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Description and Geoconservation Assessment of a Glacio-fluvial Terrace at the Southwood Development Site, and possible equivalent terraces in the Huon River Valley, Southern Tasmania

Report to John Holland Pty Ltd

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Front Cover Photo: The flat main terrace surface at the Southwood site, looking north from site 6 towards site 13 (at the far end of the visible road section). This part of the Southwood project site is mantled by an unlithified granular quartz sand facies, and is interpreted to be a mostly intact remnant fragment of an original glacial outwash plain surface, that formerly filled to Huon Valley to the same level, preserved much as it was at the time sedimentation ceased.

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SUMMARY

Background and Aims
The Southwood Project construction site is situated on the broad flat top of a spur on the north side of the Huon River, immediately opposite the Arve River confluence, in southern Tasmania. The Huon Valley and surrounding mountains are known to have been glaciated on at least two (and probably more) occasions during the Quaternary Period (Late Cainozoic), and the spur crest is mantled by unlithified Quaternary sediments whose flat upper surface is interpreted as a remnant fragment of a former valley-filling glacio-fluvial outwash plain surface deposited during an older and more extensive glaciation than the last. Because evidence for glaciations preceding the last is limited in the Huon Valley, and no other well-preserved high-level depositional outwash terrace surfaces relating to pre-Last Glacial phases have previously been documented in that region, the terrace at the Southwood site has been considered to have geoconservation significance for the scientific information it contains about an early phase of southern Tasmania's Cainozoic glacial history, and for its intrinsic value as a remnant *landform* (not just a sediment deposit) produced by that glacial phase.

The excavations, earthworks and constructions associated with the Southwood project will disturb a large proportion of the terrace surface and its contents. This is likely to result in the loss of at least some of the scientific information contained in the terrace landform, and hence, the loss of some of its geoconservation significance.

The purposes of the investigation described in this report were to:

- document the geomorphic and sedimentary characteristics of the Southwood glacio-fluvial terrace site prior to substantial disturbance and to assess the geoconservation value of the feature; and:

- to assess the likelihood of other equivalent features (i.e., other outwash terrace remnants of the same age and likely to provide equivalent scientific evidence) being present in an undisturbed state elsewhere in the Huon Valley, and to assess their likely geoconservation significance in relation to the Southwood site terrace.

Description of the Southwood site glacio-fluvial terrace
Previous geological investigations (including drilling) at the Southwood site were reviewed, and 3 days were spent in the field documenting the site and collecting samples. A variable thickness (5 to over 12 metres) of unlithified Quaternary-age glacio-fluvial outwash sediments mantle the upper surface of the Southwood Spur, approximately 70 metres above the present Huon River channel, and rest on Permian siltstone/sandstone bedrock whose upper surface slopes gently southwards towards the Huon River. The bedrock is itself deeply weathered to a soft clay regolith for a depth of 14 to 20 metres beneath the Quaternary sediments.

Three main distinctive sedimentary facies are recognisable in the glacio-fluvial sediment sequence, characterised by differing clast and matrix compositions and textures, and separated by scoured surfaces representing episodes of erosion (glacio-fluvial "degradation") during the glacio-fluvial deposition process. The sediments contain

predominantly Precambrian quartzite and Permian mudstone, siltstone and sandstone clasts. Characteristics of the sediments including their lack of any dolerite clasts and their position high in the landscape relative to other glacio-fluvial sediments, are interpreted as implying that the preserved sediments were deposited late in the glacial episode when the glacier had retreated significantly back up the Huon and Manuka Creek valley's from its maximum extent, and when the outwash plain had aggraded (accumulated) to nearly its maximum thickness. Changes in composition and texture upwards through the three main sedimentary facies may represent distinctive phases in the waning of the glacier and glacial outwash system, or may be partly related to more localised changes in the braided outwash channel system. All mudstone and siltstone cobbles in the glacio-fluvial sediments are thoroughly weathered to soft clay which, together with the deep weathering of the underlying bedrock and a number of other criteria, are interpreted as implying an age of deposition significantly greater than the Last Glaciation (circa 19,000 years BP), potentially as old as the most extensive known Cainozoic glaciation in Tasmania (>730,000 years BP, possibly circa 1,000,000 years BP), but probably no older than a few million years. Sediment samples have been obtained from the Southwood site, but no absolute age determinations on these have been attempted yet due to lack of funds.

The highest (northern-most) portions of the glacio-fluvial sediments at the Southwood site were partly incised by fluvial erosion (degradation) prior to the final phase of glacio-fluvial deposition at the site. The youngest (final) preserved sediments were deposited on a slightly lower, flat terrace lying between 100 – 105m ASL, and the available evidence suggests that a substantial portion of this terrace surface has not been further incised or eroded subsequent to the end of the phase of glacio-fluvial sedimentation. Thus, this part of the Southwood terrace surface appears to represent a preserved fragment of the original glacio-fluvial outwash plain depositional surface as it was when the glaciation ceased.

Search for equivalent terraces elsewhere in the Huon Valley

In order to identify target areas to search for equivalent high-level terrace surfaces elsewhere in the Huon Valley, two predictive models of the possible form and gradient of the original outwash plain surface were considered. Based on these models, GIS software was used to analyse the 25 metre Digital Elevation Model of Tasmania in order to identify flat surfaces in the Huon Valley at altitudes where the predictive modelling suggested that remnant outwash terrace fragments equivalent to that at the Southwood site were most likely to be found.

Two days were spent visiting potential equivalent terrace sites identified by this method. Several of the visited sites proved to be flat surfaces of other unrelated types, however two sites (one near Judbury and one north of the Huon – Weld Rivers confluence) exhibit remnant alluvial sediments that are potentially equivalent to those at the Southwood terrace site (although no absolute or relative age tests have yet been attempted). However, these sites preserve the alluvial sediments only as residual lags, not as un-modified sedimentary deposits with original surfaces intact, and it is evident that the original glacio-fluvial deposits and terrace surfaces are somewhat degraded and not preserved intact as appears to be the case for at least part of the Southwood site (nonetheless, an upper limit of glacio-fluvial sedimentation at 110m ASL can still be identified at an equivalent site north of the Huon-Weld confluence). Further potentially equivalent terrace sites were identified by the predictive modelling that could not be visited in the time available, and it remains possible that some of these may prove to be glacio-fluvial terraces in a similar state of preservation to the Southwood site.

Geoconservation significance assessment

On the basis of presently available information, the glacio-fluvial terrace at the Southwood site can be assigned Representative, and probably Outstanding, geoconservation significance at the Regional level, on the grounds that the Southwood Terrace remains the best preserved and expressed example known for the Huon Valley Glacial System region. A thorough search for data on equivalent features elsewhere in Tasmania has not been undertaken, but if such work were to identify few or no equally well preserved and expressed equivalent features elsewhere in Tasmania, then the significance of the Southwood Terrace could be upgraded to State level.

Of key importance in the geoconservation significance assessment is the fact that available evidence suggests that, not only has a deposit of intact late-stage glacio-fluvial sediments has been preserved, but importantly, a relatively intact fragment of an original outwash plain *depositional surface* landform is preserved. Although several possibly equivalent outwash sediment deposits and terrace sites have been identified by fieldwork elsewhere in the Huon Valley, these are more degraded and cannot therefore be assigned the same level of significance. However, the search for equivalent sites has not been exhaustive (due to time limitations), and the possibility of equally well-preserved terrace surface remnants being found elsewhere remains open.

The preservation of a significant sediment sequence and depositional terrace surface on the crest of the Southwood Spur - whilst equivalent high level sediments and terraces appear to have been removed from valley sides in most other parts of the Huon Valley - may be attributable to the fact that, following the waning of glacial outwash sediment supply and deposition, the resistant bedrock spur itself began protecting its cap of high level sediments from river erosion by migrating channels as soon as the fluvial incision level had dropped below the upper level of bedrock in the spur. The sediments and terrace surface on the spur top were subsequently protected from fluvial and slope erosion processes by the broad scale of the flat spur crest. The fact that this situation (a high broad pre-glacial bedrock spur projecting well into the valley but overtopped by glacial outwash deposits only in the final stages of the glacial episode) is not known to be replicated elsewhere in the valley suggests that the degree of preservation of high level glacio-fluvial sediments at the Southwood Spur could be unique in the valley.

Sensitivity

Whilst the geoconservation value of the *contents* of outwash sediment deposits at the Southwood Terrace would be significantly degraded by large-scale excavation and removal of the sediment, minor excavations (relative to the total extent of the sediment deposit) will provide useful exposures allowing better understanding of the feature. However, the intact portion of the original depositional *surface* is sensitive to mechanical disturbance, and significant disturbance of this surface, by excavation, heavy machinery or other mechanical impacts, will irreversibly modify it, reducing its intrinsic and scientific value.

Recommendations
It is recommended that:

- Excavation and site development work at the Southwood Terrace should be monitored by a suitably qualified person with a view to recording further scientific data on the glacio-fluvial outwash sediments as sections of these become exposed, in order to maximise the opportunity to improve understanding of the feature and its origin.

- Efforts should be made to preserve at least representative portions of the preserved original outwash plain depositional surface free of mechanical disturbance during the course of site development, in view of the significance of this ancient landscape surface remnant.

- Sediment samples should be subjected to dating and palaeo-environmental testing to improve knowledge of the age, depositional environment and glacial process implications of the Southwood Terrace.

