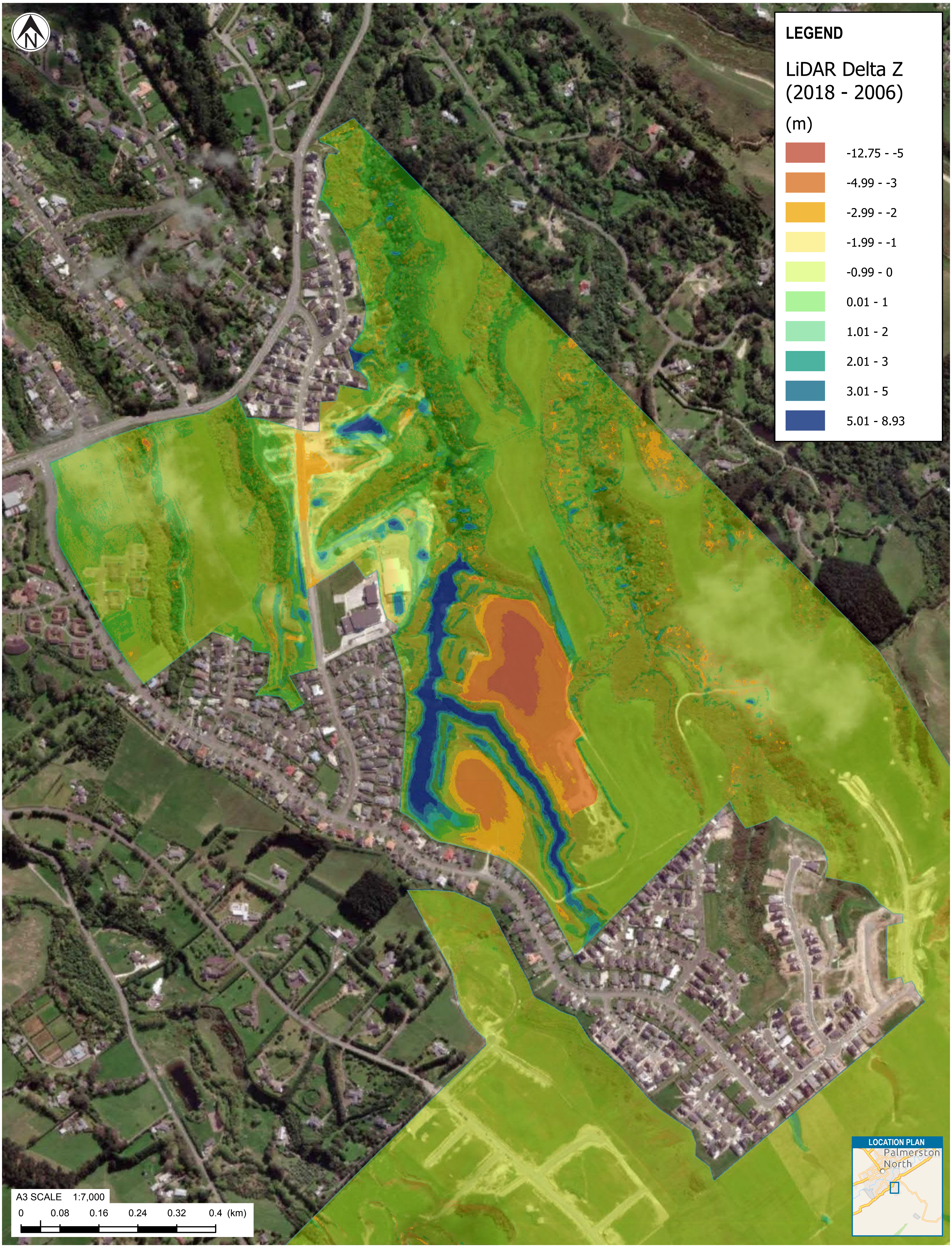
REV	DESCRIPTION	GIS	CHK	DATE
0	First version	DXLR	EDA	11/11/21

PROJECT No.	85442.0300	
DESIGNED	DXLR	NOV.21
DRAWN	DXLR	NOV.21
CHECKED	EDA	NOV.21
APPROVED	MEJ	NOV.21

CLIENT	**PALMERSTON NORTH CITY COUNCIL**
PROJECT	**AOKUTERE RESIDENTIAL LAND DEVELOPMENT**
TITLE	POTENTIAL SET BACK FROM STEEP SLOPES WITHIN THE AOKUTERE LAND DEVELOPMENT AREA
SCALE (A3)	1:12,000
FIG No.	FIGURE 1.
REV	1

Appendix D: Fill Assessment



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REV	DESCRIPTION	GIS	CHK	DATE
0	First version	DXLR		

PROJECT No.	85442.0300	
DESIGNED	DXLR	DEC.21
DRAWN	DXLR	DEC.21
CHECKED		DEC.21
APPROVED		DATE

CLIENT PALMERSTON NORTH CITY COUNCIL
PROJECT AOKAUTERE RESIDENTIAL LAND DEVELOPMENT
TITLE CHANGE IN ELEVATION BETWEEN 2006 AND 2018

SCALE (A3) 1:7,000 FIG No. FIGURE 3. REV 1

REPORT

Tonkin+Taylor

Preliminary Site Observations for Proposed Aokautere Redevelopment

Prepared for
Palmerston North City Council

Prepared by
Tonkin & Taylor Ltd

Date
June 2020

Job Number
85442.0080.v3

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Document Control

Title: Preliminary Site Observations for Proposed Aokautere Redevelopment					
Date	**Version**	**Description**	**Prepared by:**	**Reviewed by:**	**Authorised by:**
20/12/2018	v1	First draft for review	EJWL/CVS	CMW	
10/2/2020	v2	Update report to include Water's block –draft for review	EJWL	CMW	
29/6/2020	v3	Final	EJWL	CMW	MEJ

Distribution:

Palmerston North City Council — 1 PDF copy

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Table of contents

1 Introduction

This report presents the findings of our preliminary geotechnical site assessment for the proposed Aokautere redevelopment project. Tonkin & Taylor Ltd (T+T) was engaged to undertake this work by the Palmerston North City Council (PNCC) in accordance with the terms and conditions contained in our proposal dated 21 August 2018 and additional variation (No 2) proposal dated 16 October 2019.

The objective of this assessment is to provide a high-level evaluation to identify the possible geotechnical risks involved in developing land for residential and rural residential developments.

1.1 Supplied information

Information supplied by PNCC prior and during the investigation comprised of:

- August 2018
  - Five report files relating to the development area including fill assessments and resource consent enforcements
  - A workshop report (Aokautere Structure Plan PNCC Workshop 2)
  - Unmanned Aerial Vehicle (UAV) video footage of a flyover conducted 30 March 2018
  - Annotated aerial photographs of the proposed area including but not limited to:
  - Property boundaries of landowners involved
  - Topographic contours
  - A map of the zones of proposed development including access carriageways
  - A digital elevation model (DEM)
- September 2019
  - Geospatial Information Systems (GIS) files of the assessment area.

2 Site description

The proposed development contains approximately 490 ha (4.9 km^2) of land south east of Palmerston North.

Ownership of the land as at November 2019 is divided into the following blocks, (refer to Appendix A; Figure 1):

Land block owners	Overview of land	Area
Les Fugle	Flat topped hills with water eroded vegetated gullies	101 ha
Voss	Rolling hills with some water eroded gullies to the northeast. Flat level river terraces to the south west.	101 ha
Green	Flat topped to gentle rolling hills to the north east. Flat level river terraces to the south west.	58 ha
Midcity Holdings Ltd	Low lying river terrace	5 ha
Waters	Flat topped hills with river cut valleys, flat terracing to the south	104 ha
PNCC	Vegetated gullies flanking waterways to the south west. Vegetated gullies and walking paths to the north.	28 ha
Privately owned	Residentially developed land.	93 ha

The area is broadly 4km by 1.5km and slopes gently upwards to the south. The land can be typically divided into two topographies:

1 Water cut and eroded gullies in elevated flat to rolling hills within the eastern and southern sides of the site.
2 Flat, river and stream formed terraces adjacent to and including a section of the Turitea Stream within the south western side of the site.

