Appendix B Active Faulting Assessment (URS 2009)

DRAFT REPORT

Porters Ski Area Active Faulting Assessment

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Prepared for

Blackfish Joint Venture

PO Box 17-622
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Executive Summary

URS was commissioned by Blackfish Joint Venture (Blackfish) to undertake a geotechnical assessment of active faulting within the Porters Ski Area, Canterbury. Previous investigations by URS (2007) had identified that a series of active faults are reported to be located within the Porter River valley, including in close proximity to the two existing lodges (i.e. the proposed development area).

The project brief for the assessment was to determine the location and nature of faults within the Porters Ski Area and to identify constraints placed by active faulting on development of the village base area. The assessment has comprised a review of existing information, aerial photograph interpretation and field mapping.

Based on our review of existing information, any mapped faults within or near the proposed village base area are typically assessed as having not shown movement in the last 120,000 years. The only interpretation which shows possible fault movement during this time in the village base area is based primarily on projected rangefront tectonics and not on direct field evidence.

Geomorphic surfaces in the vicinity of the village base area are considered to represent deposits of Late Pleistocene age (>14,000 years old). No geomorphic evidence was identified for tectonic deformation of these surfaces during field mapping, suggesting that if any active faults are present, then the time since their last surface rupture exceeds 14,000 years. On this basis, we consider if any active faults are present within the vicinity of the proposed village base area, they are of judged low activity.

Development anticipated as part of the village base would comprise accommodation, support and staging facilities classified as of a low building importance. Due to the judged low activity of any active faults (if present) within the proposed development area, building over these faults will likely comprise a permitted resource consent activity by regional authorities.

Using the methodology proposed by Pettinga et al. in 1998, if any active faults were to be present within the proposed village base area they would be assigned to Activity Class III (i.e. are considered probably active but do not clearly affect geomorphic surfaces less than 25,000 years old).

The risk posed by surface faulting to development of the village base area (defined as accommodation, support and staging facilities) is judged acceptably low. No fault specific constraint to development has been identified.

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- Location of likely surface ground rupture (which defines the Fault Avoidance Zone).
- How often surface ground rupture is likely (defined as the Fault Recurrence Interval Class) and
- Importance of buildings to be constructed in the area (Building Importance Category).

1.3.1 Fault Avoidance Zones

Fault avoidance zones are derived from mapping geomorphic landforms associated with active faulting. Geomorphic landforms associated with active faulting can be defined by aerial photograph analysis and field mapping. These landforms represent the likely future zone of surface fault rupture. Once the zone of likely fault rupture has been identified, a 20m buffer zone is added on either side of the fault trace to ensure a level of life safety. The mapped zone of likely fault rupture, together with the included 20m buffer zone, is known as the Fault Avoidance Zone (FAZ).

1.3.2 Recurrence Interval Class

The Recurrence Interval Class (RIC) is the average time between surface rupture of the fault. Those faults with smaller recurrence intervals are generally judged more likely to rupture in the near future than those with a longer recurrence interval (see Table 1-1). Fault recurrence intervals are derived from site specific studies on faults, such as trenching and dating of recovered materials.

1.3.3 Building Importance Category

The building importance category (BIC) classifies the relative importance of a structure based upon building type, occupancy and use (Classes 1 to 4). Those with a low BIC are considered the least important. Residential and commercial structures are classified as typically BIC 2. Structures within BIC 3 or 4 are those of high occupancy, essential facilities or structures with important post-disaster functions.

Development as part of the proposed village base area will comprise accommodation, support and staging facilities. These structures would be categorised as BIC 2b (houses outside the scope of NZS 3604 'Timber Framed Buildings' and multi-occupancy residential, commercial, industrial, office and retailing buildings designed to accommodate less than 5000 people and also less than 10,000m^2 gross area). There is the potential that future development may comprise BIC 3 structures (e.g. emergency medical facilities and buildings where more than 300 people can congregate in one area). Development within the village base area would be considered an undeveloped site (i.e. a 'Greenfield Site') for resource consent planning.

Assessment of the BIC of a structure is used to determine whether construction within fault avoidance zones can be undertaken and is a permitted activity (see Table 1-1).

1.3.4 Summary

In order for surface faulting to place a constraint on development of the village base area, active faults of RIC I to IV (i.e. recurrence interval of less than 10,000 years) would need to be present beneath the proposed development area.

Should any such fault be found to have a lower fault recurrence interval (i.e. RIC V or VI), or if no active faults are present within the proposed development area, there would be no faulting specific constraint to development of the proposed village base area.

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Table 1-1 Relationship between BIC and RIC

Recurrence Interval Class (RIC)	Fault Recurrence Interval	Building Importance Category (Allowable Buildings)	
		Developed or Previously Subdivided	Greenfield Site
I	≤2000 years	1	1
II	>2000 years to ≤3500 years	1 and 2a	
III	>3500 years to ≤5000 years	1, 2a and 2b	1 and 2a
IV	>5000 years to ≤10,000 years	1, 2a, 2b, and 3	1, 2a and 2b
V	>10,000 years to ≤20,000		1, 2a, 2b and 3
VI	>20,000 years to ≤125,000 years	1, 2a, 2b, 3 and 4	

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Site Description and Setting

Section 2

2.1 Site Description

Porters Ski Area is located over the southern end of the Craigieburn Range, approximately 90km west of Christchurch (see Figure 2-1). The Craigieburn Range trends approximately northeast-southwest and forms the eastern margin of the Central Southern Alps. It comprises steep slopes (typically 30° to 45°) which rise approximately 1000m above the Castle Hill Basin to the east and the Harper River valley to the west. Upper slope areas (above approximately 1300m) are typically devoid of vegetation and covered with scree, while lower slopes are vegetated by tussock and scrub.

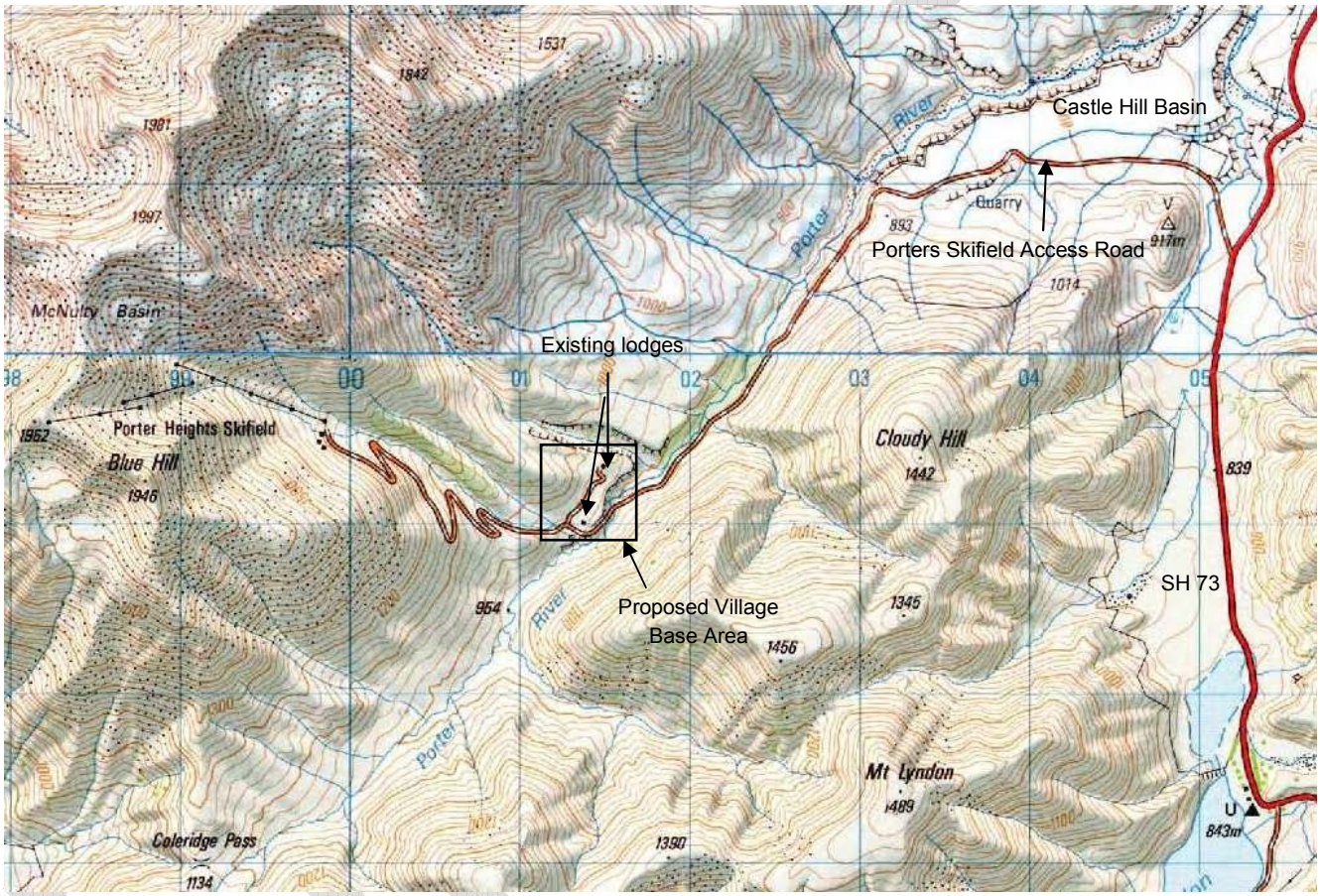

Figure 2-1 Location and layout of Porters Ski Area

The ski area is located on the eastern side of the range and access to it is provided by a gravel road which extends from SH73 up the true-right bank of the Porter River. Existing infrastructure at the skifield includes the base area and reservoir located at approximately 1300m and 3 T-Bars which extend from the base area to a ridge crest located at approximately 1900m. Two lodges have also been constructed on the northern side of the Porter River.