- Continued exploration for potential equivalent outwash terrace sites elsewhere in the valley should commence by completing the examination of all potential sites identified in section (4.2), and might progress through further refinement of the predictive models used in this investigation.

- A thorough review of available data on pre-Last Glaciation outwash terraces elsewhere in Tasmania, together with consideration of any further data obtained through other recommended actions (above), should be undertaken with a view to confirming or revising the assessment of the geoconservation significance of the Southwood Terrace.

1.0 INTRODUCTION

1.1 Purpose of this work

The Southwood Project construction site is situated on the flat top of a spur on the north side of the Huon River, immediately opposite the Arve River confluence, in southern Tasmania. The Huon Valley and surrounding mountains are known to have been glaciated on at least two (and probably more) occasions during the Quaternary Period (Colhoun & Goede 1979), and the spur crest is mantled by unlithified Quaternary sediments whose flat upper surface was previously identified by Sharples (1994a, b) as a Quaternary-age glacio-fluvial outwash terrace remnant. Although more extensive, and probably younger, outwash terraces are known at lower levels in the Huon Valley (e.g., at the Huon – Picton rivers confluence), the terrace at the Southwood site is the highest outwash terrace remnant identified in the Huon Valley to date, and for that reason is thought to relate to an older and more extensive glaciation than the last (see also section 2.0 below).

Because evidence for glaciations preceding the last is, on present knowledge, relatively limited in the Huon Valley, the terrace at the Southwood site has been considered to have geoconservation significance for the scientific information it potentially contains about an earlier phase of southern Tasmania's Cainozoic glacial history, and for its intrinsic value as a remnant landform produced by that glacial phase. The Southwood terrace site is for this reason a component of the "Huon Valley Glacial Systems" (HUO25) site listed on the Tasmanian Geoconservation Database (Dixon & Duhig 1996), as currently maintained by the Tasmanian Department of Primary Industries, Water & Environment (DPIWE)[1].

The excavations, earthworks and constructions associated with the Southwood project will disturb a large proportion of the terrace surface and, whilst this may temporarily or permanently expose more details of the stratigraphy, sedimentology and structure of the terrace, it is likely that a large part of any remaining original surface form of the terrace will be lost, together with the fabric of near-surface sedimentary units. Since this disturbance is likely to result in the loss of at least some of the scientific information contained in the terrace landform – and hence, the loss of some of its geoconservation significance – a consultants brief was prepared by the Tasmanian Department of Primary Industries, Water and Environment (DPIWE) to assess the geoconservation significance of the site prior to commencement of construction works. The consultants brief is reproduced as Appendix 1; in essence, the aims of the brief – and hence of this report – can be paraphrased as being:

- to document the geomorphic and sedimentary characteristics of the Southwood glacio-fluvial terrace site prior to substantial disturbance – so as too capture what scientific information can be obtained prior to irreversible disturbance - and to assess the geoconservation values of the feature; and

- to assess the likelihood of other equivalent features (i.e., other outwash terrace remnants of the same age, and likely to provide equivalent scientific evidence)

[1] The Tasmanian Geoconservation Database can currently be consulted on the Tasmanian Parks & Wildlife GIS website at http://www.gisparks.tas.gov.au/ .

being present in an undisturbed state elsewhere in the Huon Valley, and to assess their likely geoconservation significance in relation to the Southwood site terrace.

1.2 Work undertaken

The writer was contracted by John Holland Pty. Ltd. to undertake the work detailed in the consultants brief (Appendix 1).

Five days fieldwork were undertaken, focussing on first documenting the nature of glacio-fluvial features at the Southwood site (3 days) and then examining a selection of potentially equivalent sites elsewhere in the Huon valley (2 days).

In addition to the writer's own field observations, engineering geology logs of boreholes and exploratory pits used by Coffey Pty Ltd at the Southwood site were referred to and correlated with roadside and quarry exposes nearby. The Coffey pits have been backfilled, hence only the written logs of these pits are available (Coffey 2002).

Access to digital (GIS) map data used in this work was provided by the Earth Science Section, Nature Conservation Branch, Tasmanian Department of Primary Industries, Water and Environment, as support for this project. Analysis and use of digital map data was undertaken using ESRI Arcview (v. 3.2a) software.

Due to lack of funding, it has not been possible to attempt absolute or relative dating tests on sediments from the Southwood Terrace (or potential equivalent sites), however samples have been collected which may be suitable for future dating tests, and these are listed in Appendix 3.

1.3 Limitations and caveats

This investigation was undertaken at short notice, immediately prior to commencement of construction works at the Southwood site. Hence it was not possible to undertake an investigation in as much detail as might have been desirable. Recommendations for further investigations which could usefully be undertaken are made in sections (4.3) and (6.0).

1.4 Conventions used

Map grid references used in this report are full 6 and 7 figure metric co-ordinates of the Australian Map Grid (Zone 55), which are Universal Transverse Mercator (UTM) system co-ordinates based on the AGD66 datum. The details of numbered sites referred to throughout the text are given in Appendix 2. Map grid references listed for these sites were in all cases obtained using a Garmin 12 hand-held GPS unit.

The glacio-fluvial terrace remnant at the Southwood Project site is hereafter referred to as the "Southwood Terrace", the same location is also referred to in places as the "Southwood Site", and the bedrock spur or ridge which the Southwood Terrace caps is referred to as the "Southwood Spur".

2.0 GLACIAL HISTORY OF THE MIDDLE TO LOWER HUON VALLEY

2.1 Introduction

Tasmanian mountain regions have been glaciated on multiple occasions during Late Tertiary and Quaternary times (the "Late Cainozoic"), with evidence of early glaciation in the Forth Valley (northern Tasmania) dating back to Oligocene times circa 32 million years BP (Macphail *et al.* 1993). Most of the detailed studies of Cainozoic glaciation in Tasmania have concentrated on the West Coast Range, Central Plateau region, and outlet valleys from those regions. During the last two million years (i.e., the Quaternary Period) at least four and possibly five or more major glaciations – separated by interglacial phases such as the present – have been identified in those regions (e.g., Kiernan 1991, Fitzsimons *et al.* 1993).

The most extensive of these Quaternary glaciations was the oldest, which is known as the Linda Glaciation on the West Coast Range (Kiernan 1983). This glaciation produced an extensive ice cap blanketing the West Coast Range to Central Plateau region, and large outlet glaciers extended long distances down valleys such as the Pieman, Mersey and Derwent (Kiernan 1990b). Often referred to as "the Maximum Cainozoic Glaciation", the Linda Glaciation (and correlated glaciations in areas beyond the West Coast Range) occurred before 730,000 years ago and possibly around one million years ago (Fitzsimons *et al.* 1993).

The most recent, or Last Glaciation, in Tasmania was also the least extensive, producing a smaller Central Plateau ice cap and mostly only restricted mountain cirque glaciers elsewhere. The Last Glaciation reached its maximum extent about 19,000 years ago, and all glacial ice had melted by 10,000 years ago (Colhoun *et al.* 1996).

2.2 Glaciation and glacio-fluvial processes in the middle to lower Huon Valley

In contrast to the comparatively detailed glacial studies that have been undertaken on the Central Plateau, West Coast Range and surrounding regions, only a few systematic studies have been undertaken on the southern mountain regions including the Huon Valley region. The most detailed published study of glaciation in the Huon Valley remains that of Colhoun & Goede (1979). Kiernan (1989) published information on glaciation in part of the Picton Valley, a major tributary of the Huon. Otherwise, mainly non-systematic reconnaissance - and mostly unpublished - observations on glacial deposits and landforms have been made in the Huon and tributary Picton and Weld River valleys by Kiernan (1987, Unpublished) and others including Sharples (1994a). Sharples (1994a) summarised knowledge of glaciation in the Huon Valley region at that time, and no subsequent data has been published.

The work to date has clearly differentiated only two separate phases of glaciation in the Huon Region (Colhoun & Goede 1979, Kiernan 1989), which Kiernan (1996) has referred to in the tributary Picton Valley as the (younger) "Sydney" and (older) "Cook Ck." glacial advances. However, as close as Mt Anne, 20 kilometres to the northwest, Kiernan

