BEFORE THE HEARINGS PANEL

FOR THE PROPOSED QUEENSTOWN LAKES DISTRICT PLAN

IN THE MATTER	of the Resource Management Act 1991
AND	
IN THE MATTER	of Queenstown Lakes Proposed District Plan – Upper Clutha Mapping

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STATEMENT OF EVIDENCE OF STEPHEN FRANCIS LEARY

ON BEHALF OF HAWTHENDEN LIMITED (SUBMITTER 776)

GEOLOGICAL MAPPING

4th April 2017

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1. Introduction

1.1 My full name is Stephen Francis Leary. I hold the qualification of Bachelor of Science (Geology) from the University of Canterbury, where I received a first class honours degree in 1993. My thesis was a conducted on the Tasman and Mueller Glaciers of the Mt Cook region - glaciers actively forming landforms similar to those of the Queenstown Lakes District. I have worked as a professional geologist for approximately 24 years and am currently self employed as a geological consultant (Consultant Geo Ltd.). I am a Fellow of the SEG (Society of Economic Geologists) and a Member of the AusIMM (Australasian Institute of Mining and Metallurgy). In 2008 I was awarded the PDAC (Prospectors and Developers Association of Canada) Thayer Lindsey International Discovery Award and in 2009 the SME (Society for Mining, Metallurgy and Exploration [USA]) Robert M. Dreyer Award for Applied Economic Geology.

1.2 I am familiar with the geology of the Hawthenden farm, having mapped it in September and October 2015 and visited the area again in March 2017. To create the geological map and report I have also utilised satellite and air photo images, reports and maps from the IGNS (Institute of Geological and Nuclear Sciences) as well as reports and data from the ORC and the QLDC GIS database.

1.3 Key documents used or referred to in this assessment include:

a) My report on the Geology of the Hawthenden Farm Area, Southwest Wanaka, October 2015.
b) Otago Alluvial Fans: High Hazard Fan Investigation, ORC, June 2011,
c) Statement of Evidence of Helen Juliet Mellsop on behalf of the Queenstown Lakes District Council, Landscape, 17 March 2017.
d) Hawthenden Farm – Wanaka, Landscape and Visual Assessment by Rough and Milne Landscape Architects.

e) Environment Court Decision: *Wakatipu Environmental Society Inc v Queenstown Lakes District Council* [2002] NZRMA C73/2002.

f) Institute of Geological and Nuclear Sciences 1:250,000 map sheet 18 (Wakatipu), 2000.

1.4 I confirm that I have read the Code of Conduct for Expert Witnesses contained in the Environment Court of New Zealand Practice Note 2014 and I agree to comply with it. In that regard I confirm that this evidence is written within my expertise, except where I state that I am relying on the evidence of another person. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

2. Scope of Evidence

2.1 I have been engaged by Hawthenden Limited (submitter 776) to provide expert evidence relating to the geology of Hawthenden Farm.

2.2 The geology of the Hawthenden farm and the Queenstown Lakes District is only summarized here, for more detail please refer to the report on *The Geology of the Hawthenden Farm Area, Southwest Wanaka, October 2015* (Steve Leary).

In her Statement of Evidence on behalf of Queenstown Lakes District Council (QLDC), landscape architect Ms Helen Mellsop refers to this report and states that: "*I consider that neither the landscape assessment nor the geology report have adequately taken into account the origins and significance of the distinctive Alpha fan in the upper part of the property*" (section 7.33). Ms Mellsop also refers to a terrace (referred to as an 'escarpment' in her statement) that truncates the Alpha fan (section 7.38). In response to Ms Mellsops comment, more detail has been provided in this evidence on the Alpha fan geology and terraces, as well as an assessment of their significance and the distinctiveness of the Alpha fan and associated terraces within the Queenstown Lakes District.

2.3 A geotechnical natural hazard assessment has not been conducted during the preparation of this statement. The natural hazards that may affect the

Hawthenden farm area are documented in the QLDC GIS natural hazard database and in the report Otago Alluvial Fans: High Hazard Fan Investigation, ORC, June 2011.

3. Executive Summary

Geological mapping of the Hawthenden farm area has delineated two geological units - the Mount Alpha mountain side is composed of Permian aged schist (and associated landslide debris) while the valley floor immediately to the north is a sequence of Quaternary alluvial sediments, terminal moraine and lake sediments. Within the alluvial sediments an active alluvial fan formation (the Alpha fan) runs for 3km along the face of Mt Alpha and down to the shore of Lake Wanaka. The alluvial fan has been cut by two terraces around the time of the last glaciation event (15-18,000 years ago), the terraces have since been partly eroded and then partially buried by subsequent fan activity. Alluvial fans are very common landforms in the Queenstown Lakes District, with fans forming where streams and rivers discharge from steep mountain slopes onto flatter valley floors. Alluvial terraces are also very common in glaciated terrains - they form when lowering base water levels cause streams and rivers to cut down through the sediment, usually in interglacial periods.