The Porter River drains the southern part of the Craigieburn Range and the northwestern side of the chain of mountains which extend from Cloudy Hill to Red Hill, including the Coleridge Pass Area. At its widest point, the modern river valley is approximately 200m wide and incised to depths of approximately 50m (see Figure 2-2). The modern river channel is approximately 5m wide. The river valley is infilled by a combination of alluvial and glacial/fluvioglacial deposits, with rare fan deposits.

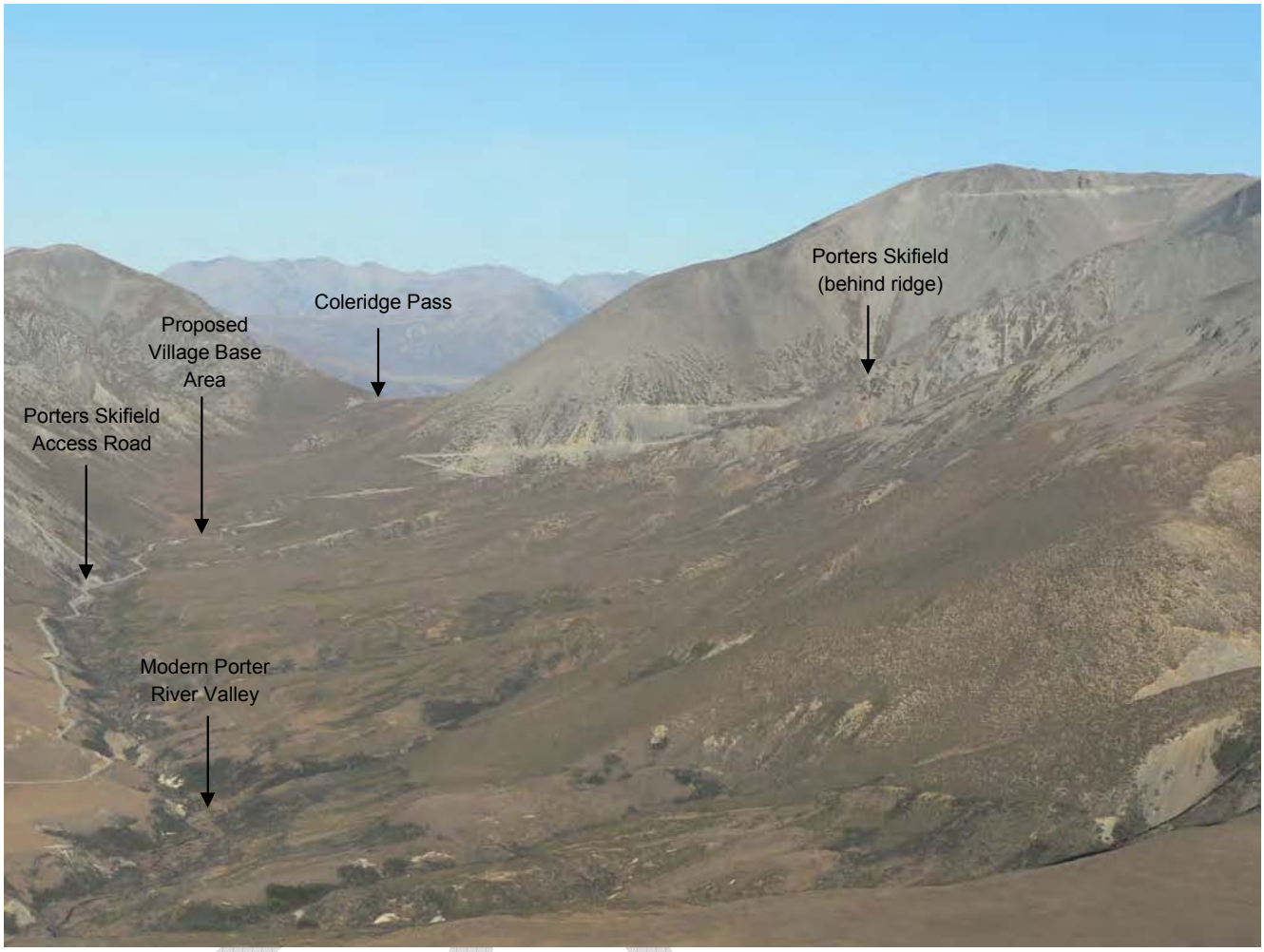

Figure 2-2 View of the Porter River valley

2.2 Published Geology

The geology of the Porter River valley is illustrated by the GNS QMAP #15 (Cox et al., 2007). This shows the valley sides are underlain by sandstone and siltstone of the Rakaia Terrane (primarily Triassic age). These rocks are described as non-schistose to schistose quartzofeldspathic sandstone (greywacke) and mudstone (argillite), which is commonly indurated (i.e. hard) but highly jointed and locally sheared. Bedding is indicated to dip towards the north at approximately 60°.

The valley floor (and the Castle Hill Basin to the north) is underlain by Tertiary aged sedimentary deposits. These comprise typically sandstones, limestones and mudstones with rare coal, conglomerate and mudstone. Bedding varies due to folding, but typically dips towards the west at approximately 15°. Tertiary aged sediments are known to unconformably overlie Rakaia Terrane rocks.

The Porter River valley has been infilled by a variety of superficial deposits. These include glacial soils, described as grey and brown till (gravel, sand, silt and clay) and are considered to represent deposits associated with both the Waimea and Otira Glacial advances (Pleistocene age). They form characteristic moraine ridges in places but are typically marked by hummocky topography. Alluvial deposits, comprising river gravel, sand and silt are present within the modern Porter River valley and form elevated terraces in parts.

Active sloping fan deposits have also been mapped on the northern side of the Porter River and are described as grey or brown angular gravel, sand and silt.

2.3 Tectonic Setting

The study area is located close to the juxtaposition of the Pacific and Australian plates (situated approximately 50km to the northwest). The oblique convergence of these two plates results in transpressional faulting (primarily strike-slip with a reverse component) within the Pacific plate to accommodate this movement. This results in a series of active faults being present within the Central Southern Alps, broadly aligned sub-parallel to the plate boundary (northeast to southwest).

Castle Hill (including part of the Porter River valley) represents a tectonically depressed basin of folded younger sediments (Tertiary age). Older Rakaia Terrane rocks ('greywacke') which form the margins of the basin (marked T on Figure 2-4) are judged to be being thrust over younger sediments (marked B, I, P and E on Figure 2-4) to accommodate crustal shortening. This overthrusting is represented by the Cheeseman and Craigieburn Faults on the western margin of the basin and the Torlesse Fault on its southeastern side. The structure of the Porter River valley and Castle Hill Basin is shown in Figure 2-3.

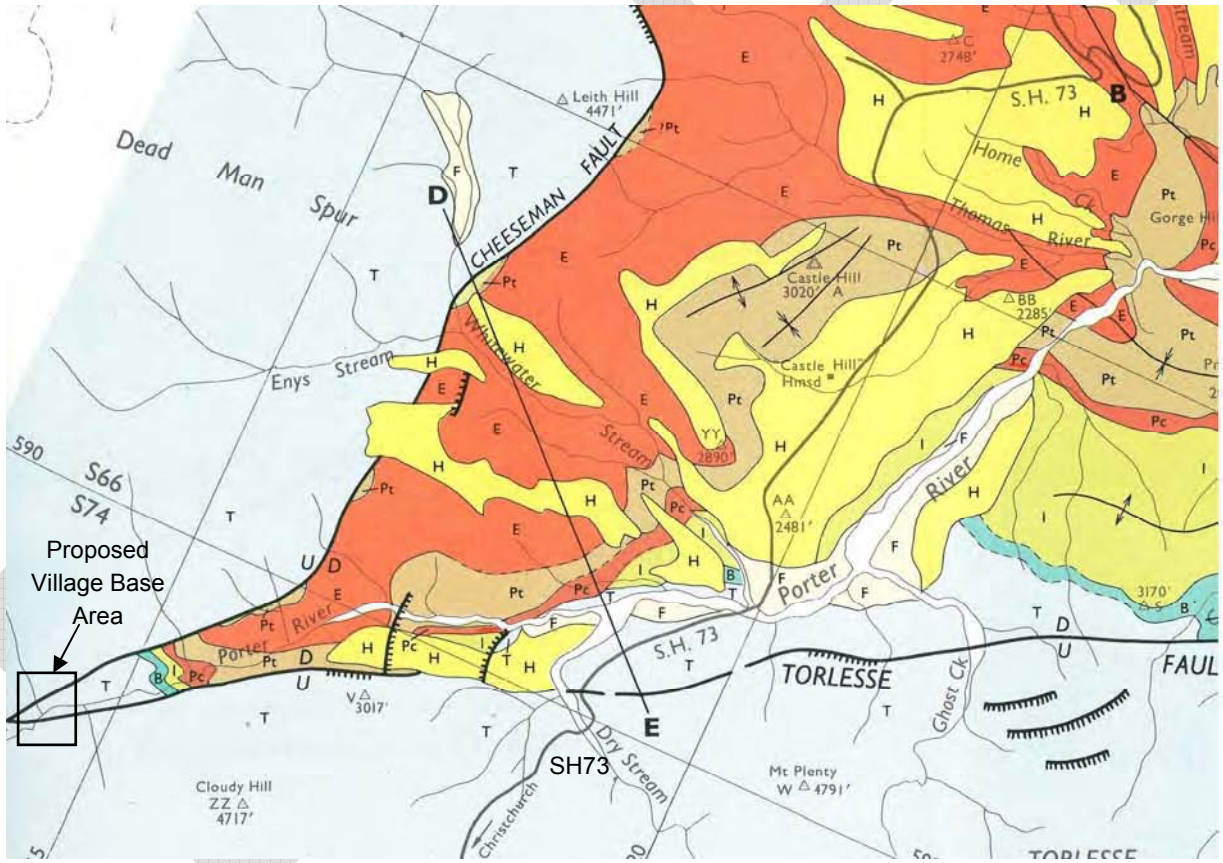

Figure 2-3 Structure of the Porter River valley and Castle Hill Basin (from Gage 1970)