2.1 Proposed redevelopment

According to supplied information and observations made onsite the proposed redevelopment land use can be divided into the following groups (refer Appendix A; Figures 2a and 2b):

Proposed development	**Area**
Residential	87 ha
Rural residential	102 ha
(Native vegetation) Green space	161 ha
Existing development or excluded land	140 ha

These proposed land areas will be connected by approximately 13km of carriageways.

3 Geology

The Palmerston North regional area lies on the boundary between the older (late Jurassic/ Early Cretaceous) exposed greywacke basement rocks (Esk Head belt) in the Tararua ranges to the south east with the younger (Holocene) alluvial river deposits of gravel, sand and silts to the north west (Refer Appendix A: Figure 3).

The Esk Head belt (Te) forms the base of the Tararua mountain range. These rocks have been deformed and uplifted through the Wellington Fault which runs NE-SW along the eastern side of the Tararua Ranges. This stratigraphy is present on the far south-eastern corner of the Waters property.

To the northwest of the Esk Head belt, towards Turitea in the southwest of the site, early Pleistocene alluvial river gravels and sands (eQa) are present. These are assumed to have been deposited as erosional runoff deposits during the uplift and formation of the Tararua Ranges.

Further northwest, up to the cliffs adjacent to the Manawatu River, are gravels and sands more conclusive to marginal marine/ beach deposits indicating a paleo-shoreline (Q5b) is present. Cutting through these beach deposits and river gravels is a prominent flat river cut terrace containing gravels and silts eroded from the Tararua Ranges and deposited in a paleo-channel (Q2a). These geological materials underlie the majority of the site.

Younger Holocene deposits of river silts and sands (Q1a) are found in the many smaller river cut terraces formed from the meandering watercourses which loosely follows the Turitea Stream, formed in the Q2a paleo-channel.

The published geology[1] of the investigation area is shown in Appendix 1: Figure 3 which indicates the regional surface geology.

[1] Lee, J.M., Begg, J.G. (compilers) 2002: *Geology of the Wairarapa area*. Institute of Geological & Nuclear Sciences 1:250,000 geological map 11. 1 sheet + 66 p. Lower Hutt, New Zealand. Institute of Geological & Nuclear Sciences Limited.

3.1 Faults

Active faults have been identified within 15km of the assessment area as shown in Table 1.

Table 1: Active faults

Fault name	Location relative to the assessment area	Recurrence interval (years)	Last occurrence (years)
Wellington Fault	7km southeast	850	335-485
Northern Ohariu Fault	9km southwest	2600	<4000
Ruahine Fault	13km east	3700	<1800

4 Assessment methodology

4.1 Desktop study

Historic aerial photographs were reviewed (1950, 1965 and 1995) of the site and surrounding areas. This confirmed the predominant usage of the land over that time period has been farmland pasture. Many gullies in the northern section of the site were bare of vegetation with observable historic landslips. Later revegetation and infilling were also observed in the photographs. Urban development along Pacific Drive became noticeable in 1995. The large water tank and associated roading on the Water's property was constructed in 2017.

The digital elevation model (DEM) supplied by PNCC was utilised to produce a slope gradient map. This produced map was overlaid with the supplied proposed redevelopment plan and aerial photograph mapping.

4.2 Mapping and observations

T+T undertook a site walkover during 26-28 September 2018 (Voss property and north) and 17 October 2019 (Water's property). Mapping and site walkover observations (Appendix A: Figures 4a and 4b) were collected for the majority of the undeveloped sites marked for future proposed development, where access approval was granted by the landowner and safety considered. Photographs of areas of interest are provided in Appendix B.

During the site walkover observations, particular attention was given to hazards associated with ground instability, water flows and soft ground conditions as summarised in Table 2.

Table 2: Summary of observations and associated hazards

Site observations	Associated hazards	Map ID (Refer Appendix A: Figures 5a and 5b)
Evidence of landslip, both recent and historic	Potential slope and land instability	
Evidence of land creep	Potential slope and land instability. May indicate future landslip failures	
Slope direction and gradients	Provides land fall direction indicating areas of water runoff catchments	
Watercourses, both current and ephemeral	Potential for erosion of land along with erosion induced landslips. Path of water runoff may indicate areas of saturated ground. Potential for flood inundation.	
Saturated ground conditions and swamp land	Settlement of ground and potential for flood inundation.	
Groundwater outflows	Potential for instability on slopes, erosion, internal gully erosion	
Uncontrolled fill	Settlement of ground and loss of bearing	

4.3 Geo-hazards identified

The associated hazards consist of the following geotechnical issues to be considered for consenting:

- Slope and land instability
- Erosion including tunnel gully erosion
- Uncontrolled fill, settlement
- Flooding/high groundwater table
- Soft soils/Peat, settlement

Detailed descriptions of the geotechnical issues are provided in Appendix C.

5 Geo-hazard assessment

By using the above methodology, a geotechnical hazard risk assessment was undertaken.

To produce the overall maps (Refer Appendix A: Figures 5a and 5b) and the associated areas of potential geotechnical risks, a range of assessment factors were considered. These are outlined in Table 3.

Table 3: Assessment factors for geotechnical risk

Maps	Description
Aerial image map	Overview of land topography and possible geotechnical hazards.
Site mapping observations	Ground truthing of new and previously identified possible geotechnical hazards.
Slope gradient map	Identification of land which may require geotechnical remediation for development.
Proposed residential, rural residential and carriageway areas	Relevancy of observations with identified possible geotechnical hazards.

All the walkover mapping field observations and notes are presented in Appendix A: Figures 4a and 4b. All the site observations presented are visual only and no intrusive investigation or lab testing was conducted.

5.1 Geomorphology risk

As described in Section 2 the topography and geomorphology of the area can be divided into two main types. These are described in more detail below in relation to land ownership blocks (refer to Appendix A: Figure 1).

5.1.1 Elevated flat to rolling hills

Les Fugle and the north-eastern Green and Voss blocks consist of level plains in the north west to gentle rolling hills in the south east. The hills become steeper with deeper water cut and eroded gullies towards the east within the Waters property. Water cut valleys have incised up to 35 m depth, these valleys hold ephemeral streams and continuous watercourses predominantly flowing south to north towards the Manawatu River. Watercourses within the southern area of the Voss block and within the Waters block predominantly flow from the south towards the northwest in the direction of the Turitea Stream.

Valleys in the Les Fugle and Green block are in the process of revegetation, the Voss and Waters block valleys are generally bare of vegetation. Signs of historic and recent landslips are evident, especially in the valleys of the eastern Voss and Waters blocks. These landslips are likely triggered by erosion at the foot of the valley and from surface water runoff which was visible along many ridges.

Water retention within the top-soil was observed to be greater in the Les Fugle and Green blocks compared to the Voss and Water's block. This may be indicative of a different subsurface geology.

5.1.2 Flat river terraces

Bi-secting the Green, Voss and north-western corner of the Water's block is an upper level river cut terrace with an associated 35m high, 20° to 30° slope. This slope shows evidence of multiple ground water outflows which form shallow water cut valleys saturating land downslope. Minor landslips where present at the head of these outflows. This terrace provides approximately 40 ha (0.4km^2) of flat level ground. Near the boundary between Green and Voss blocks is a water cut gully approximately 200m long ranging in depth from 0.5m to 13m deep with steep 80-90° slopes.