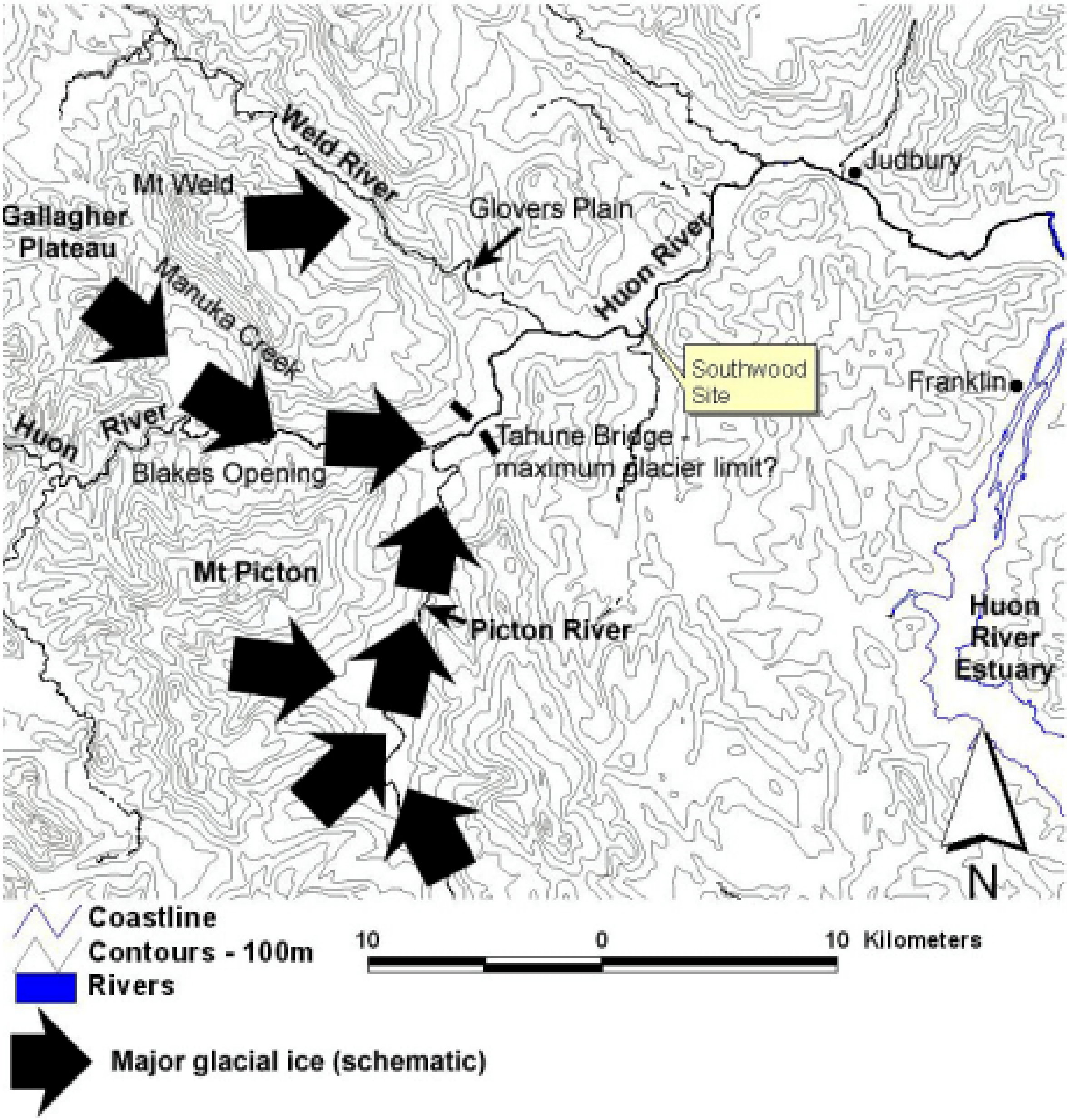

Figure 1: Locality map of the middle and lower Huon River Valley (southern Tasmania), showing Southwood Terrace site location in relation to probable extent of glacial ice in the Huon Valley during the maximum Cainozoic glaciation.

(1990c) identified evidence of at least three and possibly four separate Cainozoic glaciations, hence the possibility must be entertained that glacial features in the Huon Valley may ultimately be shown to include evidence of at least three glaciations, and not merely the two that have been identified to date.

The Last Glaciation in the Huon Valley region is considered to have produced only restricted mountain cirque glaciers at high levels on Mt Picton, Mt Weld, the Snowy Range, Hartz Mountains and other peaks surrounding the Picton Valley. The existence of well-preserved moraines on the southwest side of Gallagher Plateau (Calver 1997; see Figure 1) may indicate the existence of small cirque glaciers there during the Last Glaciation also. Colhoun & Goede (1979, p. 393) considered that glacial ice did not extend below 600m ASL on Mt Picton and the South Picton Range at that time. Although glacial ice did not extend to the valley bottoms during the Last Glaciation, it is nonetheless probable that seasonally torrential meltwaters from the glacier snouts would have carried some quantity of coarse glacio-fluvial outwash sediment into the valleys below and downstream.

However, a variety of glacial landforms and deposits including moraine ridges and till deposits have also been identified at much lower levels in the Huon, Picton and Weld valleys. The constituents of these deposits show significantly greater chemical weathering and iron pan development than Last Glaciation deposits, the moraine ridges are more eroded and degraded than Last Glaciation moraines, and palynological evidence indicates a significantly greater age than the Last Glaciation (Colhoun & Goede 1979, Kiernan 1987, Sharples 1994a). Whilst it is possible that future work will allow these landforms and deposits to be differentiated into the products of more than one distinct glaciation, they certainly represent at least one glaciation older and considerably more extensive than the Last Glaciation, and may in part be the products of the Maximum Cainozoic Glaciation (i.e., equivalent to the Linda Glaciation and other equivalent glacial phases elsewhere in Tasmania).

Colhoun & Goede (1979) consider that during the maximum (older) glaciation represented in the Huon Valley, a broad glacier occupied the floor of Huon Valley. They consider that this glacier originated in an ice cap on Gallagher Plateau, from where it flowed down Manuka Creek valley to Blake's Opening (where Colhoun & Goede identified low level moraine ridges and tills of pre-Last Glaciation age), and thence down the Huon Valley to at least the present site of Tahune Bridge, below the Huon – Picton River confluence (see Figure 1). As noted above, small cirque glaciers probably occupied cirques on the southern side of Gallagher Plateau (at the head of Manuka Creek) during the Last Glaciation, and the Huon Glacier would have retreated to these cirques during the waning phase of the maximum glaciation.

There is no currently available evidence for a contribution of ice from further upstream in the Huon Valley, for example from the Arthur Range – Arthur Plains area, although some outwash sediment from these poorly-studied glacial areas would undoubtedly have reached the Huon Glacier near Blake's Opening.

The furthest-downstream evidence of glacial ice in the Huon Valley is at Tahune Bridge, where Colhoun & Goede (1979) identified what they considered to be a very old weathered till. Although Colhoun (1987) has subsequently stated that the evidence for glacial ice having reached Tahune Bridge requires re-evaluation, at the same time it is possible that the poorly-studied areas further downstream could in future yield additional tills indicating further down-valley extension of the glacier at its maximum extent.

Colhoun & Goede (1979) consider the Huon Glacier ice did not fill the valley above 600m ASL in the Blake's Opening area (and indeed it is likely to have been significantly lower than that). Dolerite is present in low-level river-side tills at Blake's Opening, and Colhoun & Goede (1979, p. 389) consider that some glaciers flowed northwards off Mt Picton and were confluent with the Huon Valley ice below, at least at the maximum extent of glaciation. However, very little dolerite occurs in moraines at Blake's Opening (*ibid.*), suggesting that at least during later stages of glacier retreat cirque glaciers on the north side of the (dolerite-capped) Mt Picton contributed little coarse sediment to the Huon Glacier.

Several glaciers extended to the valley floor in the lower Picton Valley, for example at Cook Creek (Sharples 1994a), and these may have been confluent with the main Huon Glacier above Tahune Bridge (Colhoun & Goede 1979). Glaciers extended to low levels in the Weld Valley, at least as far downstream as Isabella Creek (Sharples 1994a), but it is unlikely that Weld Valley glaciers reached to the Huon Valley junction since the narrow Weld River gorge at Glovers Bluff shows no sign of having experienced glacial erosion. However, Glovers Plain is mantled by probable glacio-fluvial sediments that are likely to have been partly supplied by glaciers higher in the Weld Valley (Sharples 1994b). There is also a possibility that glacial ice may have descended Eddy Creek from the southern end of the Snowy Range (Kiernan 1987), supplying at least a contribution of glacial outwash to Glovers Plain. Thus, although glacial ice probably did not reach the Huon Valley via the lower Weld Valley, glacial outwash from the Weld Valley would have been confluent with outwash being supplied to the Huon Valley by glaciers occupying the Huon and Picton Valleys.

Glacio-fluvial Processes and Deposits in the Huon Valley

Glacio-fluvial outwash sediments comprise eroded rock material, usually including high proportions of both coarse and fine-grained sediment, that has been transported by glaciers and then washed out from the glacier snout by meltwaters. The sedimentary material may be derived from both direct glacial erosion and mass movement transport down unstable valley-sides on to the glacier. The meltwaters carrying the outwash sediments from the glacier snout may be seasonally torrential, particularly in temperate zone glaciers such as those in Tasmania, and this is one factor that tends to allow energetic transport followed by rapid dumping of outwash sediments, forming typically very poorly sorted glacio-fluvial deposits with high proportions of both coarse and fine material.