Active Faulting associated with the tectonic setting of the Porter River valley and Castle Hill Basin is discussed in more detail in Sections 3 and 4.

2.4 Seismic Hazard

Due to the tectonic setting of the subject area close to the boundary of the Pacific and Australian plates, the site is characterised by a high seismic hazard. Numerous active fault sources capable of producing large magnitude earthquakes are present within the Central Southern Alps. These include the Torlesse, Porters Pass, Cheeseman and Alpine Faults. The Craigieburn Ranges will also have been subjected to strong ground shaking from earthquakes whose epicentres lie outside the immediate area. Typical peak ground accelerations of 0.4 g for 150 year and 0.5g for 475 year return period events respectively have been calculated for the area (Stirling et al., 2007).

In addition to damage caused by strong ground shaking, earthquakes of these magnitudes also have the potential to generate large scale landsliding or rock avalanches. This has occurred during many historical earthquakes within New Zealand, with earthquakes greater than magnitude M5.0 considered capable of generating landslides (Hancox et al., 2001).

The area is characterised by high historical seismicity, typically of shallow depth (<40km). Significant earthquakes located within the Central Southern Alps since 1840 include the M7.1 1929 Arthur's Pass earthquake and the M6.7 1994 Avoca River earthquake.

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Desktop Study of Active Faulting Information

Section 3

As part of this assessment, we have undertaken a desktop study of published information on active faulting within the Porter River valley. As part of the desktop study the following literature has been reviewed:

- Gage 1970 – Late Cretaceous and Tertiary Rocks of Broken River, Canterbury. New Zealand Journal of Geology and Geophysics, Vol. 13, No.2, June 1970.
- Chamberlain 1996 – Seismic Hazard from Cross-Faulting in North Canterbury: Broader Implications from the Arthur's Pass Earthquake Sequence of 18 June 1994. Thesis submitted for Master of Science in Engineering Geology at the University of Canterbury.
- Pettinga et al. 1998 - Earthquake Hazard and Risk Assessment Study: Earthquake Source Identification and Characterisation. Report prepared for Canterbury Regional Council, Publication Number U98/10.
- Cox et al. 2007 – Geology of the Aoraki Area. Institute of Geological & Nuclear Sciences 1:250,000 Geological Map.
- University of Canterbury 2008 – Geological Map of the Castle Hill Basin Area.

3.1 Gage 1970

In 1970, Gage published a paper focusing on the nature of the Late Cretaceous and Tertiary rocks of the Castle Hill Basin (and Porter River valley). He also briefly discussed the structure of the area, the main findings of which can be summarised as follows:

- The Torlesse Fault marks the southern extent of the Castle Hill Basin, with the southern side of the fault upthrown. The fault zone is marked by intense deformation and is exposed in Coleridge Creek within the Porter River valley. A 'recent' fault trace is marked upslope of the existing quarry, with the remainder of the fault shown to indicate no recent movement. Gage suggests 'scarplets indicate re-activation of the fault since the peak of the Otira Glaciation and possibly after the Blackwater Glacial Advance (18,000 years ago)'.
- The Cheeseman Fault is known from few exposures but is considered a single, sinuous fault which dips moderately steeply down towards the west. The western side (i.e. upslope) is considered to have been upthrown, identified from an exposure in the upper part of Broken River. Southwards the fault appears to merge with the Torlesse Fault and may cause the Torlesse Fault to be overridden by the southern end of the Craigieburn Range. No 'recent'[2] fault traces are mapped on the Cheeseman Fault in the Porter River valley.
- Two 'recent' fault traces are present on a glacial/fluvioglacial terrace on the true right of the Porter River valley near to SH73 (see Figure 3-1).
- No 'recent' fault traces were mapped by Gage beneath or near the proposed village base area.

[2] In a geological context, 'recent' typically refers to the last 10,000 years (i.e. Holocene age).

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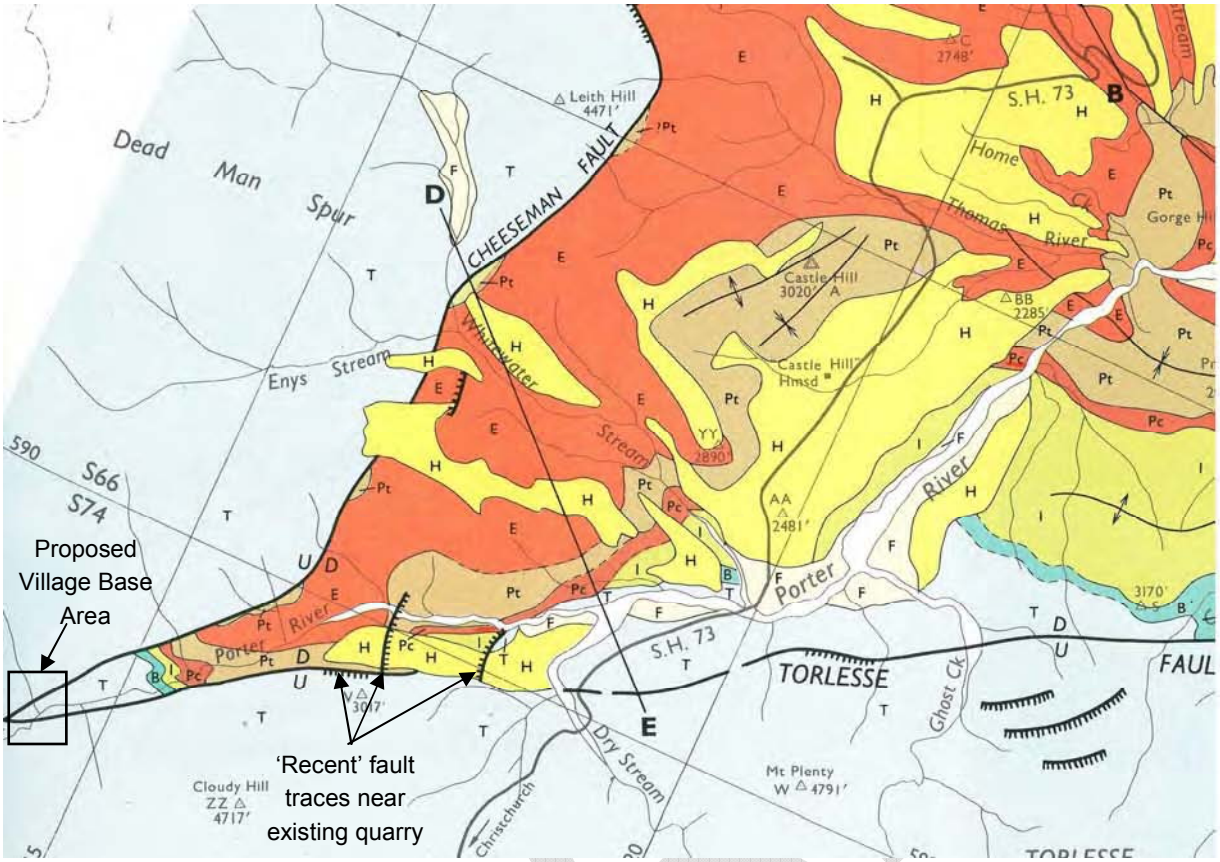

Figure 3-1 Geology of the Castle Hill Basin Area from Gage 1970 - Faulting

3.2 Chamberlain 1996

The study site was included as part of a thesis submitted by Chamberlain to the University of Canterbury in 1996. The thesis included a desktop study of the Porter River valley only, with no field mapping undertaken. The main findings of the thesis relevant to this study can be summarised as follows:

- The Torlesse Fault is mapped as extending up the true-right of the Porter River valley from the location of the quarry to the existing lodges (upslope and approximately parallel to the access run). The fault is typically marked as a single well-defined trace, but is judged to display a series of splays at its western end. The fault is mapped showing the southern side of the fault has been upthrown, with crush zones present along the trace of the fault.
- The Cheeseman Fault is mapped as extending up the true-left of the Porter River valley to Coleridge Pass. The fault is mapped as a single trace, running approximately parallel to the Porter River. Chamberlain inferred that the fault shows a reverse sense, with the western (upslope) side judged as upthrown. The fault zone is marked by crushed and sheared material, extending approximately beneath northernmost lodge.