A second observable lower river cut terrace runs adjacent to the Turitea Stream alongside the PNCC and Midcity Holdings property. The terrace forms a 13m high moderately steep (30° to 45°) slope with evidence of recent and historic landslips. Within this lower terrace is evidence of multiple river cuts, saturated ground and swampland.

5.2 Geotechnical risk

The following geotechnical hazards (Table 4), described in Section 4 and Appendix C, are shown on maps in Appendix A; Figures 5a and 5b in red. These areas may be considered for limited development/consenting restrictions and are to be addressed during development.

Table 4: Geotechnical hazard areas to be addressed

ID*	Geotechnical hazard	Urban Residential	Rural residential	Infrastructure
1	Slope and land instability Erosion	**Consequences:** Damage to service connections due to ground and building deformations. Community disruption and displacement due to damage to buildings then the complex and lengthy process of repairing and rebuilding. Large magnitude total and differential settlement due to soft soil, peat, and/or uncontrolled fill. Loss of foundation-bearing capacity, resulting in settlement/slope instability. Stretch of the foundation due to slope instability, pulling the structure apart. Additional design cost **Development consideration:** Additional site specific geotechnical investigations, Enhanced foundations; Ground improvement	**Consequences:** Damage to service connections due to ground deformations. Additional design cost Limited land use **Development consideration:** Additional site specific geotechnical investigations, Limited land use, Placement of the proposed structures away from hazard	**Consequences:** Damage to roads (cracking due to settlement/slope instability, sinkholes due to erosion). Damage to underground services due to ground deformation (e.g. 'three waters', utility networks). Disruption of stormwater drainage. Community disruption and displacement – initially due to damage to infrastructure, then the complex and lengthy process of repairing and rebuilding. Additional design cost **Development considerations:** Placement of proposed infrastructure away from hazard; Slope stabilisation; Additional site specific investigation; Ground improvement; Additional resilience; Redundant utility and road networks
2	Slope and land instability Erosion Tunnel gully erosion			
3	Slope and land instability Erosion Uncontrolled fill			
4	Slope and land instability Erosion			
5	Slope and land instability Erosion			
6	Slope and land instability Erosion			
7	Slope and land instability Erosion			
8	Slope and land instability Tunnel gully erosion Flooding Soft soil/Peat Uncontrolled Fill			
9	Slope and land instability Tunnel gully erosion Flooding Soft soil/Peat			
10	Slope and land instability Erosion Tunnel gully erosion			
11	Slope and land instability Erosion			
12	Slope and land instability Erosion			
13	Slope and land instability Erosion			
14	Slope and land instability Erosion			
15	Slope and land instability Erosion			
16	Flooding Soft soil/Peat			
17	Slope and land instability Erosion			
18	Slope and land instability Erosion			
19	Slope and land instability Erosion			
20	Slope and land instability Flooding Soft soil/Peat			
21	Slope and land instability Erosion Tunnel gully erosion			
22	Slope and land instability Erosion			
Fill	Uncontrolled fill			

*Refer to Appendix B for documented photographs of site observations.

6 Conclusions

T+T has undertaken a site walkover and desktop assessment of geo-hazards for Palmerston North City Council. The results of this assessment are considered suitable to aid PNCC in the assessment and management of geotechnical-related risk and provide guidance for the Proposed Aokautere Redevelopment.

Appendix A, Figures 5a and 5b, identifies potential areas of geotechnical risks for the Proposed Aokautere Redevelopment. Site specific information is required to refine the assessment. Land use and development within these areas shall be assessed by Chartered Engineer.

It is the responsibility of the future developer to address and ensure there will be no additional or exacerbation of hazards on-site or off-site as a result of any proposed development.

8 Applicability

This report has been prepared for the exclusive use of our client Palmerston North City 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, or by any person other than our client, without our prior written agreement.

Recommendations and opinions in this report are based on data from surface observations only. The nature and continuity of subsoil away from the surface observation and below the surface are inferred and it must be appreciated that actual conditions could vary from the assumed model.

Tonkin & Taylor Ltd

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Report prepared by:

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Appendix A: Figures

- Figure 1 - Site Plan- Land block property ownership
- Figure 2a - Proposed development zoning
- Figure 2b - Proposed development zoning - Waters block
- Figure 3 - Geological map
- Figure 4a - Site walkover observations
- Figure 4b - Site walkover observations - Waters block
- Figure 5a - Potential areas of geotechnical risks
- Figure 5b - Potential areas of geotechnical risks –Waters block

Insert: Overview map showing proposed redevelopment area

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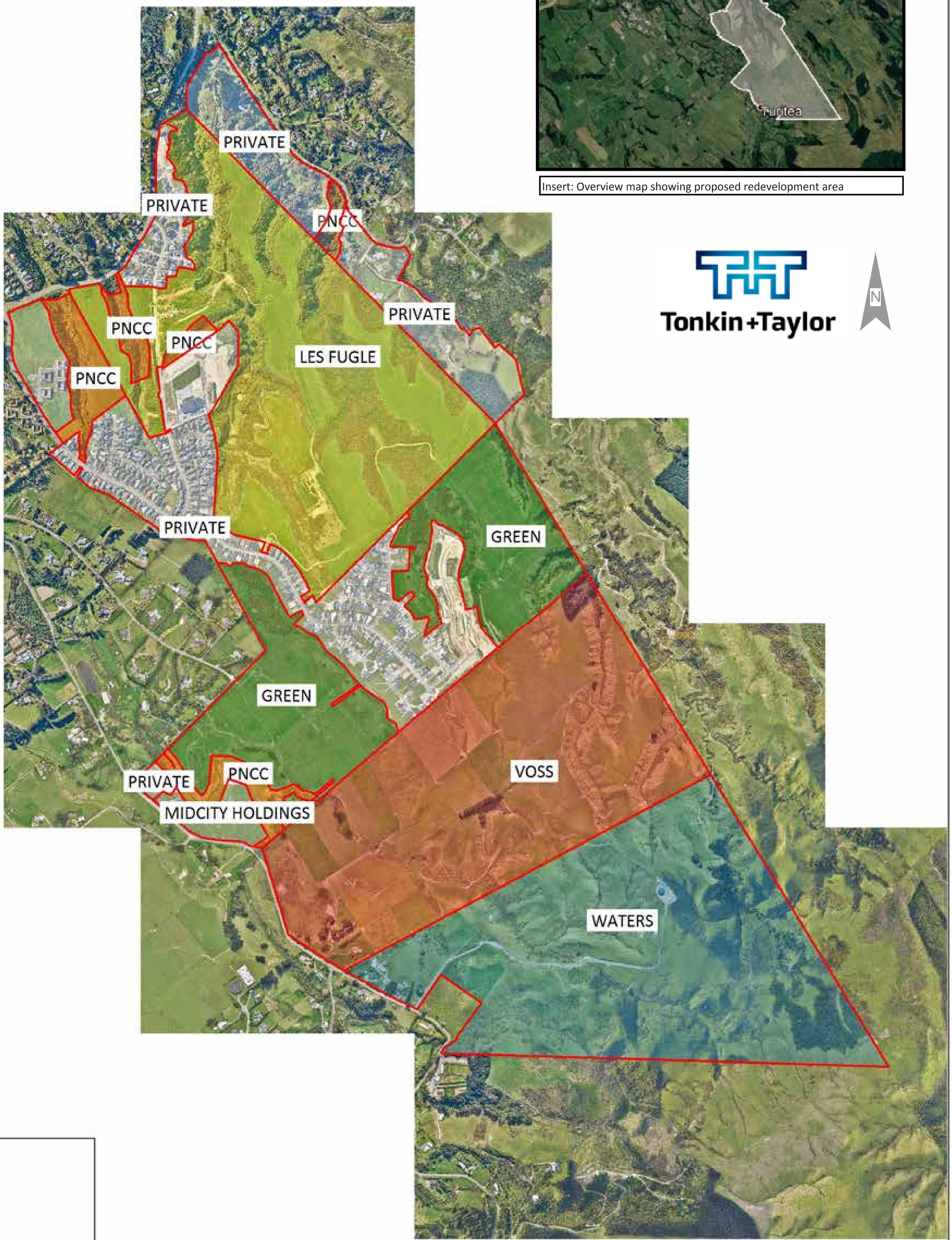