Glacio-fluvial outwash may be deposited in very broad valley-filling plains extending kilometres down-valley from glacier snouts (Figure 2), with numerous braided and anastomosing meltwater streams wandering and changing their courses over the outwash plain. A very large present day example in the Australian region is provided by the Canterbury Plains of New Zealand, which receives outwash from a number of glaciers. Outwash plains aggrade (build upwards) as long as sediment supply from the glacier exceeds the capacity of the meltwater streams to fully flush the sediment down the valley. However, when the sediment supply is diminished, typically as a result of the waning of glacial erosion and reduced valley slope instability as the glacial climatic conditions ameliorate, the rivers can begin to flush the outwash sediments down the valley. Additionally, in Tasmania at least some Cainozoic glacial periods have been more arid than the interglacials; thus not only does the reduction in bedload resulting from the waning of glaciation give the rivers more capacity to incise their beds into the outwash plains, but average river discharges may increase, allowing further capacity to degrade the outwash sediment deposits which aggraded during the more arid glacial phases. As a result, the rivers begin to incise into the thick pile of outwash plain sediments, incising deeper channels and eroding stepped series of "degradational" terraces into the outwash sediments either side of the river channels. Ultimately the river will incise down to its base level, which may be somewhere close to the original level it occupied prior to the onset of

Figure 2: A typical present day valley-filling outwash plain. This plain, in the Indus River valley of the Pakistan Karakoram Range, is supplied by outwash from several major glaciers including the Baltoro Glacier which is sourced at K2, the worlds second highest mountain.

glaciation, leaving residual outwash deposits in a series of stepped terraces on the valley sides. Colhoun & Goede (1979, p. 389) identified extensive deposits of outwash sediments which they attributed to the older (pre-Last) Huon Valley glaciation, extending from Piners Eddy (below Tahune Bridge) upstream past the Huon-Picton confluence and also further upstream at Blake's Opening. They identified several degradational terrace surfaces incised into these deposits in the area of the Huon – Picton junction, which they considered were deposited and then rapidly terraced during the retreat of the glacier, and which they consider have not been subsequently been modified.

However, extensive outwash sediments also occur below the Huon-Weld River confluence (Sharples 1994a, b), but these were not identified or considered by Colhoun & Goede (1979). These sediments are the subject of this report. The highest parts of these deposits are situated considerably higher in the landscape (at 100-110m ASL) than the sediments near the Huon-Picton junction (at 60 – 70m ASL) that Colhoun & Goede consider were deposited then rapidly incised and terraced during retreat of the glacier. If only one major pre-Last Glaciation outwash episode is involved, then this rapid sequence of events is difficult to envisage given the need for the outwash sediment to have first built up to at least 110m ASL to allow for the deposition of outwash to that height downstream of the Weld River confluence, before having been incised back down to the present levels of the outwash terraces at the Huon-Picton confluence. As discussed in section (4.2), the glacier which generated the Southwood sediments must have retreated to beyond Blake's Opening before the outwash plain ceased aggrading at Southwood.

If only one glaciation is responsible for the outwash sediments at both Southwood and the Huon-Picton confluence, then it probably would have taken a considerable period of incision, after the glacier had retreated considerably or disappeared altogether, before the degradational terraces near the Picton-Huon confluence were incised.

Alternatively, the possibility arises that the Southwood Terrace sediments were deposited during an older and more extensive glaciation than that which later deposited and terraced the Huon-Picton junction outwash, albeit chemical alteration, weathering and other evidence (this report; Colhoun & Goede 1979) imply that both glaciations must have preceded the Last Glaciation.

The glacio-fluvial outwash sediments downstream of the Weld River junction (Sharples 1994a, b) which are the subject of this report sit higher on the valley sides than any other outwash sediments yet identified in the Huon Valley from the Picton confluence downstream, and hence probably represent the oldest and most extensive – or at least long-lived - phase of glacio-fluvial deposition yet identified in that section of the valley (evidence for older but less extensive glacio-fluvial deposits would most likely have been removed or buried by a later more extensive episodes, whilst any more extensive glacial episode, whether older or younger, should have left outwash remnants at still higher levels in the valley).

As noted above, it is likely that glacio-fluvial outwash from the Weld Valley, and possibly Eddy Creek valley, was confluent with the Huon Valley outwash at Glovers Plain. Further problematical deposits of unlithified alluvial or glacio-fluvial sediments of possible Quaternary age are known even further down the Huon Valley beyond the Southwood Terrace, and may in part be related to a major glacio-fluvial outwash event, potentially the same as that which deposited the Southwood sediments. Sharples (1994a) reported poorly sorted cobble-grade alluvial deposits of quartzite and dolerite near Judbury, which are further described in this report (section 4.3). It is possible that glacio-fluvial outwash from glaciers sourced on the Snowy Range may have been confluent with the Huon Valley outwash via the Little Denison River Valley above Judbury.

Similar quartzite-dominated cobble-grade alluvium deposits occur just above present sea level in the Huon estuary, where they are exposed in road cuttings just north of the township of Franklin. Farmer (1985, p. 64) described siliceous gravel and cobble deposits up to 40 metres above river level in the Huon Estuary, which he considered to be dissected remnants of terraced gravels which formerly choked the Huon River. They are similar to features in the Derwent Valley which Colhoun (in: Leaman 1977, p. 19-20) considered to have been deposited by much higher energy rivers than prevail at present, probably under cold climatic conditions preceding the Last Glaciation. Pebbly quartzite gravels and sands near the mouth of the Huon Estuary, at Randall's Bay, are of problematical origin, but were also considered by Farmer (1985) to represent early Quaternary river deposits.

It is likely that further study of apparent older Quaternary alluvium deposits in the Huon Estuary region would contribute significantly to understanding of past glacial events in the Huon Valley, and comparison of the altitudes at which such deposits and their terrace surfaces (if any) occur would be useful, taking into account that during glacial phases the sea level has stood 130 metres or more below its present level, such that river base levels in the area of the present Huon Estuary were then significantly lower than they are at present.

3.0 GLACIO-FLUVIAL LANDFORMS AND SEDIMENTS AT THE SOUTHWOOD DEVELOPMENT SITE

3.1 Site geology and topography

The Southwood project site – and Southwood Terrace – is the flat to gently undulating broad crest of a bedrock spur centred at 484 820mE 5233 280mN. The crest of the spur is situated at 100 – 110 metres above sea level, and about 70 - 80 metres vertically above the adjacent Huon River, which flows around the base of the south-western, southern and eastern sides of the spur. The confluence of the Huon and Arve Rivers is located immediately south of the Southwood site spur.

The spur ridge of the Southwood Project site is composed of Permian-age sedimentary bedrock of the Upper Parmeener Supergroup (Ford 1956, Forsyth *et al.*1995, Coffey 2002, present writer's field observations), which was correlated with the Late Permian Ferntree Group by Ford (1956) and is probably equivalent to the Abels Bay Formation correlate mapped by Calver (1997) east of Glovers Bluff, a few kilometres west of the Southwood site. The upper surface of the bedrock spur is mantled by a thickness varying between 5 to 12 (or more) metres of unlithified sediments which are interpreted as Quaternary – age glacio-fluvial outwash, and are described in section (3.2) below.

The Permian Ferntree / Abels Bay Formation rocks have been interpreted as marine sediments deposited circa 270 – 260 million years ago during a Permian glacial episode which long preceded the Cainozoic glaciations that are the main subject of this report (Clarke & Banks 1975). The Permian bedrock is exposed in road cuttings on the side-slopes of the spur, and comprises weathered grey-brown to yellow-brown siltstones, sandstones and some mudstones with massive to planar bedding dipping gently at approximately 5º towards the south-west (Coffey 2002). Sparse rounded pebbles of quartzite and other minor lithology's occur scattered through the bedrock, and are interpreted as glacio-marine dropstones. The rock is generally unfossiliferous, and has sub-vertical joint fractures. Coffey (2002) noted a number of sub-vertical shear/fault zones in the bedrock, striking approximately N-S and containing more altered and weathered material.

Road-cutting exposures at the north and south ends of the bedrock spur show that the upper 14 – 20 metres (vertically) of the Permian bedrock has been very deeply weathered indeed, to a soft silty-clay regolith which grades downwards into the weathered but still lithified bedrock below (see figure 14). At sites 18, 29 and 46 (see figure 13 and Appendix 2), the soft weathered bedrock is overlain by distinctly different coarse unconsolidated alluvium on a former landscape surface, which at site 18 dips roughly southwards at 7º (see figures 3 & 4). The weathered bedrock is a soft uniformly textured silty to sandy clay, typically pale creamy – yellow (10 YR 8/4), but with mottling and some irregular patches of pinkish-red colouration (5 R 7/4 to 5 R 5/4). Bedding is indistinct and no fossils were seen, however fine brown (iron-stained) fractures are common, and sparse rounded quartzite and mudstone dropstone pebbles occur in the material, particularly at sites 29 and 45. On the basis of similar sedimentological texture to nearby unequivocal Permian bedrock, the presence of similar fractures and (only) sparse dropstones, and a discernable transition

Figure 3: View looking west at Site 18 (near site 40) at the northern end of the Southwood site, showing unlithified silty-clay pebble/cobble alluvium (LHS, here yellowish grey) overlying soft yellowish, very deeply weathered Permian bedrock (RHS) on a former landscape surface dipping at 7º towards the south. Hammer above red pack is on the contact. The whole is overlain by a more recent surface mantle of quartz-pebble lag and colluvium.

Figure 4: Detail of soft, deeply weathered Permian bedrock at site 18, showing patchy pale yellowish and pinkish-red colours, and fine iron-stained fractures. Visible pebbles are debris from the overlying alluvium.

from less weathered Permian bedrock beneath (eg, from sites 2 to 46), this material is considered to be deeply weathered Permian bedrock regolith, rather than a Quaternary silty clay sediment related to the overlying alluvium.