3.3 Pettinga et al. 1998

In 1998 Pettinga et al. undertook a study for Environment Canterbury to determine and characterise earthquake sources for the Canterbury District. The information and mapping undertaken as part of that investigation forms

the basis of Environment Canterbury's Active Fault Database (Ecan AFD). The active faults contained within the Ecan AFD for the Porter River valley are shown on Figure 3-2.

Building upon work by Gage, the Torlesse and Cheeseman Faults were incorporated within the Porters Pass-Amberley Fault Zone (Domain 3), characterised as containing hybrid strike-slip and thrust faulting. The main findings of their investigation specific to this study can be summarised as follows:

- No detailed mapping of the Torlesse Fault was undertaken. At its southern end it is thought to join the projected continuation of the Cheeseman Fault. There is 'strong circumstantial evidence to suggest, based on rangefront geomorphic considerations, that the Torlesse Fault is seismogenically active and has ruptured repeatedly during the Late Quaternary. It was assigned Activity Class I Status, suggesting it has been active in the last 10,000 years'.
- Mapping by Young (1997) noted evidence for repeated fault rupture along various strands of the Cheeseman Fault Zone. Fault displacement has affected late last glacial deposits and associated scree slopes. While repeated fault movement can be demonstrated for the late last glaciation (i.e. >14,000 years ago), evidence for Holocene fault rupture remains equivocal. It was assigned Activity Class II Status, suggesting it has been active in the last 25,000 years.
- All mapped active faults within the Porter River valley (considered continuations of the Torlesse and Cheeseman Faults) were assigned to Activity Class 3, defined as 'faults and folds probably active but do not clearly affect geomorphic surfaces less than 25,000 years old'.

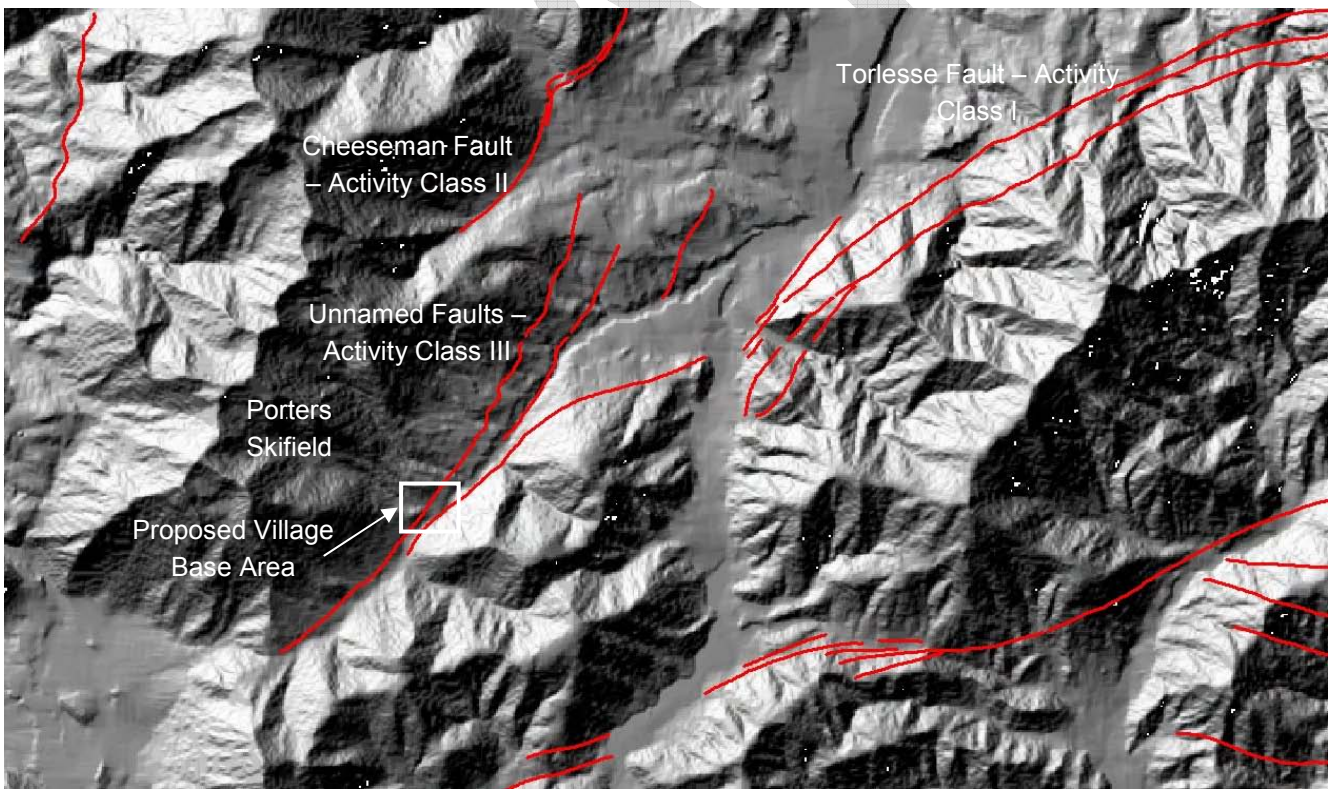

Figure 3-2 Active Faults in the Porter River valley taken from Environment Canterbury's Active Fault Database

3.4 Cox et al. 2007

In 2007 Cox et al. completed the compilation of the 1:250,000 geological map of the Aoraki Area, part of the GNS Science (GNS) QMap series. The map and memoir has been compiled from pre-existing information supported with additional mapping as required. Active faults depicted on the map form the basis of the GNS Active Fault Database. Active faults mapped within the Porter River valley contained within the database are shown on Figure 3-3.

The Torlesse Fault is mapped as inactive (i.e. has not shown movement in the last 120,000 years) on the western side of SH73, with the faults location considered to be approximate or concealed. The southern side of the fault is identified as being upthrown. The Cheeseman Fault is not depicted as extending south to Coleridge Pass; its termination is shown on the true left bank of the river approximately opposite the existing quarry. Two short active faults (i.e. have shown movement in the last 120,000 years) are mapped within the lower river valley. No faults showing movement in the last 120,000 years are mapped as passing beneath or near the proposed village base area.

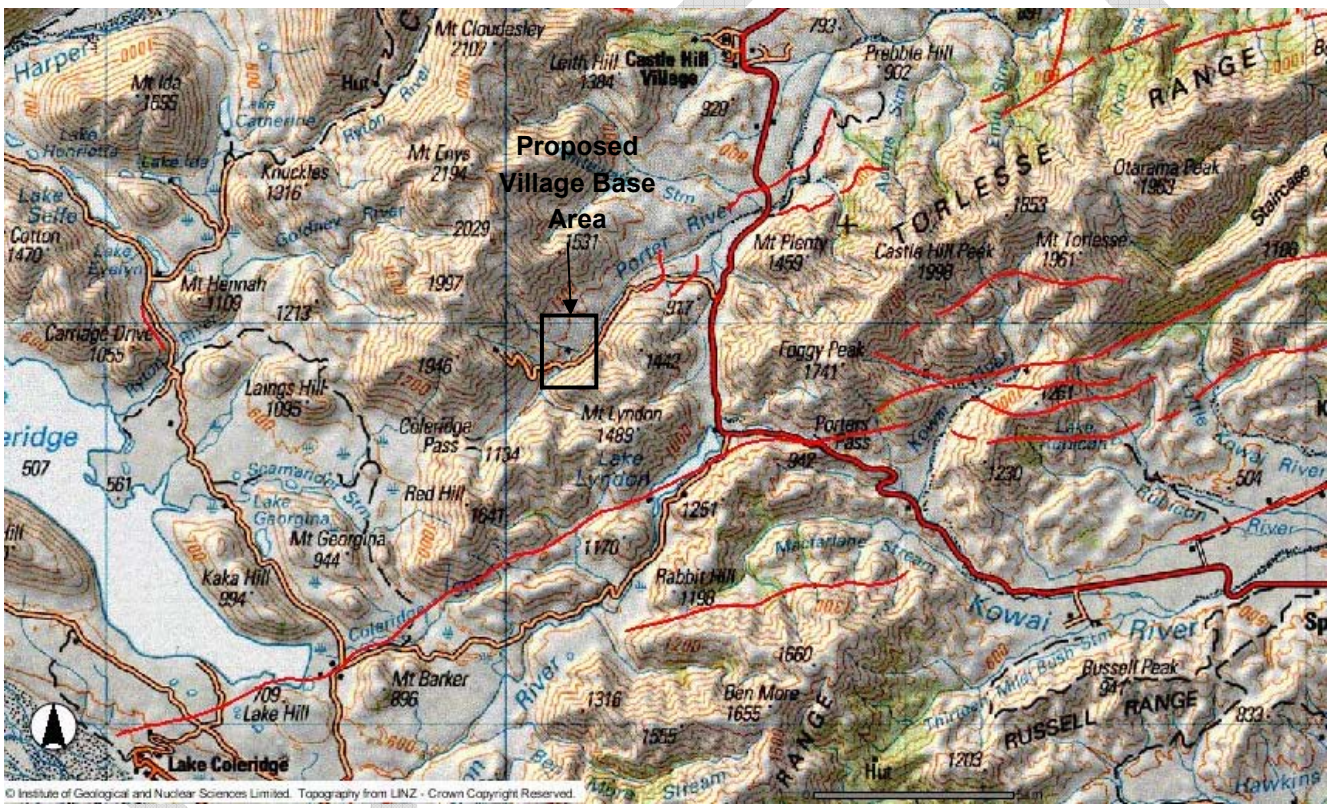

Figure 3-3 Active faults within the Porter River valley from the GNS Active Fault Database