Legend

- GREEN
- LES FUGLE
- MIDCITY HOLDINGS
- PNCC
- PRIVATE
- VOSS
- WATERS

Proposed Aokautere Redevelopment Assessment

Figure 1: Site Plan- Land Block Property Ownership

0 m 500 m 1000 m

Scale 1:1500 at A3

Aerial image sourced from tif data files supplied by PNCC 25/9/2019

Ownership boundaries based on *Aokautere_Structure_Plan_Vector_Data* files supplied by PNCC on 25/9/2019

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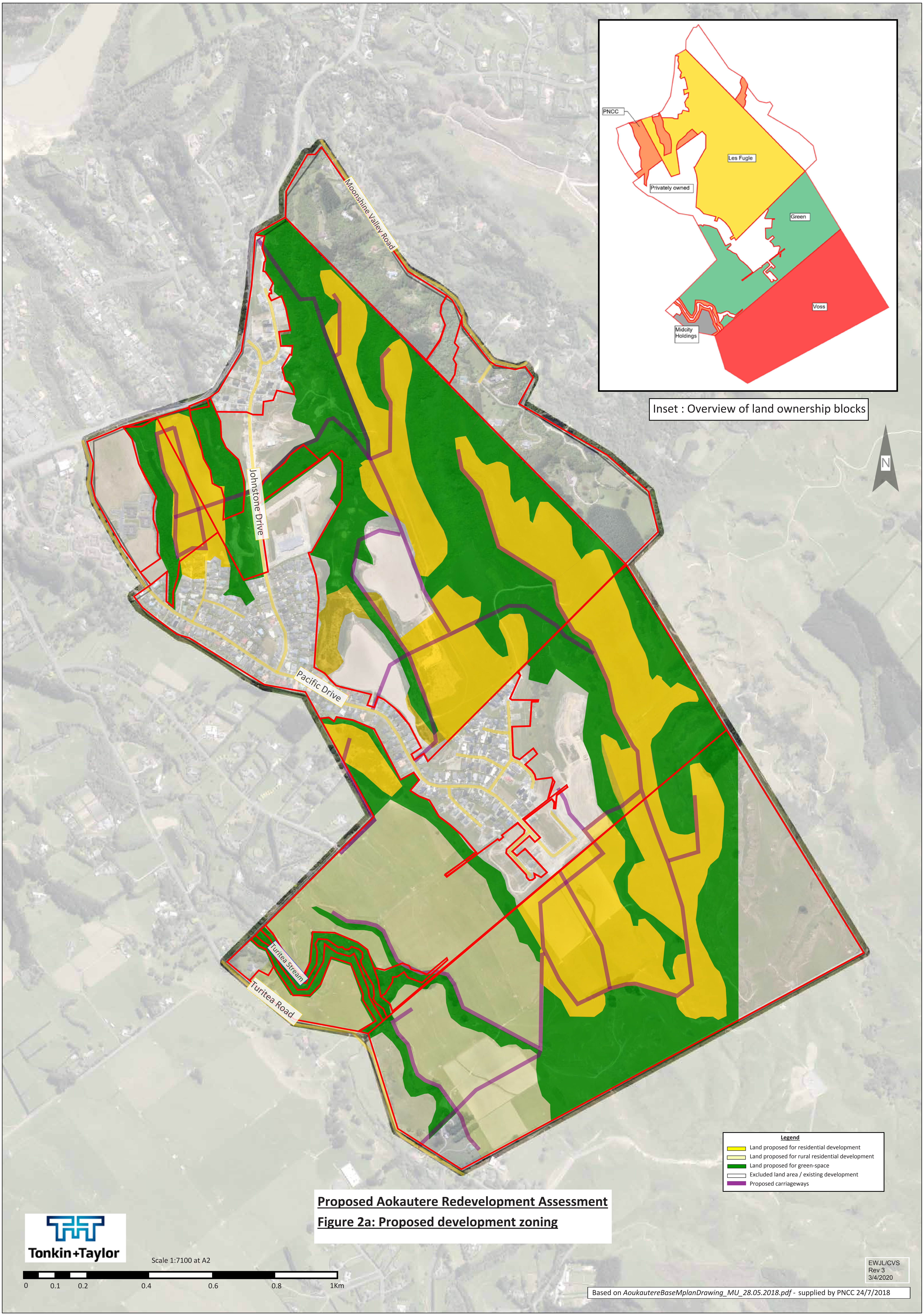
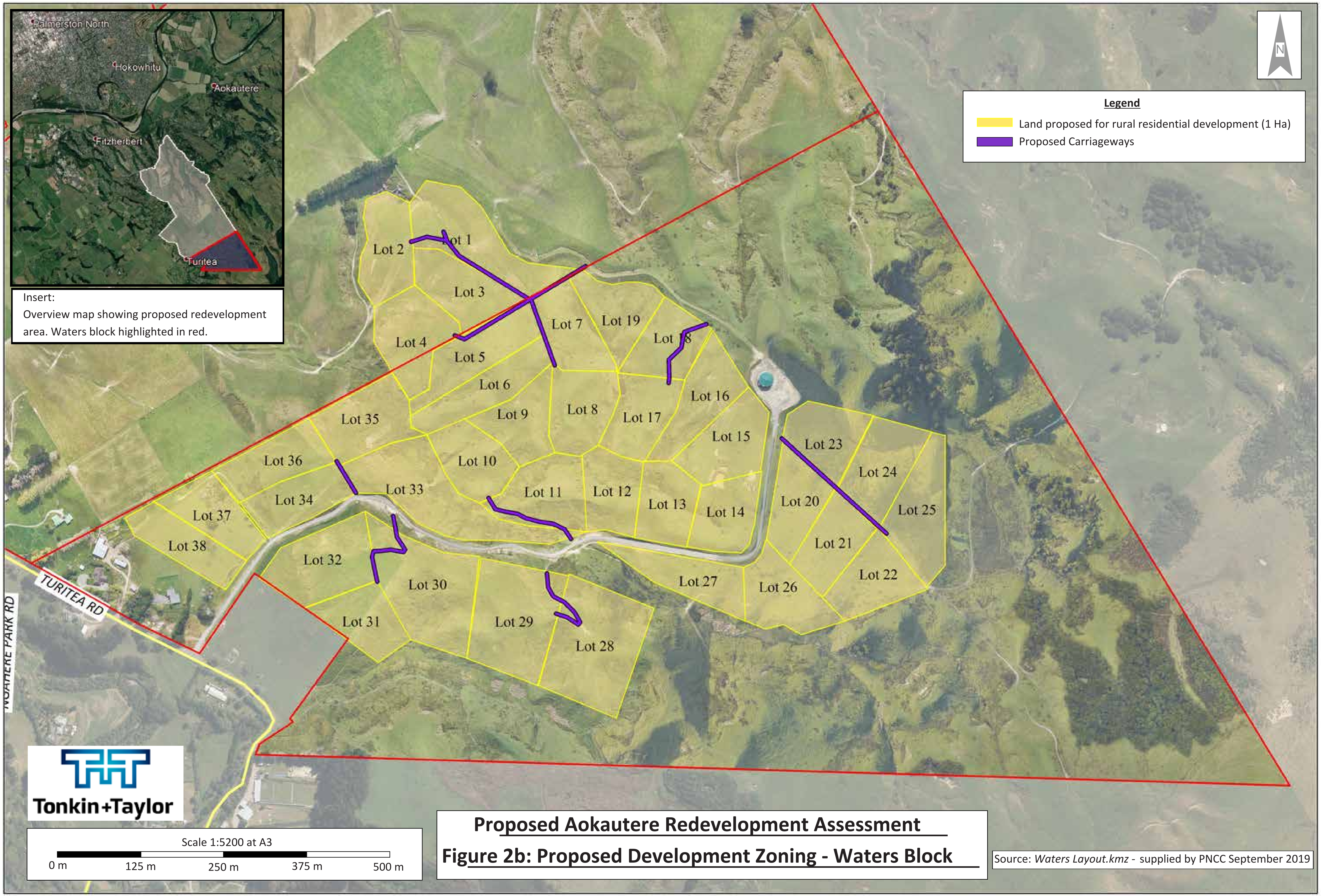