Extrapolation between road cutting exposures and logs of two of the Coffey boreholes (Coffey 2002) suggests that the deeply weathered Permian bedrock was encountered in these holes, but not logged as such. Coffey borehole SMB1 (figures 13 & 14) extended to 31.5 metres depth (Coffey 2002). The drill log records weathered (Permian) mudstone and siltstone below 26m depth, however below 11.6m the log indicates an increase in clay content, and below 14.6m records predominantly sandy clay with some silty sand and some quartz pebbles. The 11.6m – 26m interval is close to the same level as deeply weathered Permian bedrock observed in the road cutting nearby to the south (sites 3, 45 – 46 and 29, see figure 14), and probably represents deeply weathered Permian siltstones and sandstones with some quartz dropstones, rather than unconsolidated alluvium. Similarly, in Coffey borehole SMB2 (figures 13 & 14), white silty clay below 4.5m depth contrasts strongly with overlying alluvium described as brown silty quartz sand with cobbles (Coffey 2002), and is also probably deeply weathered Permian siltstone.

The material in Coffey boreholes SMB1 and SMB2 which is here interpreted as deeply weathered Permian bedrock was assumed to be Quaternary alluvium in figures 3, 4 and 5 of Coffey (2002), hence the thickness of alluvium indicated in those figures is probably greater than the actual thickness of Quaternary alluvium present at the Southwood site.

Based on outcrop exposures and interpretation of Coffey (2002) borehole logs, it is evident that the bedrock surface under the crest of the Southwood site spur, upon which the Quaternary alluvium was deposited, slopes markedly downwards from north to south, towards the present Huon and Arve Rivers, and also slopes down somewhat from west to east (see figures 13 & 14). At site 18, the (deeply weathered) bedrock surface slopes southwards at about 7º (see figure 3). This is likely to represent a former valley slope towards the channel of the pre-glacial Huon River. It is assumed that the upper soft part of the bedrock was not soft and deeply weathered prior to deposition of glacio-fluvial alluvium, otherwise it would undoubtedly have been rapidly removed prior to deposition of the alluvium.

Subsequent to deposition of alluvium on the spur crest as part of a much broader outwash plain filling the Huon valley, post-glacial incision by the Huon River has removed most alluvium from areas around the Southwood spur. Coffey (2002, Figure 2: "degradational elements") noted several areas on the side-slopes of the Southwood spur where residual patches of alluvium remain well below the main spur-crest alluvial terrace[2]. See figure (13). These were only examined at site 33 during the present work, however if these are at least partly residual patches or incised ("degradational") terraces of *in situ* glacio-fluvial alluvium rather than purely colluvial (slope) deposits derived from the upper terrace area, then their existence implies that prior to glaciation, the Southwood Spur already existed as a spur of roughly similar form to the present feature, which was gradually engulfed by glacial outwash alluvium aggrading around and eventually over-topping it.

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[2] Extensive deposits of alluvium also occur on the Huon-Weld Plains below and west of the Southwood spur. These were not examined, but may be lower level deposits laid down at an earlier stage in the glacial phase that produced the Southwood Terrace and later re-exposed by fluvial incision, and/or may include more recent outwash deposits from later glacial episodes.

Although it is thus likely that post-glacial incision has to a large extent simply re-exposed a pre-existing bedrock spur at the Southwood site, nonetheless there has undoubtedly been some scarp retreat and modification of the bedrock side slopes of the spur by (fluvial) gully and slope erosion subsequent to post-glacial removal of surrounding alluvium deposits. In addition, Coffey (2002) note morphological evidence of at least three ancient landslips on the spur side-slopes, below the crest terrace, which probably represent phases of mass movement associated with scarp retreat of the bedrock side slopes. Coffey (2002) consider the side slopes stable today, and it is likely that, as in many other places in Tasmania, the ancient landslips at the site resulted from more active slope erosion and mass movement processes that occurred under the more arid conditions of the Last Glacial climatic phase (by which time interglacial fluvial erosion had already removed from around the slopes most of the sediment deposited in the large outwash plain that formed during the even earlier and more extensive glacial phase that the Southwood Terrace sediments date from).

3.2 Quaternary stratigraphy and sedimentology of the Southwood site

Unconsolidated sediments cap the crest of the Southwood Spur, resting on deeply weathered bedrock, and collectively vary in thickness from less than 5 metres near the north end of the site to over 12 metres thick near the south end (see figure 14). Three main sedimentary facies, and arguably a fourth basal facies at the southern extremity of the site, can be distinguished in these sediments. In addition, residual surface lags and colluvium (slope deposits) derived from these facies can be recognised. From the base of the Quaternary sediments (on deeply weathered Permian bedrock) upwards, the recognised facies are described as follows (see also map figure 13 and cross-sections figure 14); see the final part of section (3.2) for a discussion of the interpretation and origin of these sediments.

1. Basal alluvium with boulders

This basal unit was only observed in road cutting exposures at the southern extremity of the Southwood site (site 46), and does not appear to be present at the basal contact at the northern end of the site (around site 18). It is likely to lens out to the north of site 46, although a single rounded quartzite boulder nearly 1m diameter near site 35 suggests that the unit continues eastwards at the southern end of the Southwood deposits. The basal unit is approximately 3 - 4 metres thick at site 46, and grades up into the overlying silty-clay pebble/cobble alluvium. The basal unit is sedimentologically similar to the overlying alluvium, differing mainly in the occurrence of a proportion of larger boulder-grade clasts, and apparently some differing clast lithologies .

The basal sediment has a very poorly sorted clast-supported fabric comprising well rounded pebbles and cobbles, predominantly of quartzite, in a brown silty clay matrix. A small proportion of well rounded by generally elongate quartzite boulders up to 1 metre long are a characteristic feature of the basal facies. The sediment appears massive (no bedding was identified) and no imbrication or other common clast orientation was observed. A few deeply weathered pale speckled grey-white soft clayey cobbles 100 – 200 mm in diameter are exposed in a roadside drain at site 47, and appear to have a medium-

Figure 5: Typical exposure of silty-clay pebble/cobble alluvium at Site 40, showing apparent increase in matrix proportion below hammer which is mainly due to a higher proportion of very deeply weathered mudstone and siltstone clasts.

Figure 6: Detail view of silty-clay pebble/cobble alluvium at Site 40, showing hard unweathered quartzite cobbles, and soft, deeply weathered mudstone and siltstone clasts (eg, "ghost" clast outline visible immediately to LHS of hammer head).

grained igneous texture. These clasts form a minor component of the basal facies, and may be completely weathered Jurassic dolerite clasts, or possibly another igneous rock type.

2. Silty-clay pebble/cobble alluvium

This facies forms the basal unit sitting on underlying weathered bedrock throughout the Southwood terrace site, except at the southern end where a boulder - bearing basal lens (described above) is present. At the northern end of the Southwood site (at site 40), a full unit thickness of 5 metres is exposed between the underlying bedrock surface and the overlying sandy pebble/cobble alluvium. The thickness of the unit was not measured at the southern end of the Southwood Terrace, but is over 10 metres thick between its base at site 47 and exposures at site 5; the log of Coffey borehole SMB1 (Coffey 2002) is interpreted by the present writer as giving a thickness of over 11.4 metres at that site (immediately adjacent site 5), to which at least another metre thickness must be added to allow for adjacent outcrops above the borehole collar, yielding a thickness of over 12.5 metres at the southern end of the Southwood Terrace. See figure 14. This facies ranges in colour from a greyish to light brown colour at site 40 to a strong brown colour at site 5.

In road-cutting exposures near the northern end of the Southwood site (at site 40), the sediment is a very poorly sorted, unlithified, clast-supported conglomerate comprising granules, pebbles and cobbles up to 200mm diameter in a silty clay matrix (figures 5 & 6). The sediment appears massive, with no bedding or clast imbrication evident. The clasts are well-rounded with medium to low sphericity, and comprise approximately 60% (by volume) hard grey-white meta-sedimentary quartzite and roughly 40% soft weathered yellowish-brown to grey-white mudstone, siltstone and sandstone clasts. No dolerite clasts were identified, despite searching. The mudstone and siltstone clasts are completely weathered to soft clay and, on a cursory examination, give the conglomerate the appearance of having a much higher percentage of clay matrix than is actually the case (figure 6). The quartzite clasts are typical of meta-sedimentary quartzites found in the headwaters of the Huon River and some tributaries (including Manuka Creek), whilst the soft clasts are typical of Permo-Triassic sedimentary rocks also found in the Huon region; albeit no definitive evidence for this, such as fossils, was identified. However, the lack of obvious cleavage or veining in most of the mudstone and siltstone clasts suggests a Permo-Triassic rather than Precambrian provenance. The conglomerate matrix at site 40 comprises approximately 20 – 30% of the sediment by volume, and is a silty clay, varying to sandy silty clay in patches, with a mottled colour ranging from light grey (N8) to dark yellowish-orange (10 YR 6/6).