4. Geology of the Queenstown Lakes District

4.1 The geology of the Queenstown Lakes District is dominated by two major geological units. The mountains and rocky promontories (roche moutonnée's), are comprised of Permian aged (299 to 251 million year old) schist, while the valley floors contain a Quaternary age (2.58 million years to present), sequence of alluvials, moraine (till) and lake sediments (Figure 1). Two geological processes have dominated the formation of the landscapes – 1. the actions of glaciers and 2. fluvial processes (flowing water – rivers and streams).

4.2 At least five major glaciation events have occurred during the ice ages, carving deep, u-shaped valleys and deposited extensive moraine deposits. The largest of these occurred around 400,000 and 600,000 years ago with ice

at least a 1000m above the present lake level and the glaciers reaching almost as far as Cromwell. While these events created the valleys and the Upper Clutha and Wakatipu basins, three smaller glacial events that occurred at approximately 200,000 years ago (the Luggate advance), 60-80,000 years ago (the Albert Town advance) and 15-18,000 years ago (the Mt Iron/Hawea advance) and it is these three events and associated fluvial processes that have shaped the floor of the Upper Clutha and Wakatipu basins. The valley fill is therefore geologically very recent, having been deposited within the last 250,000 years or so.

4.3 The steep mountain sides carved by the glaciers were subjected to heavy erosion when the ice retreated, from landslides and by streams and rivers. The later transporting large volumes of material from the mountain slopes to the valley floor, depositing it as alluvial outwash gravels and fans. The erosion (glacial, fluvial and landslide) processes have left the schist mountain sides steep, rough and often incised by ravines while the moraine, alluvials and lake sediments deposited on the valley floors are generally smoother and flatter. The contrast in the angle of the slope and the difference in the surface character makes the schist-valley fill (alluvial, moraine and lake sediment) contact generally easy to identify on the ground or in satellite images and aerial photographs.

4.4 The Upper Clutha Basin part of the IGNS 1:250,000 geological map (map 18, Wakatipu, 2000) has been include as Figure 1 (below) and is considered an accurate geological representation for this area.