3.5 University of Canterbury 2008 – Geology of the Castle Hill Basin Area

We have also reviewed a geological map (1:25,000) of the Porter River valley from the University of Canterbury. The map has been compiled from a variety of sources, including from Chamberlain (1996), Young (1997), Bradshaw (1975) and Gage (1970). Additional fieldwork was also completed by Richard Jongens. The geological map (see Figure 3-4) provides the following details about active faulting within the Porter River valley:

- The Torlesse Fault is shown to extend from the Torlesse Range, across SH73 and up the true-right of the Porter River valley and merge with the Cheeseman Fault southwest of the existing lodges. The location of the fault is marked as approximate over its eastern half and accurate over its western half. The upslope side of the fault is identified as being upthrown. Splays of the fault have been mapped southwest of the quarry and southwest of the existing lodges where the fault merges with the Cheeseman Fault. The fault is marked near the proposed village base area as not showing activity in the last approximately 120,000 years.
- The Cheeseman Fault is mapped as extending up the true-left of the Porter River valley towards Coleridge Pass. The location of the fault is mapped as a combination of approximate (near the existing lodges) and accurate, with the western side of the fault (upslope) upthrown. The fault is marked near the proposed village base area as not showing activity in the last approximately 120,000 years.
- Two discontinuous active fault traces are mapped on terrace deposits north and east of the quarry (i.e. have moved in the last approximately 120,000 years). The western fault trends approximately north-south for 500m across the terrace and indicates dip-slip movement with the western side of the fault upthrown. The eastern fault also extends for approximately 500m across the terrace, but is marked as an oblique-slip fault (sinistral movement with the eastern side of the fault upthrown).

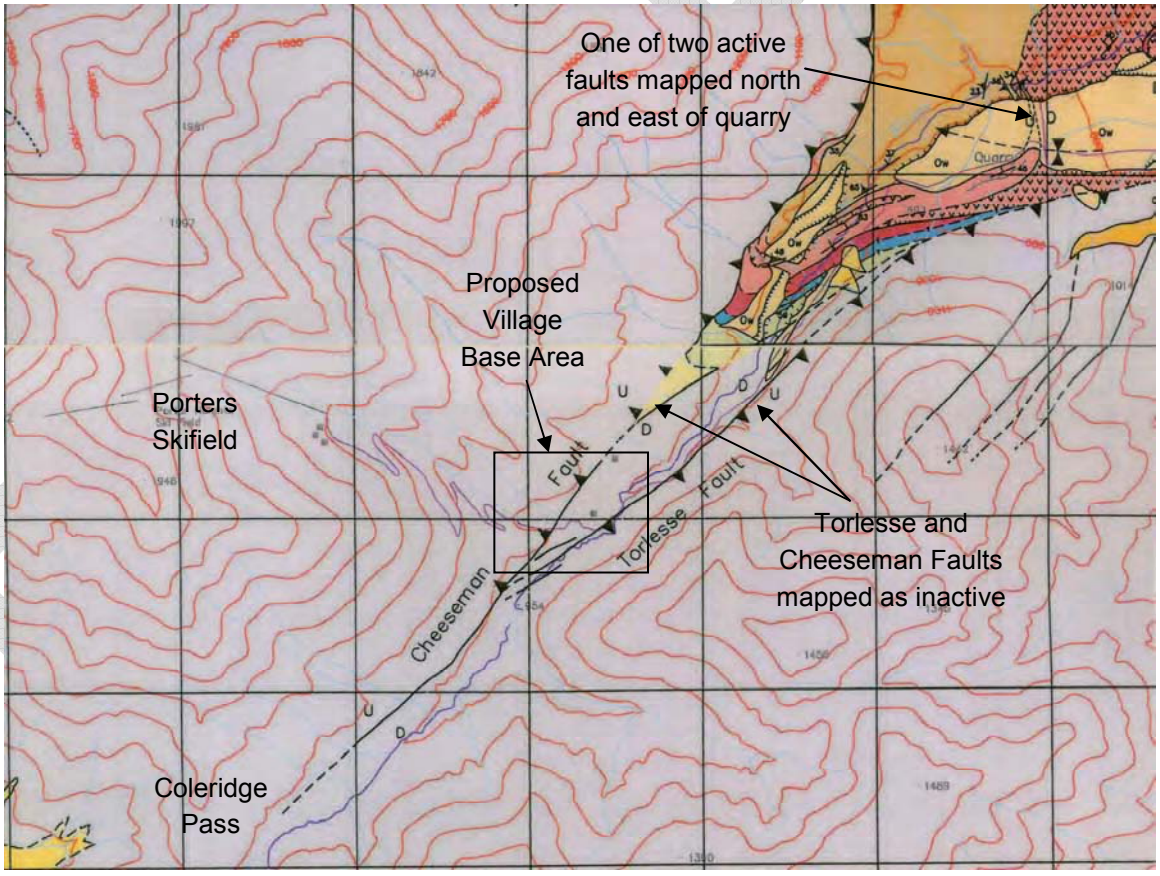

Figure 3-4 Geology of the Porter River valley from the University of Canterbury Geological Map of the Castle Hill Basin Area – 2008

3.6 Summary

From our review of published and unpublished literature pertaining to active faulting within the Porter River valley, limited evidence has been identified for active faulting within the village base area (i.e. the Upper river valley). The Torlesse and Cheeseman Faults are described as not having moved in the last 120,000 years. The ECan AFD is the only information source which shows considered active faulting within the village base area, categorised primarily on the basis of projected rangefront tectonics and not on direct field evidence/observations.

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Active Faulting Investigations Section 4

This section of the report presents the findings of URS investigations to assess evidence for active faulting within the Porter River valley. Two main tasks have been undertaken as part of the investigation:

- Aerial Photograph Analysis – stereoscopic review of black and white aerial photographs for the subject area flown in 1959/1960.
- Field Mapping – two days field inspection of possible active faulting landforms defined from the desktop study. Assessment of rock outcrops and superficial deposits.

The findings of the investigations are summarised below.

4.1 Aerial Photograph Analysis

4.1.1 Geomorphology of Superficial Deposits

Review of aerial photographs confirms that the Upper Porter River valley has been infilled by a variety of superficial deposits. Typically, the true-right of the river valley contains limited cover deposits. Extensive cover deposits are evident of the true left of the river valley, based upon incised streams present in this area. Cover deposits identified within the river valley can be broadly grouped into glacial/fluvioglacial and alluvial deposits.

A variety of glacial deposits (till) are present within the vicinity of the village base area (see Figure 4-1). These landforms, derived directly from ice, are likely associated with glaciers originating from both the McNulty (Porters) and northern part of Crystal Basin. Deposits of lateral moraines appear to indicate two different ages of advance. The largest of these lateral moraines are most likely associated with the last glacial maximum (approximately 22 to 18 ka BP). Younger lateral moraine deposits contained within these older moraines probably represent the last major glacial advance associated with the end of the Otira Glaciation (approximately 14 ka BP).

A large extensive surface on the true left of the river valley (which includes the proposed village base area) appears to be of fluvioglacial origin (i.e. deposited by meltwater). This surface is hummocky in appearance and slopes moderately steeply down towards the river valley. It is incised by a number of surface water drainage features and by the Porter River at its toe. Based upon the amount of incision at the toe of this surface by the Porter River (including the development of two river terraces) and by the well developed, braided drainage network on its surface (derived from a large water supply) it probably represents reworking of deposits from the last glacial maximum (see Figure 4-2).

Alluvial deposits largely comprise river terraces and fan deposits. Two river terraces can be distinguished within the modern river valley (see Figure 4-2) and are considered to be of Holocene age (<10,000 years old). Both terraces are evident on the true left of the river valley, with the upper terrace evident on the true right of the valley only (along which the skifield access road has been constructed). Fan deposits are found at the base of most major streams.