Proposed Aokautere Redevelopment Assessment

Figure 2a: Proposed development zoning



Proposed Aokautere Redevelopment Assessment

Figure 2b: Proposed Development Zoning - Waters Block

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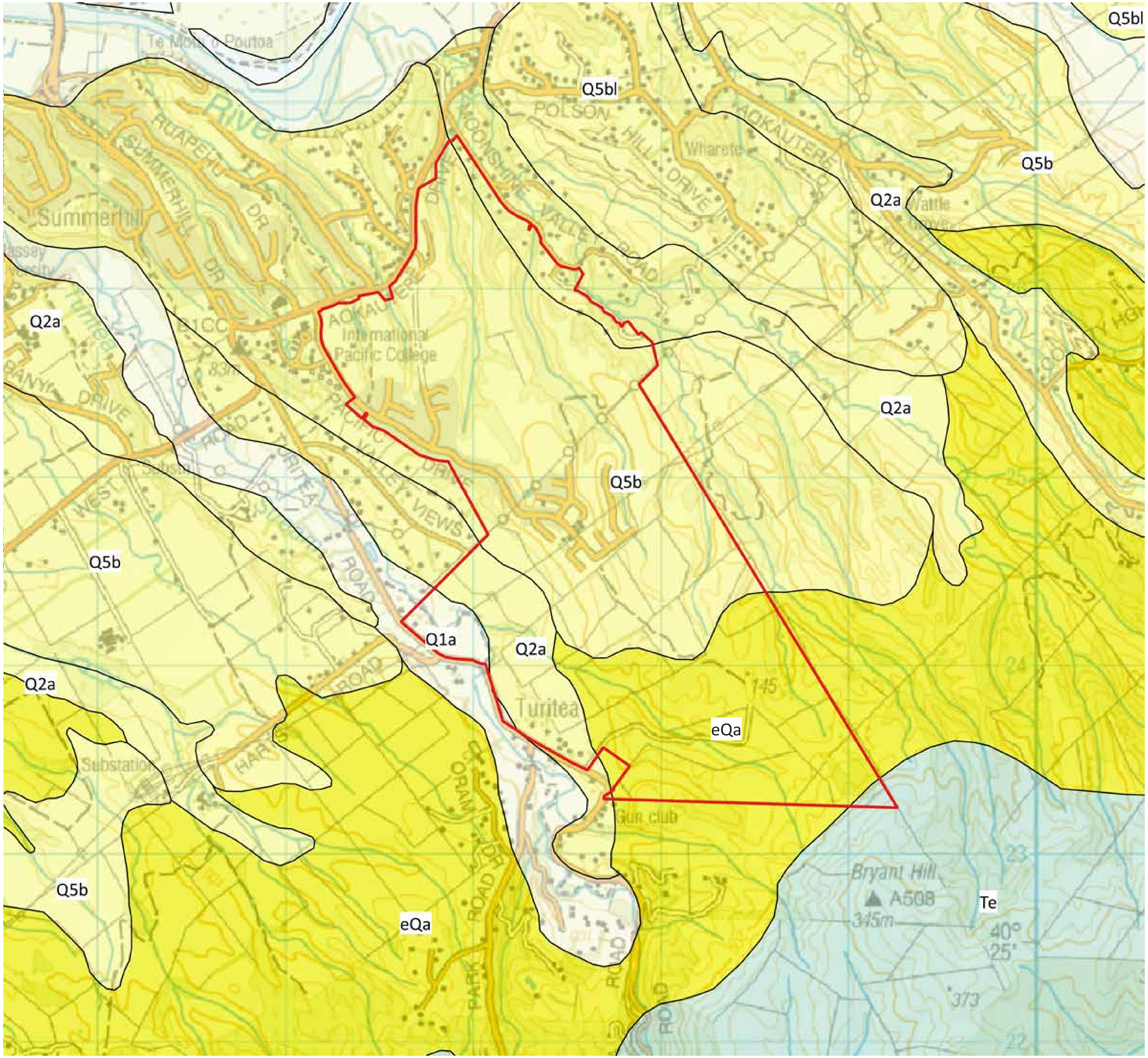
Rev 3
3/4/2020



Legend

Key	Published description (Age)	Site observations
Te	Esk Head Belt: Sandstone and Mudstone (Late Jurassic to early Cretaceous)	Exposed boulders and outcrops
eQa	River deposits of pumiceous sand and gravel (early Pleistocene)	River gravels and silts, trace weathered volcanic gravel.
Q5b / Q5bl	Beach deposits of sand and gravel (late Pleistocene)	Beach sand and marginal marine gravels.
Q2a	River deposits of gravel and sand (late Pleistocene)	River gravels and silts.
Q1a	River deposits of gravel, sand, clay and peat (Holocene)	Silts and swamp.

Simplified Geology

	Indurated sandstone
	Pumiceous sand
	Sand and gravel
	Gravel sand and peat

Proposed Development Boundary

A3 SCALE: 1:20,000

0 210 420 630 840 1,050 (m)

N

1. Geological Boundaries,Inactive Faults,Active Faults GNS Science, Lower Hutt, New Zealand.
2. geotiffs Eagle Technology, LINZ
3. Property Boundary sourced from the LINZ Data Service and licensed for re-use under the Creative Commons Attribution 3.0 New Zealand licence.

Created On:	18/12/2019
Created By:	ELiddle
Approved By:	
TT Proj Ref: 85442.0080	
TT Map Ref: TTMAPREF1433463001.902	