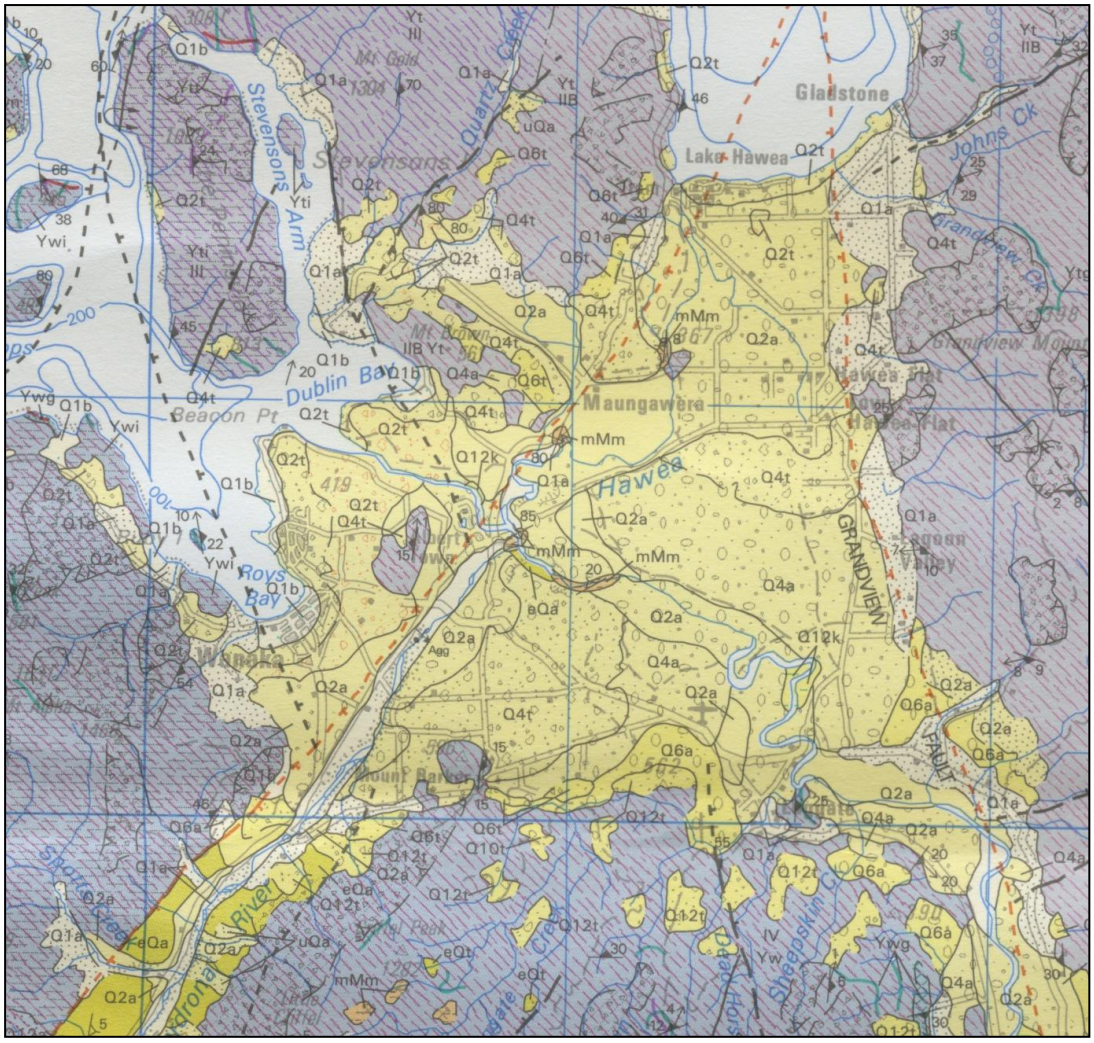


Figure 1. Geology of the Upper Clutha basin, from IGNS 1:250,000 geological map 18 (Wakatipu), 2000. Yellow units are the Quaternary basin fill - lithology Q1a is the active alluvial fans. The Permian schist is purple. The map grid is 10km squares.

5. Alluvial Fans and Terraces

5.1 Alluvial fans are a fan-shaped 'apron' of alluvial sediments that has been deposited along the margin of a valley. They occur where a stream or river discharges from a steep mountainside onto a flatter valley floor - the change in gradient decreases the velocity (energy) of the water resulting in the stream changing from erosional (on the mountain side) to depositional (on the valley floor), refer to Figure 2 below. Lateral migration (avulsion) of stream channels across the fans during flood events creates the characteristic fan shape of the alluvial deposits. Erosion and sedimentation tends to occur during heavy rain and flood events. Most fan systems are

composites (bajada) - where two or more streams have created overlapping fans along a mountain front. Alluvial fans tend to form slightly elevated, gentle sloping smooth landforms that have free draining soils – they are usually considered ideal places for cultivation and development.

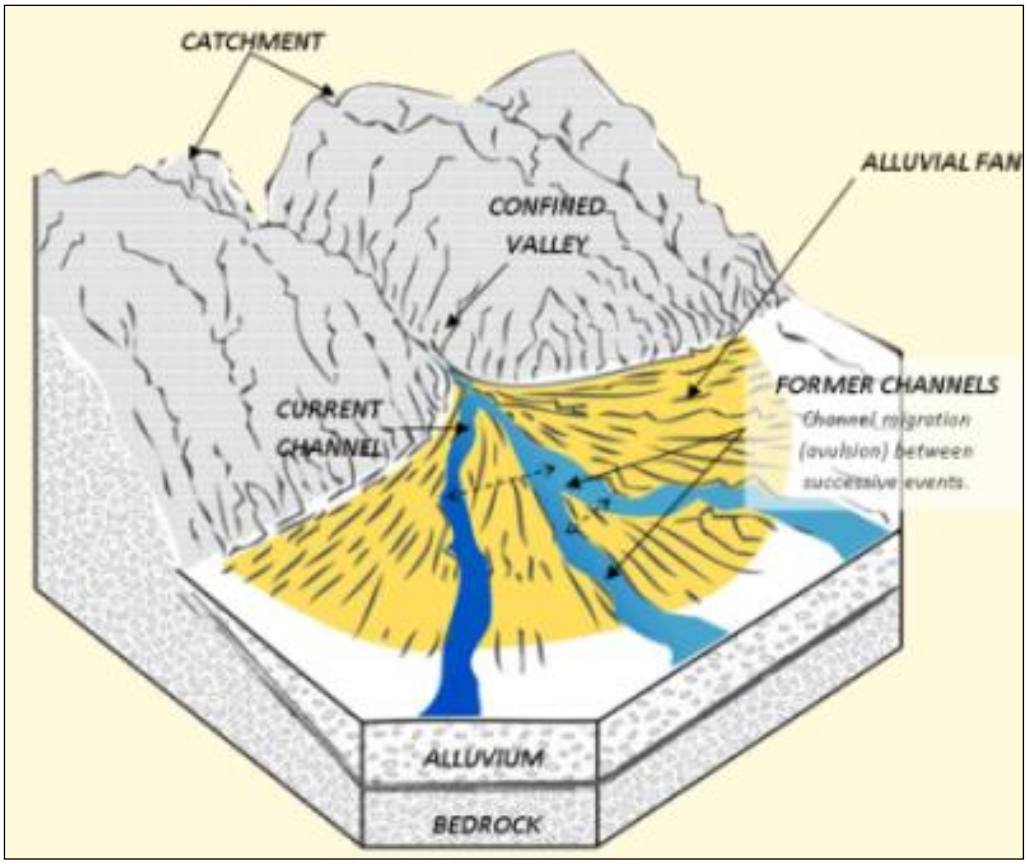


Figure 2. Diagram of a typical alluvial fan (From ORC website).