Sediments exposed in road cuttings towards the southern end of the Southward Terrace, at site 5, appear to be part of the same sedimentary unit as those described above at site 40, but are notably browner and have a higher apparent matrix proportion than the latter. At site 5, immediately adjacent the collar of Coffey borehole SMB1 (Coffey 2002), the road cutting exposes a surface lag (probably part colluvial) 100-200mm thick of quartzite pebbles and cobbles in an sandy organic soil O-horizon, underlain by at least several metres of very poorly sorted, unlithified, conglomerate in a brown silty-clay matrix (figure 7). The conglomerate is massive with no evident bedding structures or clast imbrication. The clasts comprise well-rounded, commonly elongate, pebbles and cobbles up to 200mm diameter of hard unweathered meta-sedimentary quartzite, and softer, weathered sandstone

Figure 7: Brown silty-clay pebble/cobble alluvium exposed in a road cutting at site 5, overlain by a winnowed lag and/or colluvial deposit of quartz pebbles probably derived from erosion of the upper part of the brown unit, and/or nearby or formerly overlying parts of the sandy pebble/cobble facies (see below). The apparent high matrix proportion of this sediment is partly due to deeply weathered "rotten" mudstone and siltstone cobbles which are difficult to distinguish in this view. Dark material immediately above the hammer head is organic material forming part of the soil O-horizon in which the lag is concentrated. The surface lag in this view is partly disturbed by excavation.

Figure 8: Road cutting at site 39 (northern part of Southwood terrace), showing sandy pebble/cobble alluvium overlying the silty-clay pebble/cobble alluvium on a scoured surface which was probably a shallow fluvial channel. A winnowed quartz pebble lag (thin whiter-coloured layer) is visible at the surface.

which appears typical of Triassic-age quartz sandstones from southern Tasmania. No dolerite clasts were identified. Fewer deeply weathered mudstone and siltstone cobbles are evident at site 5 compared to site 40, but it is likely that what appears to be matrix at site 5 includes a significant proportion of soft deeply weathered mudstone and siltstone clasts. Thus, although the conglomerate at site 5 appears superficially to be matrix-supported, it is likely that, as at site 40, it is clast-supported with many clasts being very deeply weathered and difficult to distinguish from the matrix. The matrix at site 5 is a silty clay which is distinctly browner in colour (dark yellowish-orange 10 YR 6/6 to light brown 5 YR 5/6) compared to that at site 40.

Generally brown unlithified silty-clay conglomerates similar to those at sites 40 and 5, lying above the underlying bedrock, and below the overlying sandy conglomerate, are exposed in road cuttings and in several Coffey pits and boreholes (Coffey 2002) at a variety of other sites on the Southwood Terrace, and are considered to be part of the same sedimentary unit on the basis of lithological similarity and apparent contiguity (see figure 13).

3. Sandy pebble/cobble alluvium

The silty-clay pebble/cobble alluvium (conglomerate) is overlain by sandy pebble/cobble alluvium which in the main terrace area varies in thickness from less than 0.5 metres (eg, at site 25) to about 2.0 metres (at site 17), and which both thickens and steeply descends in altitude from the main terrace down the eastern side of the Southwood Spur, reaching over 2.5 metres thickness at site 16 (see figures 13 and 14). The base of the sandy pebble/cobble unit also drops a few metres between the northern and the middle parts of the main terrace, and the unit fills a shallow scoured channel in the underlying sediment at site 39 (see figure 8). The uneven surface upon which the sandy pebble/cobble alluvium lies is interpreted as being at least partly erosional, representing a phase of scouring and fluvial degradation of the Southwood Terrace intervening between the deposition of the silty-clay and sandy pebble/cobble deposits.

The sandy pebble/cobble alluvium is of distinctly different sedimentological character and composition to the underlying silty-clay pebble/cobble alluvium. At site 12 (see figure 9), the sandy pebble/cobble alluvium is a poorly sorted, unlithified grey-white clast-supported conglomerate comprising granules, pebbles and cobbles up to 150mm diameter in a sandy matrix. The sediment is massive and no bedding structures – including cross-bedding – or clast imbrication was identified. The pebbles and cobbles are well-rounded with moderate to low sphericity, and comprise approximately 70% – 80% of the sediment by volume. Nearly all clasts identified were of hard unweathered grey to white quartz or meta-sedimentary quartzite; no dolerite, mudstone, or siltstone lithologies were seen, however a small proportion of softer quartz sandstone clasts can also be identified: these may represent Triassic sandstones of the Parmeener Supergroup rather than meta-sedimentary quartzite. A few quartzite clasts (at this and some other sites) have small roughly angular "holes", which may be indicative of box-work replacement silica after dolomite such as occurs at Blake's Opening, Glovers Bluff area and some other parts of the middle Huon valley area.. These were also previously noted by Sharples (1994a, vol.2, p. 109), but are rare and equivocal; it is possible the "holes" seen were simply mechanical impact features related to glacial processes, rather than replacement silica boxworks. The finer matrix, comprising 20% - 30% of the sediment by volume, is an unconsolidated, mostly fine-

Figure 9: Sandy pebble/cobble alluvium on the main Southwood Terrace surface at site 12. Note the lack of a distinct quartz pebble lag or colluvial layer at the surface, either within or immediately beneath the surface organic soil horizon, which is interpreted as indicating that there has been little if any denudation (erosion or surface lowering) at this site subsequent to the end of the phase of glacio-fluvial sedimentary processes.

Figure 10: Exposure of over 2.5 metre thickness of sandy pebble/cobble alluvium in a quarry face at site 16, where the unit thickens and descends to lower altitude on the eastern side of the Southwood spur (see figures 13 and 14).

grained (but poorly sorted with granules and some silt) sand comprising sub-angular to sub-rounded quartz grains. The matrix sand is a very light grey to white (N8 – N9) colour when freshly exposed.

At site 16, the sandy pebble/cobble alluvium is at least 2.5 metres thick in quarry face exposures (see figure 10). The sediment is lithologically identical to that at site 12, except that larger cobbles seem more abundant than at site 12. Coffey borehole SMB2 (collared a metre or so below the top of the sandy pebble/cobble unit exposed nearby at site 14, adjacent the lower part of the quarry) intersected 2.2 metres of the sandy pebble/cobble alluvium overlying 2.3 metres of brown silty alluvium which is here interpreted as the underlying silty-clay pebble/cobble alluvium (Coffey 2002). The upper surface, and presumably the base, of the sandy cobble/pebble unit dips steeply eastwards at site 16, the upper surface dip being visible in a road cutting between sites 12 and 14 (see also figure 14).

At some sites (eg, site 13; see below) the sandy pebble/cobble alluvium is partly cemented by iron oxides or hydroxides below about a metre depth, producing a hard, dark greyish-brown (5 YR 3/2) "coffee rock" horizon which is a soil B horizon iron pan. As noted by Coffey (2002, p. 9), this less-permeable iron pan, which probably underlies much of the flat main terrace area, probably impedes groundwater drainage, partly accounting for poor drainage and wet surface conditions that were observed over much of the terrace surface (see also section 3.3).

4. Granular quartz sand facies

The sandy pebble/cobble colluvium is in some areas overlain by discontinuous thin lenses of fine quartz sand with a granular fraction, which forms the uppermost distinct Quaternary sediment facies at the Southwood Terrace (see figures 13 & 14). The maximum observed thickness of this unit was 1.05 metres (at site 13); thicknesses of 0.6 and 0.4 metres were logged in Coffey pits STP1 & STP3 respectively, and the unit is up to 1 metre thick in a road cut descending from site 12 down the eastern slope of the Southwood spur to site 14, where it lenses out.

The granular sand unit rests on an uneven surface at the top of the sandy pebble/cobble unit, which at site 13 is exposed as a channel-shaped scour about 38 metres wide in the road cutting exposure (see figure 11). It is inferred that a phase of fluvial erosion and scouring intervened between deposition of the sandy pebble/cobble unit and the overlying granular sand unit. The sandy pebble/cobble unit occurs at the surface on the highest, northern parts of the Southwood site, but has been scoured to an altitude about 5 metres lower in the main terrace part of the Southwood site, suggesting that this erosion (fluvial degradation) phase left a higher terrace surface at the northern end of the site. At site 9, the granular sand rests directly on the silty-clay pebble/cobble facies, indicating that in some areas the sandy pebble/cobble facies was entirely removed prior to deposition of the granular sand. The granular sand unit was not observed on the highest (northern) parts of the Southwood Terrace, but occupies parts of the main terrace surface at 100 – 106m ASL, and, as with the underlying Quaternary units, the base of the granular sand unit descends steeply down the eastern side of the Southwood Spur (see figures 13 & 14).

Figure 11: View looking to the southwest of the granular sand lens overlying sandy pebble/cobble facies at site 13, showing scoured surface on which the sand lens was deposited. The sand facies lenses out to both the south (shown) and north (out of photo to the RHS).