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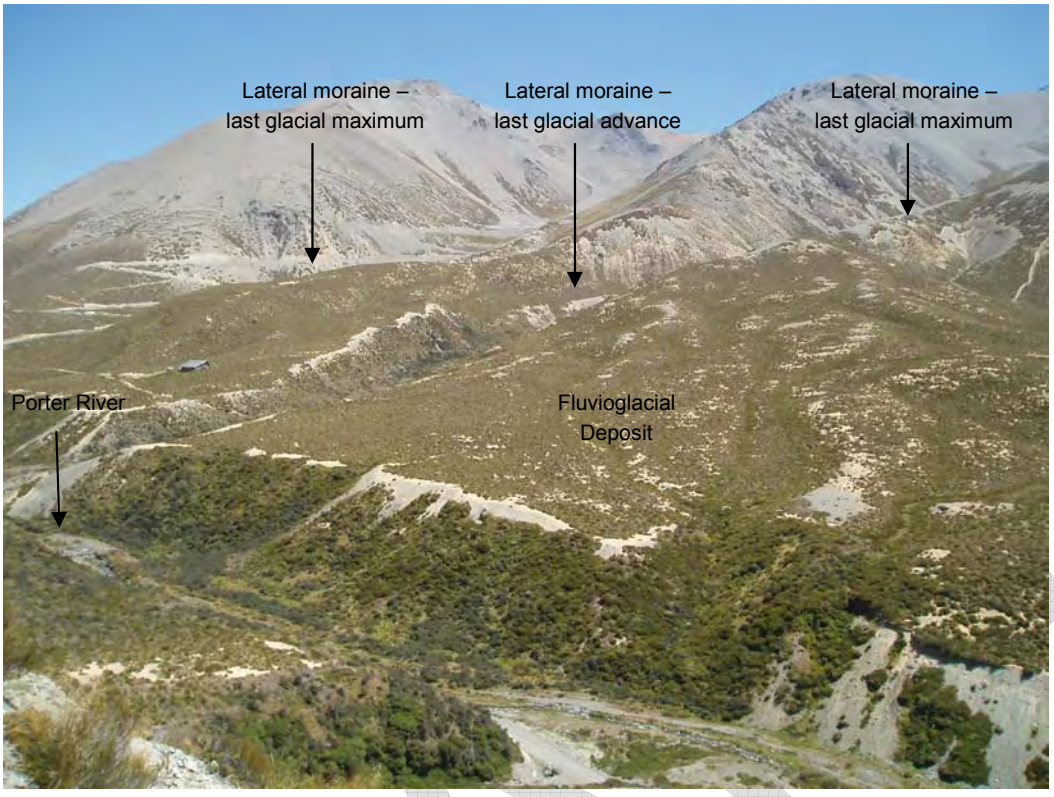

Figure 4-1 Glacial/Fluvioglacial Deposits within the Upper Porter River valley

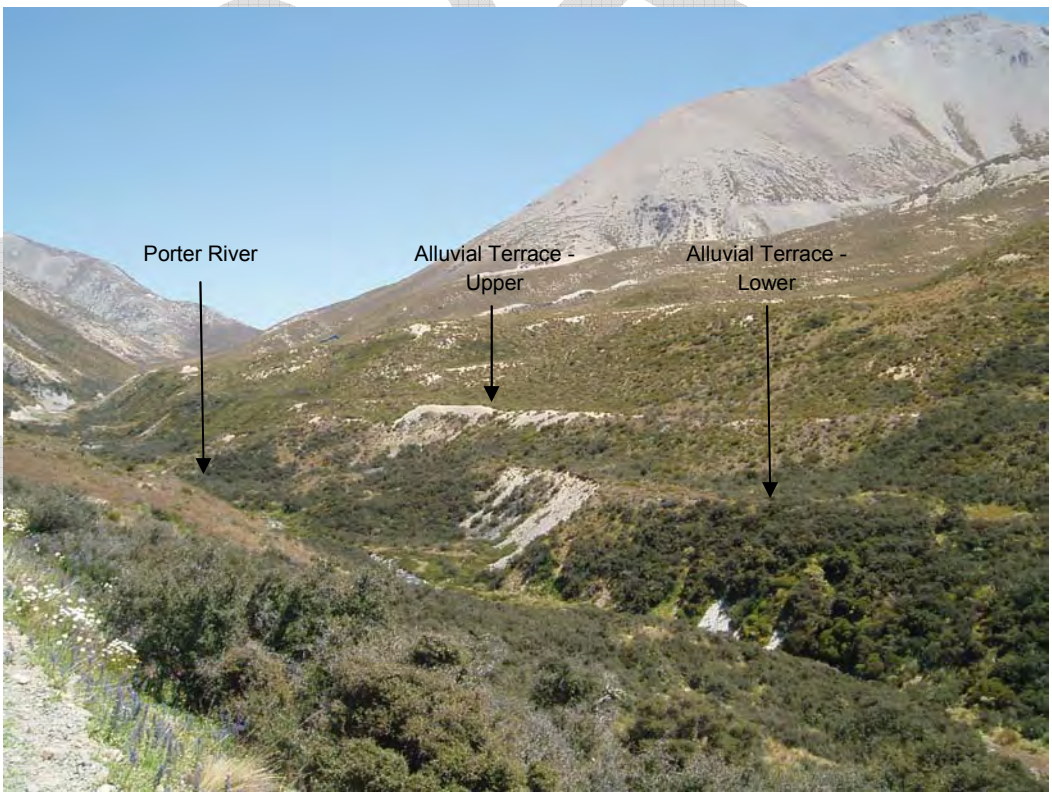

Figure 4-2 View of Alluvial Deposits in the Porter River valley

4.1.2 Active Faulting Landforms

Limited evidence for landforms associated with active faulting was observed on aerial photographs (shown on Drawing 1). Two discontinuous active fault traces could be identified on a terrace north and east of the existing quarry, remote from the proposed village base area. These faults comprise linear, well-defined traces which appear relatively fresh in appearance (striking approximately north-south). The easternmost of the two faults can be clearly seen to offset a drainage feature, suggesting a sinistral strike-slip fault sense.

A third fault trace is considered likely upslope of the existing quarry. This feature extends for approximately 2km along the northern slope of Cloudy Hill and is marked by a prominent change in slope, weathering profile and vegetation (striking east-west). A highly degraded fault scarp may also be present in this area, suggesting surface rupture of this part of the fault. Two topographic saddles may also be as a result of a fault in this location. The fault appears to be splayed at its western edge, where the fault trace is truncated by the Porter River.

No evidence for active faulting was identified within the proposed village base area.

4.2 Field Observations

Landforms associated with active faulting identified during field mapping are shown on Drawing 1. The presence of the two active fault traces on the fluvioglacial terrace adjacent to the existing quarry was confirmed by field inspection (see Figure 4-3). The western most of these two faults appears to be a dip-slip fault, with a maximum scarp height of approximately 2m, with the western side of the fault upthrown. The eastern fault appears as an oblique-slip fault (sinistral), with a maximum scarp height of approximately 1m (eastern side upthrown). The faults appear of limited extent (around 500m) and display a fresh, unmodified appearance. The age of surface rupture associated with these faults can be constrained by the age of the displaced deposits to be of Late Pleistocene to Holocene age.

A possible highly degraded surface fault trace was mapped upslope of the existing quarry (as observed on aerial photographs). This discontinuous fault trace extends for approximately 2km and was delineated by a prominent change in slope angle and vegetation cover (see Figure 4-4). The maximum scarp height observed was approximately 3m, suggesting the upslope (southern) side of the fault has been upthrown (reverse sense). At its western end, the fault trace appears to terminate at the Porter River as a series of splays which are evident upslope of the access road (see Figure 4-5). This possible surface fault trace is considered to represent the Torlesse Fault (based on strike and sense) and likely marks the boundary of Tertiary aged deposits to the north and Rakaia terrane to the south. The age of this surface rupture is unknown due to the limited geological surfaces encountered along the fault, but we anticipate it is of Late Pleistocene age (>10,000 years old) based on morphology.

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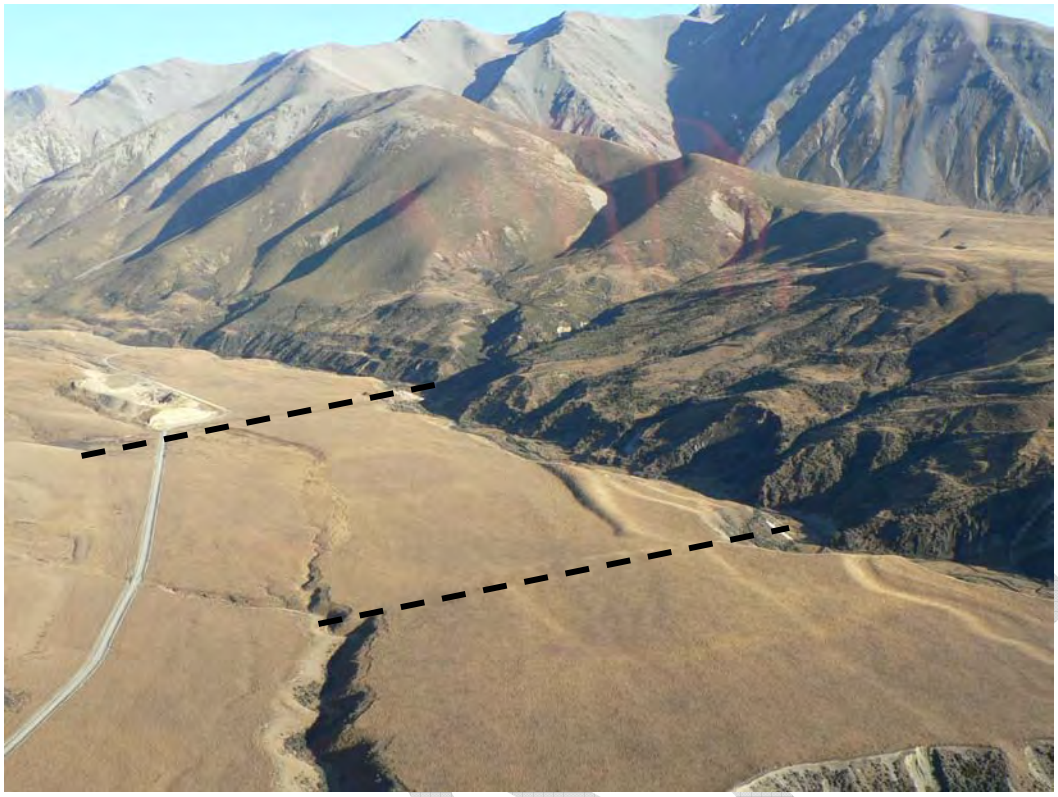