5.2 Alluvial terraces are very common in areas where glacial processes have sculptured the landscape. During glacial periods huge volumes of sediments are transported by glaciers and then by rivers, creating extensive alluvial outwash plains and fan systems. During interglacial periods when the glaciers retreat, the sediment supply lessens and localised dropping of the water base level results in the rivers cutting down through the sediment and creating terraces. The multiple glaciation events that have occurred in the Queenstown Lakes District have resulted in alluvial terraces being a common feature across the Upper Clutha Basin.

5.3 The mountainous and flat valley floor nature of the Queenstown Lakes District, makes alluvial fans very common - a 2011 report on Otago alluvial fans by the ORC located 2197 alluvial fan landforms occupying 1970km^2 (6% of Otago's land area) in the Otago region (Otago Alluvial Fans: High Hazard Fan Investigation, ORC, June 2011). Alluvial fans around the Upper Clutha and Wakatipu basins are illustrated in Figures 3 and 4 (attached as pages 11 and 12) and tabled in Table 1 (page 13) - the Alpha fan is of medium size compared to other fans in the Queenstown Lakes District. The best examples of well formed and preserved alluvial fans in the district are probably the Stevensons Arm fan (fan 3 in Figure 3, and Figure 5 attached as page 14) and the extensive composite fan systems along the base of Coronet Peak and the Remarkables (fans 13 and 16 in Figure 4).

6. The Geology of Hawthenden Farm (and the Alpha Fan)

6.1 The mountain side behind and the very upper part (approximately seven hectares or 3%) of the Hawthenden farm is comprised of Permian schist and associated landslide debris on the mountain slopes. Most of the farm (approximately 85%) is comprised of a sequence of alluvial sediments behind part of the Wanaka terminal moraine (approximately 12% of the farm) from the 15-18,000 year glacial advance. Most of these alluvial sediments have been deposited within an alluvial fan complex (the Alpha fan), comprised of a gently sloping apron of typically sub-rounded to sub-angular clasts of schist eroded from the mountainside above. The sediment varies from fine silt to cobble sized casts and would have been deposited during flood events - typical of an alluvial fan sequence. The fan sediments are probably interbedded with glacial outwash gravels in the NE part of the farm – this contact is not clear as in this area two terracing events have truncated part of the fan. These terraces are roughly parallel and have a general WNW orientation and are approximately 250 to 550m apart (refer to the attached geological map, Figure 6, page 15). The alluvial outwash gravels occur to the east of the Wanaka terminal moraine and extend across the Upper Clutha Basin.

6.2 The Alpha fan is a fan landform southwest of Wanaka that occurs along the base of the Mount Alpha mountainside. It is a composite fan system and is

made up of numerous smaller fans, the largest being the Stoney and Centre Creek fans - the only creeks large enough to be named. It should be clarified that what has been referred to as the 'Alpha fan' in the Environment Court Decision C73/2002 and by Ms Mellsop (2017) is only the upper part (approximately one third) of the fan system. The fan extends well beyond the Hawthenden farm – for approximately 3km along the front of Mt Alpha and for 2km down to the shores of Lake Wanaka through the Far Horizon, Sargood Drive, Roys Bay and Meadowstone subdivisions (refer to the cross-hatched unit on the geology map, Figure 6).

6.3 The Alpha fan probably began forming after the Albert Town or Luggate glacial advances – depending on the level of ice during these glaciations (ice that extends further down the valley will have eroded any valley marginal sediment). The terracing event that created the two terraces that cut across the fan are likely to be associated with a river that was active around the time of the 15-18,000 year glacial advance that terminated at Wanaka.

6.4 As the ice has receded or the level of the subsequent lake fell, the water table has dropped result in the river cutting down through the alluvial sediment to form terraces. The terraces are roughly parallel suggesting that they formed at a similar time and from the same river system. The terracing event eroded part of the fan, but fan construction never 'stopped' - the fan has been continuously active (during flood events) since the glacier receded from this corner of the Upper Clutha Basin. Centre and Stoney Creeks have eroded two sections (180 and 300m wide) of the upper terrace before the build up of new alluvial fan material began to fill in the eroded sections. Similarly, smaller, (unnamed) creeks have incised small erosion gullies and deposited small fans elsewhere along the terrace face. This process has effectively superimposing new fan structures over the older ones, all of which have originated from the same creeks (see attached photographs, Figures 7 and 8, pages 16 and 17).

6.5 The Alpha fan remains active with flood events occurring on Stoney Creek in November 1999 and January 2004 (refer to section 5, Otago Alluvial Fans: High Hazard Fan Investigation report, ORC, 2011). The majority of stream

water coming off Mt Alpha flows underground through the alluvial fans, resulting in dry creek beds for most or part (Stoney Creek) of the year.

6.6 Other alluvial fans and terraces in the Upper Clutha and Wakatipu basins are likely to be related to the same glacier advance and retreat sequence and therefore be of similar age and have a similar history.