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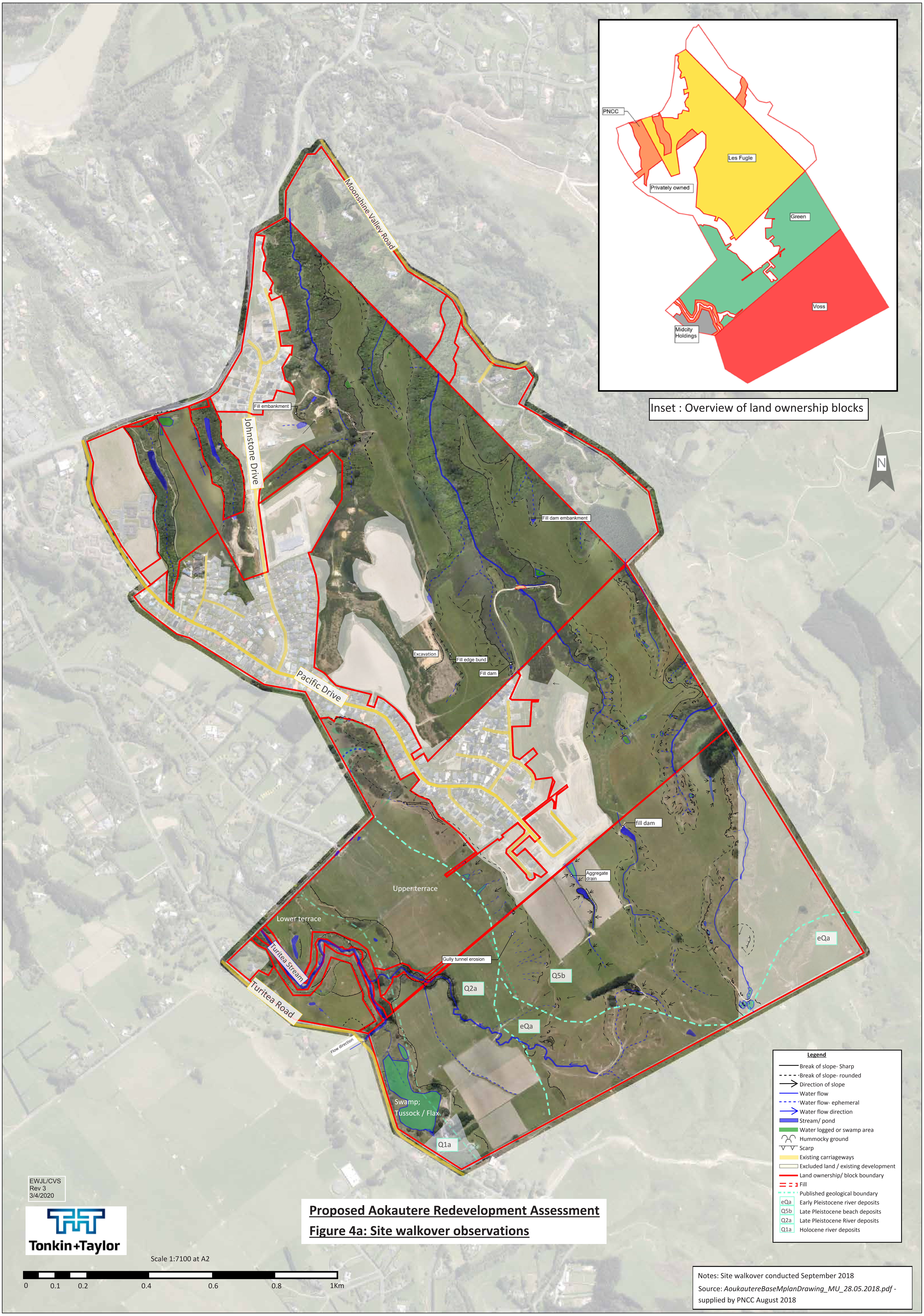
PALMERSTON NORTH CITY COUNCIL
PRELIMINARY SITE ASSESSMENT
PROPOSED AOKAUTERE REDEVELOPMENT
GEOLOGICAL MAP

FIGURE No.
3

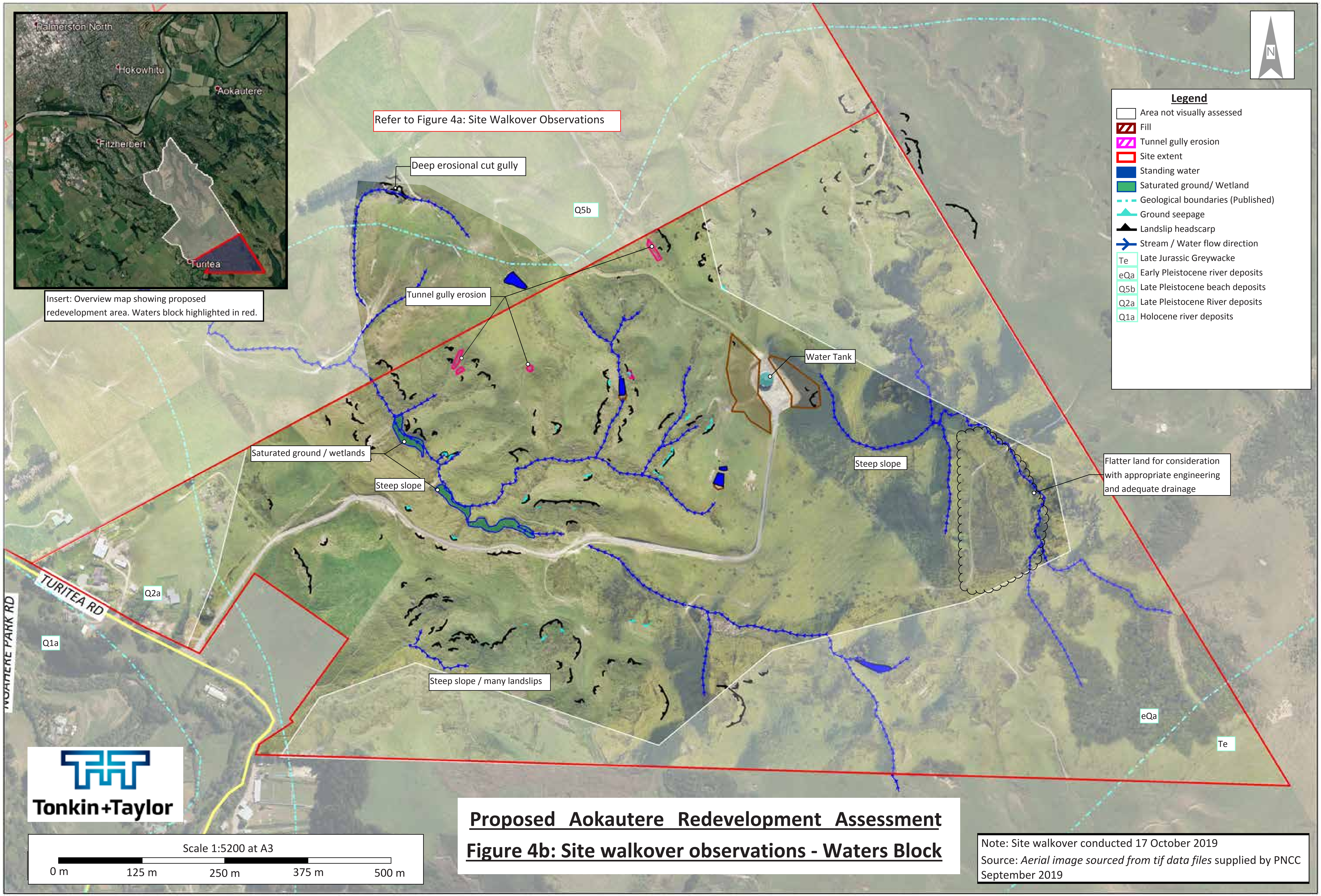


Proposed Aokautere Redevelopment Assessment

Figure 4a: Site walkover observations

Notes: Site walkover conducted September 2018

Source: *AoukautereBaseMplanDrawing_MU_28.05.2018.pdf* - supplied by PNCC August 2018



Proposed Aokautere Redevelopment Assessment

Figure 4b: Site walkover observations - Waters Block

Note: Site walkover conducted 17 October 2019
Source: *Aerial image sourced from tif data files* supplied by PNCC September 2019