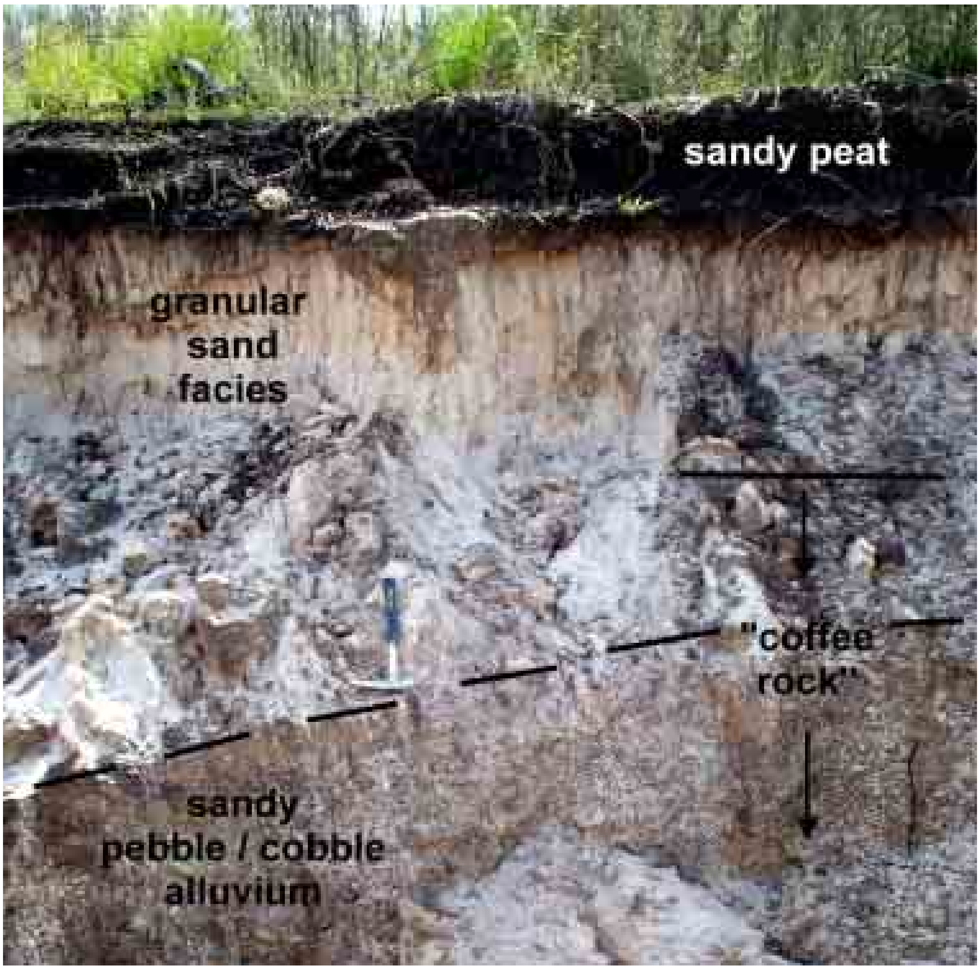

Figure 12: Detailed view of granular sand unit at site 13, showing overlying sandy peat O-horizon, and underlying sandy pebble/cobble alluvium. Hammer handle approx. 300 mm long.

At site 13 (see figures 11 & 12), the granular sand unit is overlain by an organic soil O-horizon comprising 0.3 m of greyish-black (N2) sandy peat, with no pebble lag or colluvium. The lower boundary of the O-horizon is sharply defined and is underlain by 1.05 m of granular sand in the thickest (central) part of the sand lens, which lenses out to zero thickness 18 metres horizontally to the south, and 20 metres to the north. The granular sand lens at site 13 is underlain, on a sharp boundary, by sandy pebble/cobble alluvium contiguous and identical with that described (above) at the adjacent site 12. The upper 0.8 metre of granular sand is soft, unlithified and has a bleached white to light grey (N7 – N8) colour, constituting a podzolic soil A horizon. Below this there is a gradual transition into the lower 0.25 m of granular sand which is a relatively hard semi-lithified (Fe – cemented) "coffee rock" sand that is a podzolic soil B horizon. The semi-lithified granular sand shows mottled light grey (N8) and dark greyish-brown (5 YR 3/2) colouration, with the brown colouration becoming more dominant downwards. The semi-lithified "coffee rock" B horizon extends into the underlying sandy pebble/cobble alluvium, which is similarly Fe-cemented at this site.

The upper (unlithified) and lower (Fe-cemented) parts of the granular sand unit at site 13 are sedimentologically similar. The sand is massive with no indication of bedding, including cross-beds. The sediment predominantly comprises fine grained (0.2 mm av. diameter) sub-angular to sub-rounded quartz grains, but includes up to 20% by volume of sub-angular to sub-rounded quartz granules 1.0 – 2.0 mm diameter, overall making the sediment a moderately to poorly sorted bimodal fine + granule grade quartz sand.

At other sites where the granule sand facies was examined (eg, sites 7, 26, 27 and 38), it is similar to that at site 13 except that in some cases a small proportion of rounded quartz pebbles is also present.

Lower – level alluvium

Coffey (2002, fig. 2) noted the presence of patches of Quaternary alluvium at several levels on the slopes of the Southwood spur, mantling Permian bedrock below the base of the Quaternary sediments capping the spur crest (see figure 13). These are interpreted as residual remnants of alluvium deposited earlier and at lower levels in the outwash sediment pile than the sediments capping the spur, which have been re-exposed as post-glacial fluvial incision eroded and removed most of the sediments in the former valley-filling outwash plain.

These lower-level sediments were only examined at site 33 (see figure 13), where they comprise approximately 1 metre thickness of rounded quartzite cobbles in a sandy matrix, overlying soft clayey deeply-weathered Permian siltstone bedrock similar to that underlying the main terrace sediments beneath the spur crest. The sediment composition and deeply weathered nature of the underlying bedrock is consistent with these sediments being of similar age to the sediments on the crest of the Southwood Spur. It is noteworthy that at site 31, which is nearby at the same altitude (figure 13), Permian bedrock which does not have a mantle of alluvium is relatively unweathered. The presence of deeply weathered bedrock under the mantle of alluvium at site 33 suggests that the alluvium has been protecting the bedrock at that site from erosion for a considerable period, while it has been weathering to soft clay.

The existence of lower level residual alluvium patches on the spur side-slopes, that are likely to have been deposited earlier in the same glacio-fluvial episode that finally deposited the Southwood Terrace sediments above them, is interpreted as demonstrating that the Southwood Spur already existed as a spur ridge, of roughly the same form as today, prior to deposition of the outwash sediments which eventually engulfed and over-topped the spur (see also discussion in section 3.1).

Lower still, extensive blankets of coarse alluvial sediments blanket the Weld Plains (beside the Huon River) from the western foot of the Southwood spur westwards to the Weld River confluence (figure 13). These were examined at site 28 (figure 13), where they comprise coarse rounded quartzite cobbles (no dolerite seen) in a pale grey clay matrix. The age of these deposits is unclear, however it is likely that, at least in part, they were also deposited in an earlier stage of the same glacio-fluvial deposition episode in which the Southwood Terrace sediments were deposited. It is possible, however, that deposits of younger (even Last Glacial-age) outwash sediments are also present on the Weld Plains.

Quartz pebble lag and colluvium

Concentrated deposits of rounded white quartzite pebbles and cobbles, typically associated with organic soil material, form surface layers up to 0.3 m thick over some areas of the Quaternary alluvial deposits and on slopes over Permian bedrock below the alluvial sediments capping the Southwood Spur (see figures 7 & 8). These are interpreted as lags formed by erosion of the pebble/cobble alluvium, resulting in concentration of coarser clasts as the finer matrix is winnowed out, and colluvial (slope) deposits resulting from down-slope creep of the lag material.

Quartz pebble lag and colluvium is present on most slopes around the main Southwood terrace, and lags also occur on some areas of flat to only gently sloping ground, for example on the higher northern parts of the Southwood site (around sites 18 & 39) and on slightly lower parts of the terrace such as around sites 5 & 8 (see figure 14). However, quartz pebble lags are mostly absent from the main part of the Southwood Terrace (between sites 7 & 12), including areas such as site 12 where pebble/cobble alluvium forms the upper sedimentary facies (see figure 9).