6.7 The Environment Court Decision C73/2002 contains some vague descriptions of the geology and geomorphology of the Alpha fan that should be clarified. These include a description by Ms Lucas [49]:

> "*The ...Alpha fan is a strongly rolling surface below the steep mountain slope. I understand the landform unit derives from moraine smeared on this mountain slope by an earlier glaciation (some 30,000 years ago). The younger fans running off the mountain slopes above are now overwhelming it. No longer a rippled surface, the moraine has been buried and smoothed. The toe has been truncated by the later glaciation."*

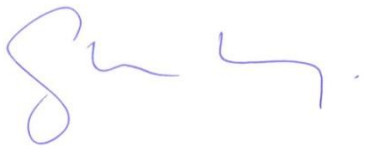
And:

> *"The stark line across the mountain slope above the landform unit is merely a management boundary – a bracken line ... that comes and goes. I assess the Mt Alpha fan to be part of the mountain range landscape."*

6.8 Detailed geological mapping of the Alpha fan has not located any exposed lateral moraine smeared on the mountain slope. The fan is entirely composed of alluvial sediments and is geologically part of the Quaternary Upper Clutha Basin valley fill - not the mountain side which is comprised of Permian schist (or associated landslide debris).

6.9 I disagree with Ms Lucas description of 'the stark line across mountain slope above the landform' as just 'a management boundary – a bracken line'. It is the location of the alluvial fan-schist contact. This geomorphological contact displays a distinct contrast in surface texture from the smoother depositional surface of the alluvial deposits to the rougher, eroded face of the schist

mountainside above (refer to Figures, 7, 8 and 9, attached as pages 16, 17 and 18). Although it should be noted that farming activities naturally stop at the break in the slope that also occurs at this contact, so the 'stark' contrast described is also probably partly agricultural.



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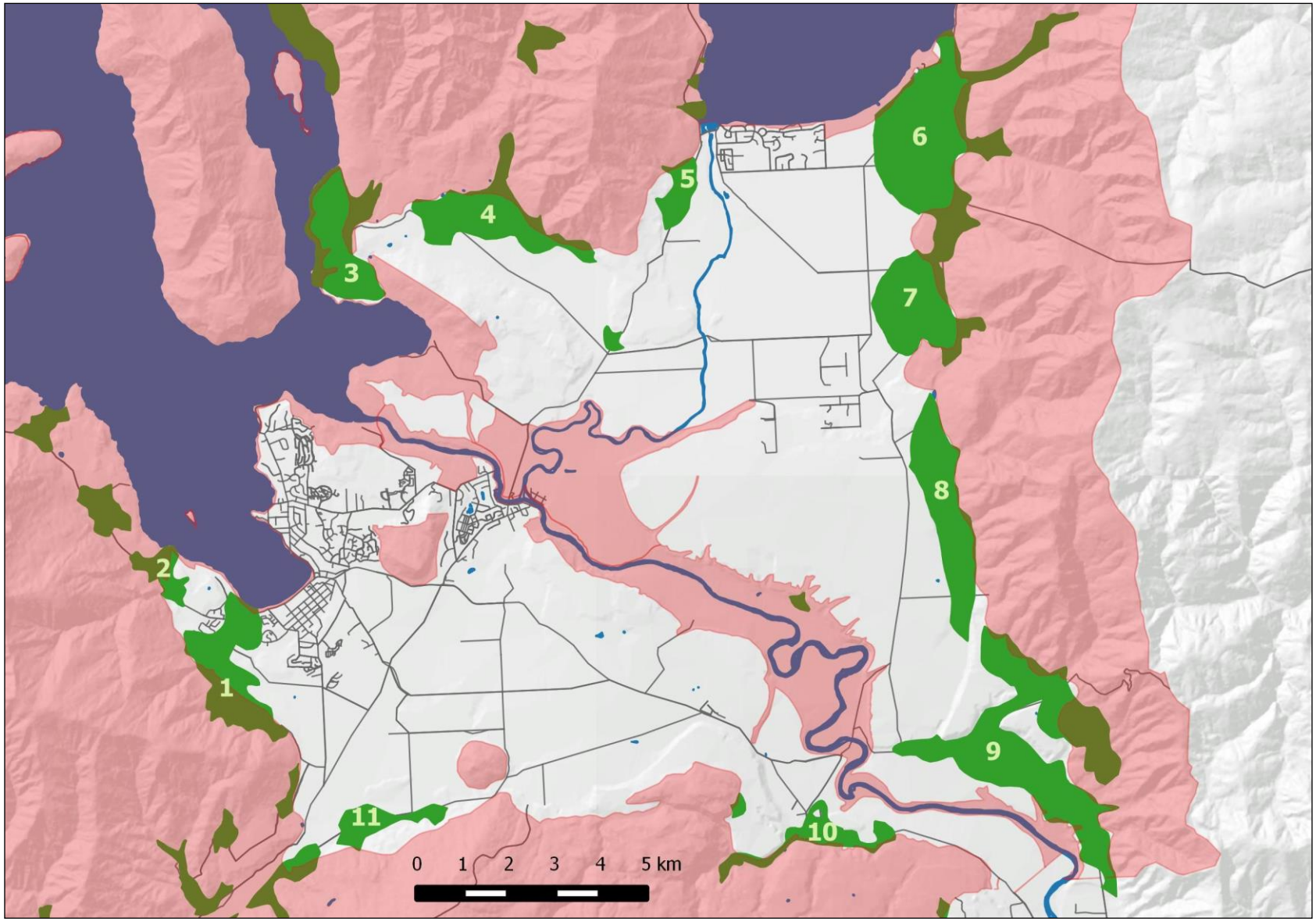