Figure 4-3 Active fault traces near existing quarry

Figure 4-4 Possible surface fault trace mapped upslope of the existing quarry

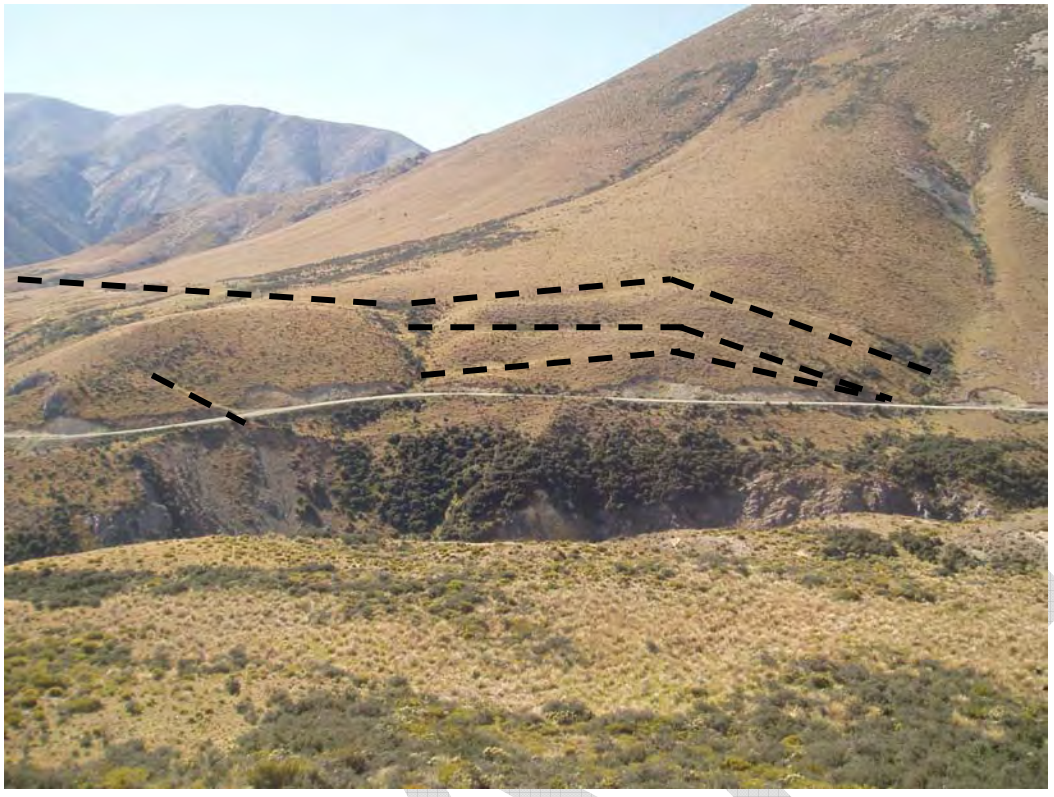

Figure 4-5 Splayed western end of surface fault trace near the skifield access road

A zone of intensely sheared and deformed rock (Rakaia Terrane 'greywacke') was mapped for approximately 1km within the Porter River from near the existing lodges (i.e. the proposed village base area) downstream. The sheared zone typically comprised moderately to highly weathered, very weak rock of low RQD with numerous clay filled shear surfaces (see Figure 4-6). The presence of this sheared zone within the greywacke could not be traced into Tertiary rocks exposed within the Porter River downstream. No associated surface trace of the fault could be identified (likely due to erosion/deposition by the Porter River) and no young geological surfaces (i.e. Late Pleistocene or Holocene age) are clearly offset by this feature.

Based on the location of the sheared zone within the river, we consider that this fault may form the boundary between Rakaia Terrane and Tertiary rocks within the middle to lower Porter River valley (although no direct exposure could be identified). The possible surface fault trace mapped upslope of the existing quarry may represent an eastern continuation of this sheared zone. Based on limit exposures, we judge that this sheared zone (and the possible fault trace upslope of the existing quarry) may represent the continuation of the Torlesse Fault west of SH73 up the Porter River valley.

A further active fault trace was identified up valley of the proposed village base area. This fault trace was identified by URS (2007) during an aerial inspection of the site as part of previous investigations, extending for approximately 1km near Coleridge Pass (striking approximately east-west). The fault appears to comprise a reverse fault, with the downslope (southern) side of the fault upthrown (see Figure 4-7). An antislope scarp of approximately 1m in height was identified on the ground, being highly degraded in form. The age of this surface rupture is unknown due to the limited geological surfaces encountered along the fault, but we anticipate it is of Late Pleistocene age (>10,000 years old). Based on fault sense, it could be postulated that this fault may be associated with the Torlesse Fault.

Figure 4-6 Sheared rock (Rakaia Terrane 'greywacke') exposed within the Porter River

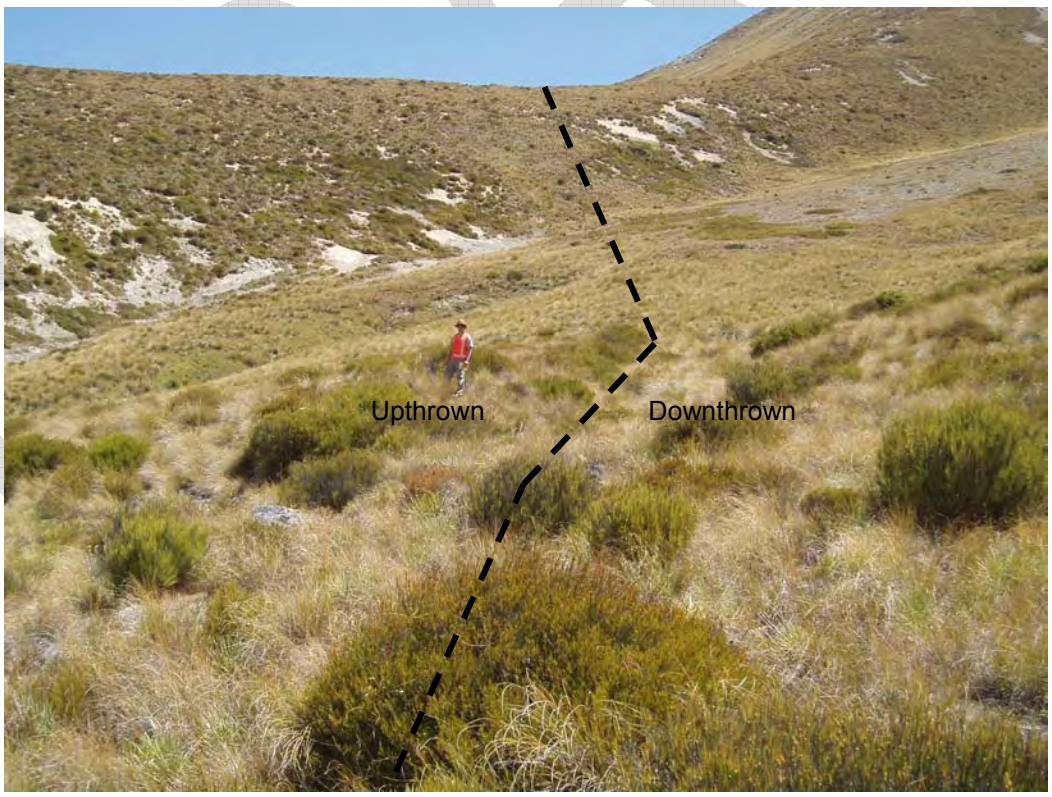

Figure 4-7 Active fault trace near Coleridge Pass (looking west)

Inspection of the superficial deposits in the proposed village base area suggests they are of glacial/fluvioglacial origin, with a loess covering evident in parts. No evidence for stratification was observed within the materials, indicating they may be glacial (till) in origin, with their surface re-worked by significant meltwater (glaciofluvial) associated with either the last glacial maximum (approximately 20,000 years ago) or the last glacial advance (approximately 14,000 years ago). This suggests that these surfaces are greater than 14,000 years in age.

No evidence for surface faulting was identified on these geomorphic surfaces during our investigation. Surface drainage features show no evidence for tectonic deformation (see Figure 4-8).

Figure 4-8 Glacial/Fluvioglacial surface of the proposed village base area

4.3 Summary

Based on aerial photograph analysis and field mapping, no geomorphic or geological evidence for active surface faulting within the proposed village base area has been identified. Geomorphic surfaces in the vicinity of the proposed village base area are judged to be of glacial/fluvioglacial origin (i.e. >14,000 years old). No evidence for tectonic deformation of these surfaces was observed during field investigation.

Active faults identified by this investigation within the Porter River valley are remote from the proposed development area, in the vicinity of the existing quarry and near Coleridge Pass.