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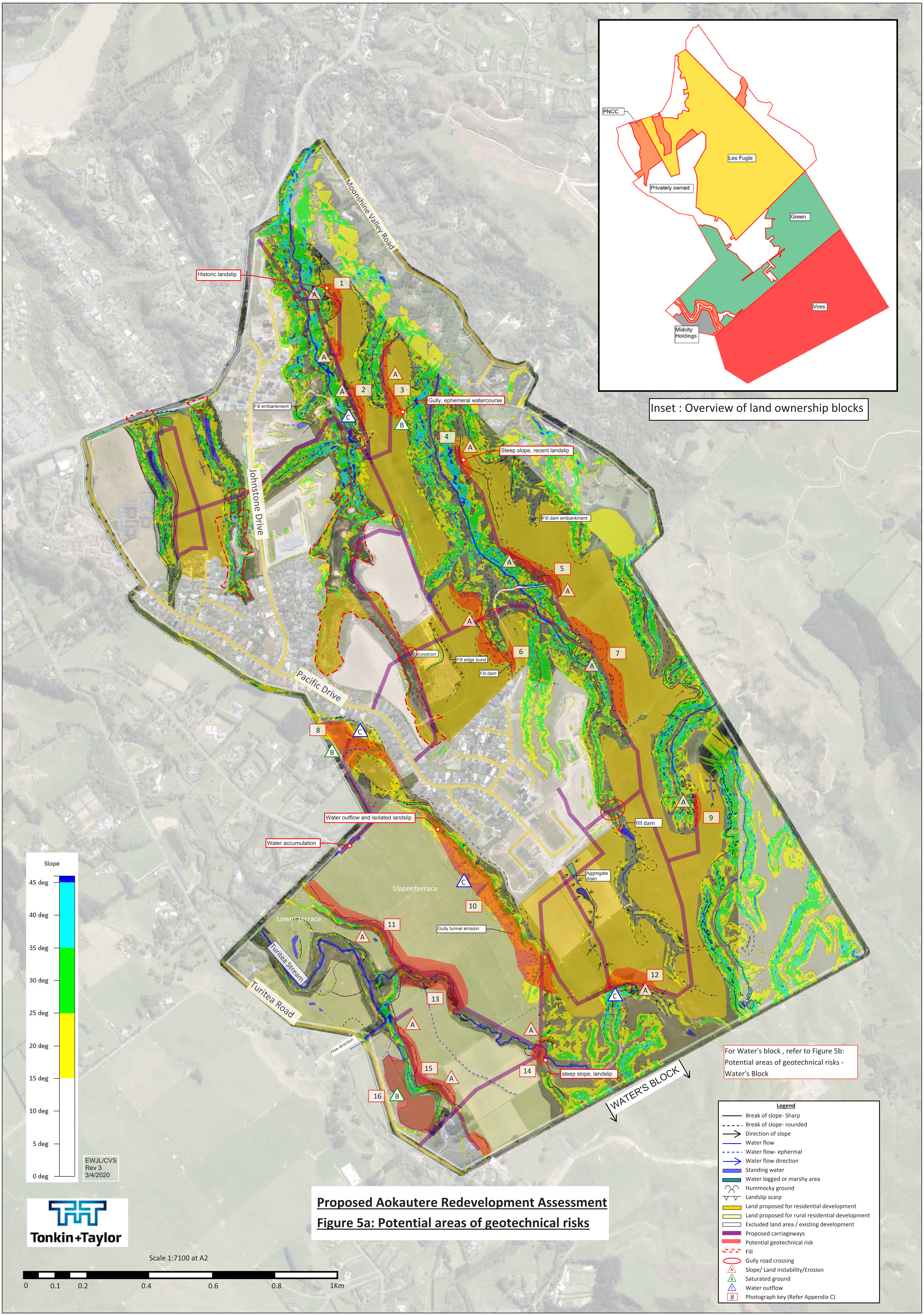
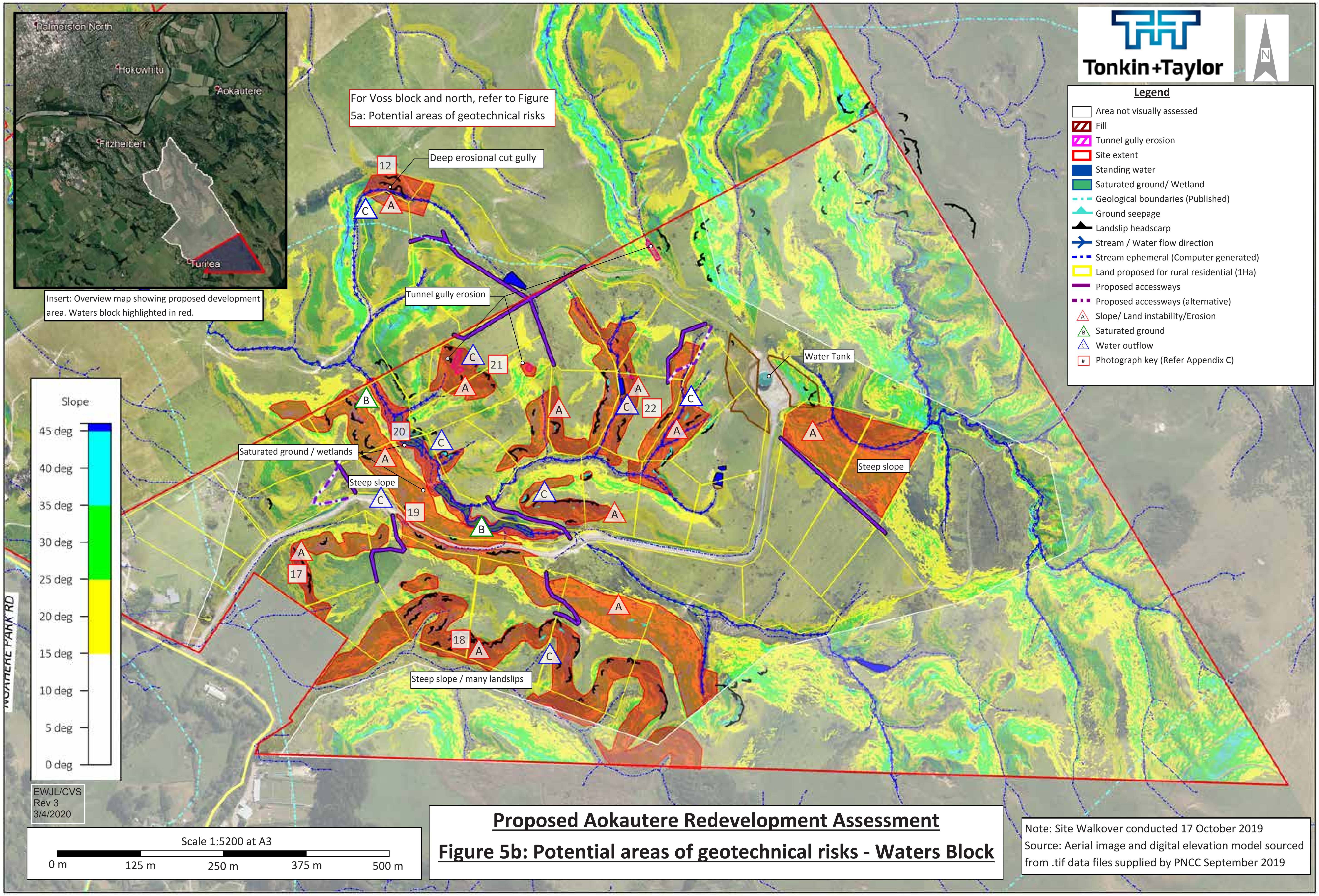


Proposed Aokautere Redevelopment Assessment

Figure 5a: Potential areas of geotechnical risks



Proposed Aokautere Redevelopment Assessment

Figure 5b: Potential areas of geotechnical risks - Waters Block

Note: Site Walkover conducted 17 October 2019
Source: Aerial image and digital elevation model sourced from .tif data files supplied by PNCC September 2019

Appendix B: Photographs of site observations

Photograph 1: Les Fugle block; hummocky ground

Photograph 2: Les Fugle block; hummocky ground

Photograph 3: Les Fugle block, top of gully and watercourse with soft ground

Photograph 3b: Les Fugle block, watercourse at base of gully

Photograph 4: Les Fugle block; recent landslip

Photograph 5: Les Fugle block; hummocky ground

Photograph 6: Les Fugle block, standing water created by fill dam.