Figure 3. Alluvial fans around the Upper Clutha basin. Alluvial fans are green - the data is from the QLDC GIS database (regional scale data). Numbering refers to the list in Table 1, the Alpha fan is number 1. ONL and ONF areas are pink.

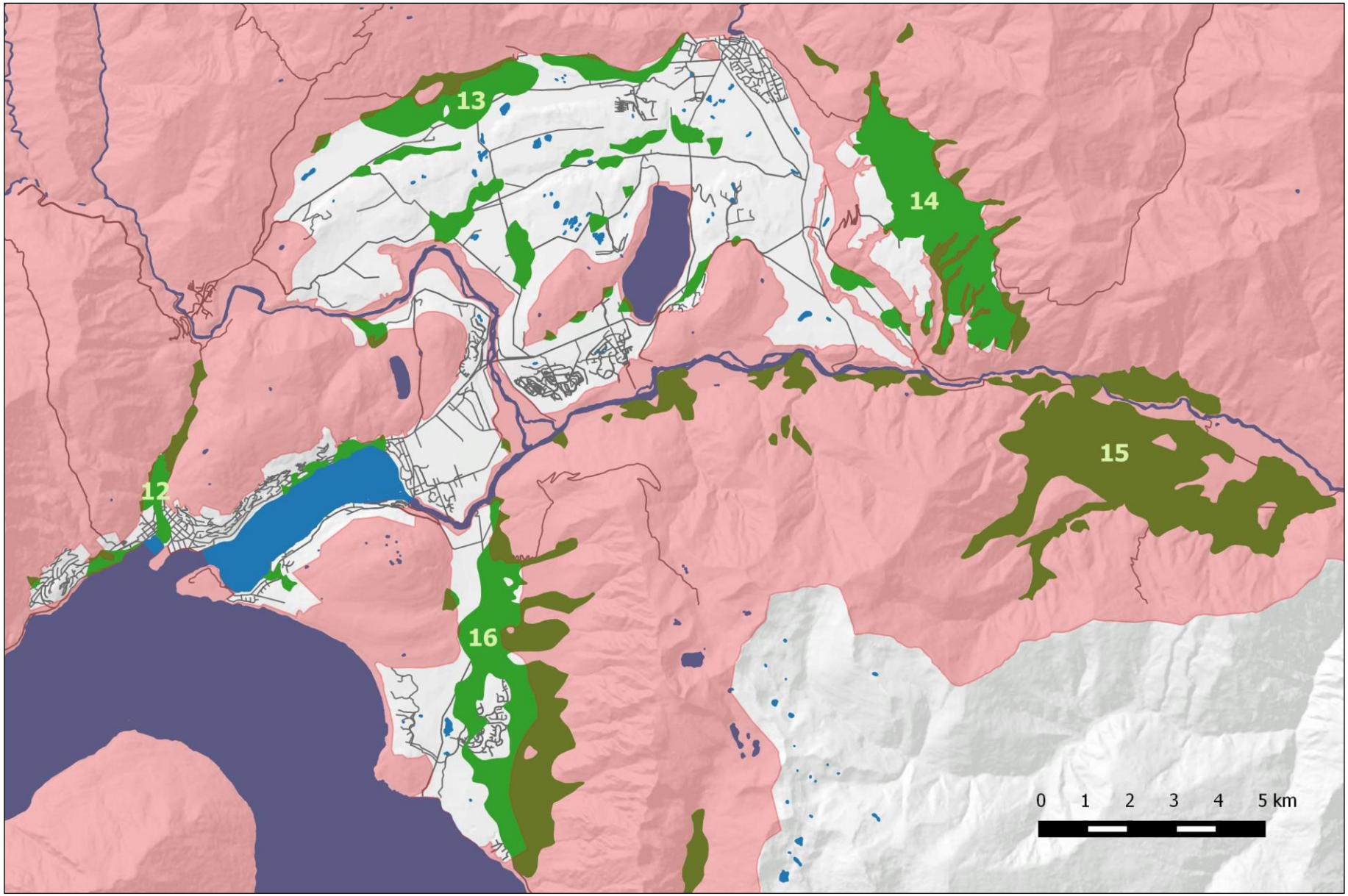

Figure 4. Alluvial fans around the Wakatipu basin. Alluvial fans are green - the data is from the QLDC GIS database (regional scale data). Numbering refers to the list in Table 1. ONL and ONF areas are pink.