A sheared zone evident within the Porter River is likely associated with faulting. No surface trace was identified as being associated with this feature and no young geological surfaces (i.e. Late Pleistocene or Holocene age) are clearly offset. This fault is judged a continuation of the Torlesse Fault up the Porter River valley and for this assessment has been considered active. Due to the close proximity of this inferred fault trace to the proposed development area, it should be considered for future development of the village base area (see Section 5).

Active Faulting Risk Assessment

Section 5

This section of the report summarises the findings of an active faulting risk assessment undertaken for the proposed village base area. Active faulting poses three main hazards which should be considered for any development at the site:

- Surface Rupture – This occurs during large earthquakes when movement (rupture) along a fault extends to the earths surface. Shallow earthquakes greater than M6.0 are generally considered capable of creating surface rupture during an earthquake. Evidence for previous surface rupture along active faults within the Porter River Valley has been identified during field mapping (see Section 4). The hazard posed by surface rupture along active faults can be mitigated by development planning and is discussed in more detail in Sections 5.1 and 5.2.
- Earthquake Shaking – The subject site is located within an area of high seismic hazard and is likely to suffer ground shaking from earthquakes located both within and outside the Central Southern Alps region. In the event of an earthquake along one of the active faults located within the region, the site will suffer intense ground motion. The risk posed by earthquake shaking can be mitigated by appropriate structural design.
- Slope Instability – Slope instability can be triggered by earthquake shaking. Assessment of slope stability within the proposed village base area is outside the brief of this report.

5.1 Ministry for the Environment Active Fault Guidelines

5.1.1 Fault Avoidance Zones

Landforms associated with surface fault rupture in the Porter River valley are discussed in Sections 4. Defined FAZ for all identified active (or potentially active) faults within the vicinity of the proposed village base area are shown on Drawing 2. These FAZ have been defined at 1:10,000 scale.

5.1.2 Recurrence Interval Class

For this study, recurrence intervals have been obtained from a desktop study of existing information (i.e. for similar and neighbouring faults within the Porters Pass – Amberley Fault Zone). Very little paleoseismic information is available for faults with the Porter Pass – Amberley Fault Zone and no data has been published for the Cheeseman and Torlesse Faults. The lack of reliable paleoseismic data for faults within the Porter River Valley introduces a major uncertainty in this MfE risk assessment.

Stirling et al. (2007) calculated recurrence intervals for the Cheeseman and Torlesse Faults as part of earthquake source identification and characterisation for the Canterbury Seismic Hazard Model. Recurrence intervals were calculated by dividing the estimated single event displacement (mm) by fault slip rate (mm/yr). Indicative recurrence intervals of 2200 years for the Cheeseman Fault and 3000 years for the Torlesse Fault were calculated.

Within the Porters Pass - Amberley Fault Zone, the Porters Pass and Mt. Grey Faults are judged to display recurrence intervals of less than 2000 years (Cowan et al., 1996). A recurrence interval of between 2000 and 5000 years has been postulated for the Lees Valley Fault. Other similar faults within the Central Southern Alps (i.e. reverse faults with some strike-slip component), such as the Esk and Harper Fault's, have also not been studied in detail. No recurrence intervals have been determined for these faults but the time since last surface rupture is considered >10,000 years.

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Surfaces in the vicinity of the village base area considered to represent superficial glacial/fluvioglacial deposits of Late Pleistocene age (>14,000 years old). If any active faults are present within the vicinity of the village base area, it can be assumed any surface rupture over the last 14,000 years would be represented on these surfaces. No geomorphic evidence was identified for tectonic deformation of these surfaces during field mapping, suggesting the time since last surface rupture exceeds 14,000 years.

On this basis, it is considered unlikely that any such fault (if present) would display a low recurrence interval (i.e. RIC 1 to 3) based on recent performance. There is a possibility that this period (i.e. the last 14,000 years) represents a 'seismic gap' in the history of the fault (similar to that seen on the Alpine Fault) and that over a longer period of time, the fault may indicate a lower RIC. There is no basis for assessing this possibility and we have discounted it for this study.

5.1.3 Building Importance Category

We understand that development in the village base area is likely to comprise accommodation, support and staging facilities (BIC 2b). It can be anticipated that in the future some structures, such as emergency medical facilities, may be considered BIC 3. Development within the village base area would be considered an undeveloped site (i.e. a 'Greenfield Site').

5.1.4 Conclusions

Due to the lack of existing information to accurately define the RIC of any faults within the Porter River valley, caution should be applied when considering this risk assessment. Better definition of RIC for faults with the Porter River valley could be obtained by detailed paleoseismic investigations.

We have found no geomorphic evidence for active faulting in the vicinity of the proposed village base area. Should the Torlesse and Cheeseman Faults extend up the Porter River valley, we judge that these sections of the faults are likely to fall within RIC IV or V (based on past performance and approximate age of last rupture of >14,000 years). Building of structures classified as BIC 1 to 3 would likely be allowed by a regional authority as a permitted activity within the defined fault avoidance zones (see Table 5-1). Active faulting within the Porter River valley should therefore provide no constraint on development of the village base area.

Table 5-1 Relationship between BIC and RIC for village base area

Recurrence Interval Class (RIC)	Fault Recurrence Interval	Building Importance Category (Allowable Buildings)	
		Developed or Previously Subdivided	Greenfield Site
I	≤2000 years	1	1
II	>2000 years to ≤3500 years	1 and 2a	
III	>3500 years to ≤5000 years	1, 2a and 2b	1 and 2a
IV	>5000 years to ≤10,000 years	1, 2a, 2b, and 3	1, 2a and 2b
V	>10,000 years to ≤20,000		1, 2a, 2b and 3

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Recurrence Interval Class (RIC)	Fault Recurrence Interval	Building Importance Category (Allowable Buildings)	
		Developed or Previously Subdivided	Greenfield Site
VI	>20,000 years to ≤125,000 years	1, 2a, 2b, 3 and 4	

5.2 Pettinga et al. 1998 Methodology

A more easily applied method for assessing the risk posed by active faulting when little is known about the RIC of a fault is by applying the methodology used by Pettinga et al. in 1998. The risk posed by a fault is defined by the age of the last surface rupture (i.e. those faults which have ruptured most recently are considered of highest activity and present the greatest risk to future development). The age of the last surface rupture is more easily distinguished in the field by assessing the nature of displaced (and undisplaced) deposits and does not rely on detailed paleoseismic investigation and dating.

Three Activity Classes were defined by Petting et al.:

- Activity Class 1 – faults or folds which cut or displace Holocene surfaces (i.e. younger than 10,000 years).
- Activity Class II – faults or folds which cut or displace deposits of the late last glaciation (i.e. younger than 25,000 years) and Holocene deposits are not displaced or proven displaced.
- Activity Class III - fault or folds which are considered probably active but do not clearly affect geomorphic surfaces less than 25,000 years old.

Based on aerial photograph analysis and field mapping, we identified no geomorphic evidence to suggest surface fault rupture of Late Pleistocene or Holocene deposits within the area of the proposed village base. This suggests that if any fault is present in this region, it would be considered to be of Activity Class III. The judged risk posed by any active fault (if present) to development in this area (defined as accommodation, support and staging facilities) is therefore deemed acceptably low.

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Conclusions

Section 6

The main findings of this assessment can be summarised as follows:

- Limited evidence has been identified for active faulting within the village base area (i.e. the Upper river valley). Any mapped faults within this area are typically assessed as having not shown movement in the last approximately 120,000 years. The only interpretation which shows 'considered' movement within the last 120,000 years within the village base area is not based on direct field observation.
- On the basis of aerial photograph analysis and field mapping, we have confirmed active faults near the existing quarry and Coleridge Pass (i.e. remote from the proposed development area).
- A zone of sheared rock present within the Porter River near the proposed village base area is judged to be associated with the Torlesse Fault and for the purposes of this assessment, has been considered active.
- Geomorphic surfaces in the vicinity of the village base area are considered to represent superficial glacial/fluvioglacial deposits of Late Pleistocene age (>14,000 years old).
- No geomorphic evidence was identified for tectonic deformation of these surfaces during field mapping, suggesting that the time since their last surface rupture exceeds 14,000 years. On this basis, we consider that if any active faults are present within the vicinity of the proposed village base area, they would be judged to belong to RIC IV or V.
- Development anticipated as part of the village base would comprise accommodation, support and staging facilities classified as BIC 2b and 3. Due to the judged low RIC of any active faults if present (RIC IV or V), building over these faults will likely comprise a permitted resource consent activity by regional authorities (i.e. building is allowed in the developed FAZ).
- Using the methodology proposed by Pettinga et al. in 1998, if any active faults were to be present within the proposed village base area they would be assigned to Activity Class III.
- The risk posed by surface faulting to development of the village base area (defined as accommodation, support and staging facilities) is judged acceptably low. No fault specific constraint to development has been identified.
- Due to the tectonic setting of the subject site, the potential for extreme ground motion (shaking) should be considered during the design of any structure. All structures should be designed in accordance with New Zealand Building Code for seismic design.

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Section 7

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Limitations

Section 8

URS New Zealand Ltd (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of Blackfish Joint Venture and only those third parties who have been authorised in writing by URS to rely on the report. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated 19 November 2008.

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared between 22 December 2008 and 11 February 2008 and is based on the conditions encountered and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

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