Photograph 7: Green block; historic landslip scarp

Photograph 8: Green block; saturated hummocky land

Photograph 8b: Green block; saturated hummocky land

Photograph 8c: Green block; saturated soft land and standing water

Photograph 9: Voss block; recent landslip scarp and saturated ground

Photograph 9b: Voss block; recent landslips and saturated ground

Photograph 10: Voss block: water induced landslips and watercourses

Photograph 11: Voss block; steep hummocky river terrace slope

Photograph 12: Voss block; steep water-cut gully with recent landslips

Photograph 13: PNCC block; steep water-cut gully with recent landslips

Photograph 14: Voss block, landslip scarp and watercourse (photograph from UAV footage)

Photograph 15: Voss block; steep slope with landslips

Photograph 16: Voss block; saturated ground and swampland

Photograph 17: Waters block; Steep slope and landslip headscarps

Photograph 18: Waters block; Steep slopes and multiple landslip headscarps

Photograph 19: Waters block; Steep slope, water seepage, multiple landslip headscarps

Photograph 20: Waters block; Streams and saturated surrounding land.

	
Photograph 21: Waters block; Tunnel gully erosion	Photograph 22: Waters block; Steep slopes, landslide headscarps and watercourse

Appendix C: Geotechnical hazard descriptions

Slope and land instability

Slope failures are major natural hazards occurring both globally and locally. They are referred to as the downslope movement of rock debris and soil in response to gravitational stresses. Slope failures are generally classified according to the type of downslope movement namely falls, slides, and creep.

Common causes of slope failure include:

- Slope steepness/gradients
- Excessive water in slopes adding weight, erosion, and reducing strength
- Modifications (excavations and removal of the slope's base, loading of the slope or crest, surface or groundwater manipulation, and irrigation)
- Seismic loading

Erosion

Erosion is the loss or displacement of land along a watercourse, through runoff or surface overland flow water or ground water seepage. Gullies are permanent erosional features. The gullies function as sediment sources, stores, and conveyors that link hillslopes to downstream water channels and flow paths.

Changes in land use, may accelerate gully expansion by head cutting, sidewall collapse, tunnelling, and other processes, which lead to widespread land degradation and potential damage to structures and infrastructure.

Tunnel gully erosion

Tunnel gully erosion is a process involving the removal of subsurface soil layers by water. The water moves down through the soil profile until it reaches a less permeable layer where it concentrates to form a downslope channel (tunnels). As the tunnel widens the risk of ground surface collapse increases, which can then often continue as gully erosion and increase the risk of losing larger areas of pasture and productive land.

Tunnel gully erosion is likely to be found where there is a variation in the permeability within the soil profile such as a free draining soil or subsoil overlying an impermeable layer. It often occurs towards the base of colluvial slopes, which are lower slopes formed by previous mass movement and slope instability.

Uncontrolled fill

Uncontrolled fill consists of soil placed without documentation and without engineering input. There are various areas of know uncontrolled fill located within the area (refer Appendix A: Figures 4a and 4b). There is risk of subsidence and differential settlement of structures, as a result of uncontrolled fill.

The following reports document a portion of land formed by uncontrolled fill and the ground conditions:

- David Napier (2007), Filling Assessment Report, Barthos Properties Abbey Road Extension, dated March 2007
- Abuild (2012), Peer Review, Earthworks Review, Pacific Drive, Palmerston North, ref 8566,Dated 13 February 2012

Flooding/High groundwater

The assessment areas physical landscape presents varying levels of flood risk. During high rainfall events flooding can occur within minutes of the event and can result in significant damage. Property and structures located adjacent to a river and stream corridor are more susceptible to damage from flooding. Buildings located in ponding and shallow surface water flow areas are also susceptible to damage from flooding. Furthermore, development within, river and stream corridors can adversely affect the structural integrity of existing flood mitigation structures and works and increase the potential for damage and loss of life.

Soft soils/Peat

Soft and very soft sediments were identified as a potential geological hazard in the assessment area. When additional loads are applied (e.g. by fill placement or building construction) they can produce large total and differential settlements. This has the potential to damage buildings and other infrastructure founded on these materials.

Soft and very soft sediments are usually formed when fine grained materials are deposited in a low energy environment (e.g. settle out of suspension in a standing water body such as a lake or swamp).

Two distinct environmental settings within the area that are conducive to the formation of layers or beds of soft to very soft sediments. These areas are:

1. Current or historical swamps; and

2. Stream and river deltas.

Appendix D: Supplied files

File Name	File Format	Supplier	Date supplied
Aokautere Structure Plan Workshop Aerial	pdf	PNCC	24/7/2018
Aokautere Structure Plan Workshop Flightpath	pdf	PNCC	24/7/2018
Aokautere Structure Plan Workshop Owner detail	pdf	PNCC	24/7/2018
Aokautere Structure Plan Workshop Reserves	pdf	PNCC	24/7/2018
Aokautere Structure Plan Workshop Topography	pdf	PNCC	24/7/2018
Aokautere Structure Plan Workshop Waters	pdf	PNCC	24/7/2018
Aokautere Structure Plan Workshop Zoning	pdf	PNCC	24/7/2018
Flightpath01_YouTube1080	mp4	PNCC	24/7/2018
Flightpath02_YouTube1080	mp4	PNCC	24/7/2018
Flightpath03_YouTube1080	mp4	PNCC	24/7/2018
Aokautere Structure Plan_Workshop 2_28.05.18	pdf	PNCC	24/7/2018
Aokautere Workshop 1_Record_4 April 2018	pdf	PNCC	24/7/2018
AokautereBaseMplanDrawing_MU_28.05.2018	pdf	PNCC	24/7/2018
ABuild Report for LU 404 Pacific Drive Final Report (784577)	pdf	PNCC	24/7/2018
David Napier March 2007	pdf	PNCC	24/7/2018
Environment Court 2014NZEnvC198 Final Enforcement Order	pdf	PNCC	24/7/2018
Environment Court ENV-2015-WLG-000018 Change to Enforcement Order	pdf	PNCC	24/7/2018
Pacific Farms Ltd ÔÇô 28 Abby Road Earthworks and Subdivision, Time Extension Application Part A (881320)	pdf	PNCC	24/7/2018
Pacific Farms Ltd ÔÇô 28 Abby Road Earthworks and Subdivision, Time Extension Application Part B (881323)	pdf	PNCC	24/7/2018
DEM	tif	PNCC	1/11/2018
Aokautere_Structure_Plan_Vector_Data	Folder containing various files including .spx, .gdbtablx	PNCC	25/09/2019
ShareData V2	Folder containing various files including .las , .shp, .asc, .tif	PNCC	25/09/2019
Waters Layout	.kmz	Hudson Associates Landscape Architects	9/10/2019

6 Conclusions

T+T has undertaken a site walkover and desktop assessment of geo-hazards for Palmerston North City Council. The results of this assessment are considered suitable to aid PNCC in the assessment and management of geotechnical-related risk and provide guidance for the Proposed Aokautere Redevelopment.

Appendix A, Figures 5a and 5b, identifies potential areas of geotechnical risks for the Proposed Aokautere Redevelopment. Site specific information is required to refine the assessment. Land use and development within these areas shall be assessed by Chartered Engineer.

It is the responsibility of the future developer to address and ensure there will be no additional or exacerbation of hazards on-site or off-site as a result of any proposed development.

7 Further work

There are various potential opportunities for PNCC to take an active role in managing geotechnical related risk, while also facilitating development by simplifying site-specific ground investigation and foundation design requirements where appropriate. We would be happy to work with PNCC to explore how these could be implemented. Possible examples include:

- Defining succinct geotechnical information requirements for resource and building consent applications, which focus on resolving the key uncertainties in the geotechnical hazards relevant for each development area.
- Undertaking ground investigations and/or soil testing across parts of the development area. This would provide greater certainty in the assessment and could allow some types of development to proceed relying only on the existing information without the need for site-specific investigations (where appropriate, and subject to a requirement for robust foundations).