Alluvial fan number (maps)	Location	Approximate area (km^2)
1	Alpha fan (Upper Clutha)	3.3
2	Waterfall Creek (Upper Clutha)	0.7
3	Stevensons Arm (Upper Clutha)	2.9
4	Maungawera Valley (Upper Clutha)	3.0
5	Hawea Mt Maude (Upper Clutha)	1.3
6	Hawea Gladstone (Upper Clutha)	7.2
7	Hawea Flat (Upper Clutha)	4.7
8	Kane Rd (Upper Clutha)	3.7
9	Luggate-Tarras Rd (Upper Clutha)	11.1
10	Luggate (Upper Clutha)	1.6
11	Mt Barker (Upper Clutha)	1.0
12	Queenstown CBD (Wakatipu)	1.8
13	Coronet Peak (Wakatipu)	4.9
14	Crown Terrace (Wakatipu)	8.8
15	Gibbston Valley (Wakatipu)	14.7
16	Remarkables (Wakatipu)	15.0

Table 1. Significant alluvial fan systems around the Upper Clutha and Wakatipu basins. Refer to Figures 3 and 4 for locations.

Figure 5. The Stevensons Arm alluvial fan, view looking south (Google Earth image). The fan measures approximately 3km N-S by 1km E-W. The pivot irrigator circle is on the southern part of the composite fan.

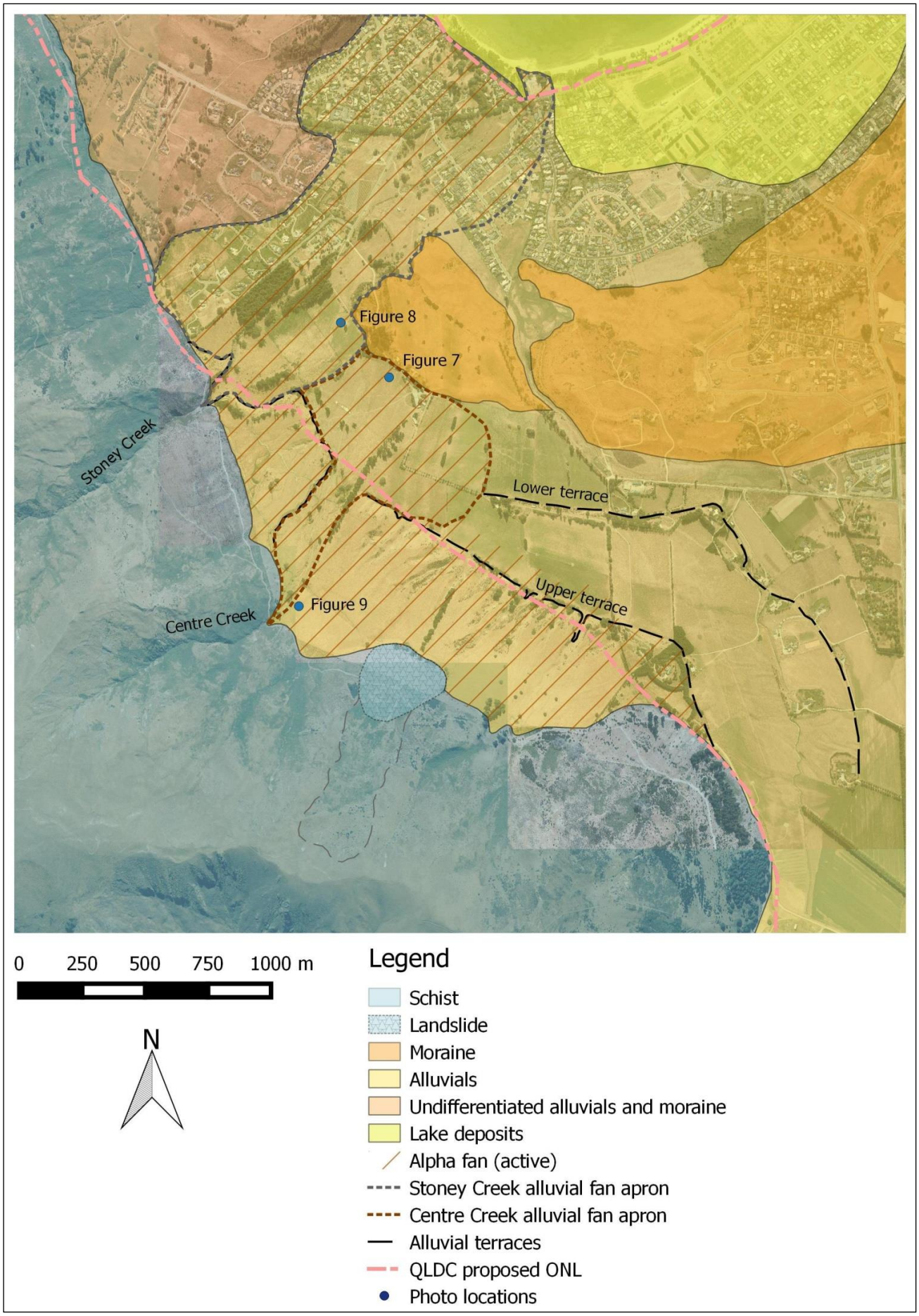

Figure 6. Geology map of the Hawthenden farm area.

Figure 7. View looking up the Alpha fan from the middle of the Hawthenden farm. The active fan from Centre Creek is the broad apron (limits are the brown dashed lines) in the foreground and has partly eroded and covers the upper terrace - seen on the right and far left of the photo. The contact between the schist and alluvials has been marked by the dashed black line. For photo location refer to the geology map, Figure 6.

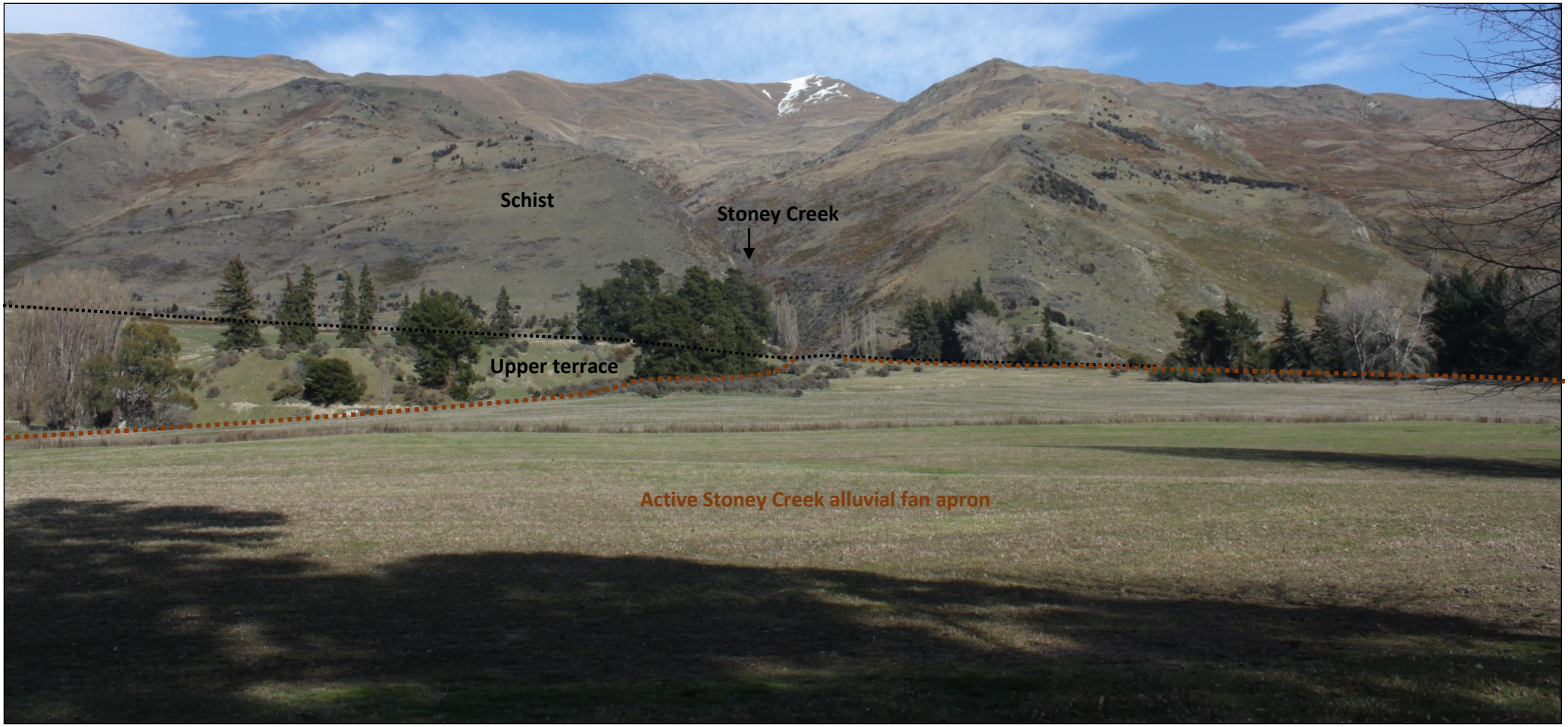

Figure 8. View looking up the Alpha/Stoney Creek fan on the west side of the Hawthenden farm. Where Stoney Creek exits the steep gorge onto the flatter valley floor it transitions from erosional to depositional creating the alluvial fan apron (limits are the brown dashed lines). The upper terrace has been partly eroded and then covered by the active Stoney Creek fan. The contact between the schist and alluvials is delineated by the black dashed line. For photo location refer to the geology map, Figure 6.

Figure 9. The 'Turnip Paddock' at the top of the Hawthenden farm looking east. This is the highest and steepest part of the Alpha fan. The contact between the schist and the fan alluvials is the black dashed line. The area of landslide debris has also been indicated (separated from the schist by the brown dashed line). For photo location refer to the geology map, Figure 6.