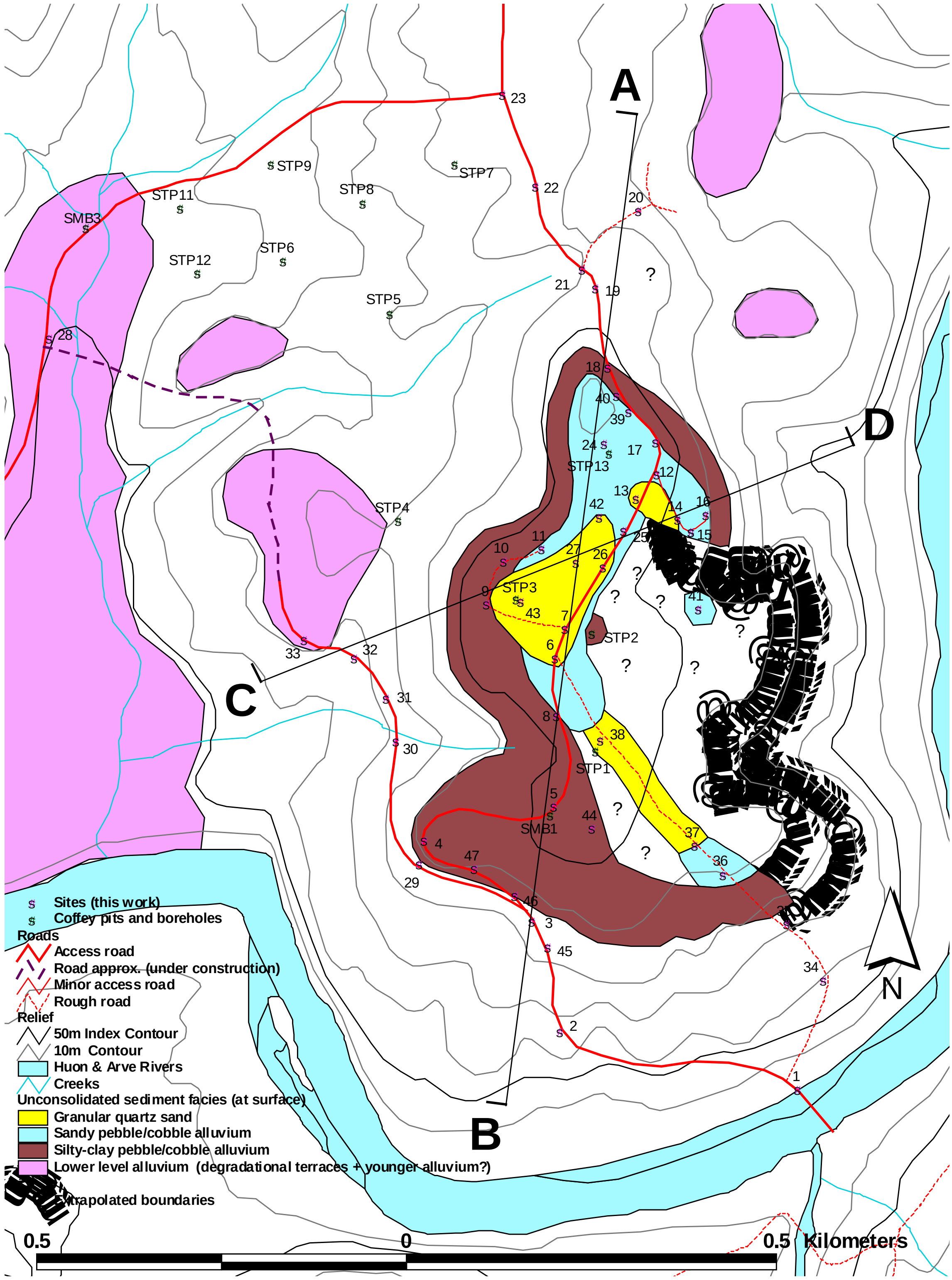

Figure 13: Surface distribution of unconsolidated Quaternary sedimentary facies at the Southwood site. Basal boulder alluvium not shown, but is a thin lens forming the base of the silty-clay pebble/cobble alluvium at site 46. Underlying bedrock is not indicated, but in the area shown is entirely Permian-age siltstones, mudstones and sandstones of the Upper Parmeener Supergroup. Colluvium is not shown, but quartz pebble lag and colluvium mantles slopes over and well below the *in situ* Quaternary sedimentary units (see cross-section Figure 14 following). Poor substrate exposure in the eastern part of the sediments has resulted in mapping gaps in that area. Cross-section lines (A-B and C-D) refer to figure 14.

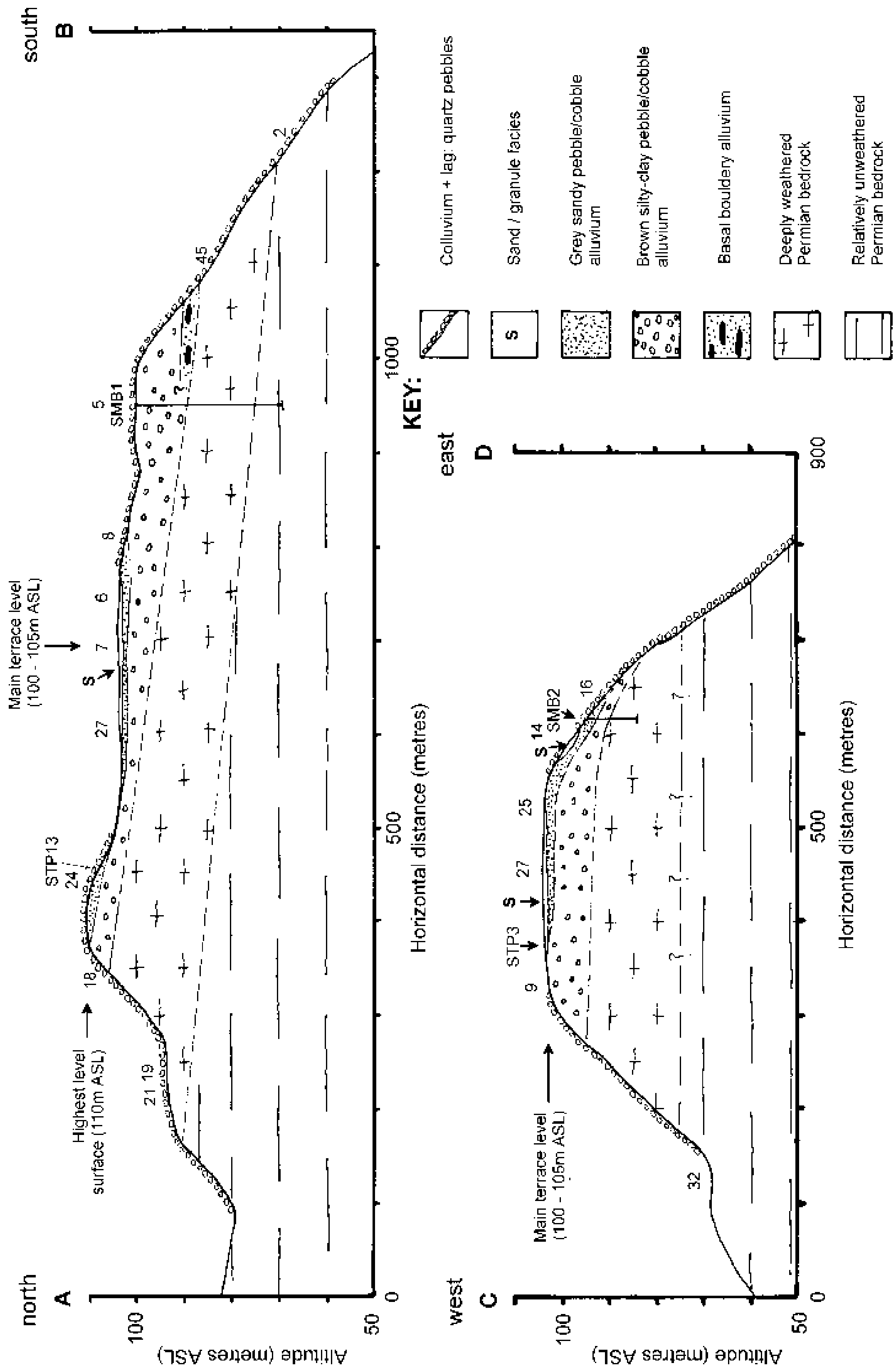

Figure 14: Cross-sections through Southwood terrace Quaternary sediments (see figure 13 for cross section locations). Numbers above profiles correspond to numbered sites (see figure 13) and Coffey boreholes and pits (Coffey 2002).

Interpretation: nature, origin and age of unlithified sediments at the Southwood site

Origin and depositional environment of the unlithified Southwood sediments

Given the soft and deeply weathered nature of the underlying Permian siltstone bedrock, and the complete lack of Jurassic dolerite clasts in the overlying sediments, one possible explanation for the pebble-cobble grade sediments on the crest of the Southwood spur is that they represent deeply weathered residual deposits from Permian or possibly Triassic age sedimentary rocks overlying the siltstone. However, this explanation is unlikely on the following grounds:

- Residual patches of similar and probably related coarse sediments occur at lower levels on the side slopes of the spur, in positions where the laterally – equivalent bedrock is siltstone of completely different lithological character, containing only rare quartz pebble dropstones. It is improbable to conceive of the adjacent bedrock yielding weathering lags containing abundant coarse quartzite cobbles.

- The coarse sediments on the spur crest contain mudstone, siltstone and sandstone cobbles which are themselves likely to have been eroded from pre-existing Permo-Triassic bedrock some substantial time after deposition, lithification and uplift of the latter (albeit this has not been unequivocally demonstrated).

- The underlying bedrock is considered to be a correlate of the Late Permian Ferntree and Abels Bay Formations (section 3.1). These units contain only minor scattered quartz pebble dropstones, and neither correlates of these units, nor overlying Late Permian or Triassic bedrock units anywhere in Tasmania, are known to contain large quartzite cobbles in sufficient concentration to yield the sort of deposits found on the Southwood Spur by weathering processes.

The unlithified conglomerates and sands on the Southwood Terrace are instead considered to be primary sedimentary deposits. However, they lack the characteristic matrix-supported textures of tills and some slope or mass movement deposits, and their location on the crest of a spur which probably existed as a spur prior to their deposition indicates that an origin by slope transport is unlikely. The only other explanation that appears to be available for these sediments is that they are water (i.e., river) laid sediments. However, the very poor sorting and lack of discernable bedding or imbrication in the coarser units (the silt-clay pebble/cobble and sandy pebble/cobble facies) makes it difficult to envisage deposition by rivers having the relatively constant and moderate discharges of Tasmanian rivers under interglacial climatic conditions.

Coarse facies

The poor sorting and mostly structureless nature of the coarse sediments is suggestive of energetic pulses of fluvial transport followed by rapid dumping of both coarse and fine material. The most likely mechanism available to explain such a mode of transport and deposition is the highly variable discharge characteristic of a temperate glacial meltwater system. Such glacial meltwater systems experience both diurnal and seasonal pulses of strongly waxing and waning meltwater flows, which produce energetic meltwater floods (eg, during the daytime) capable of transporting very coarse material, interspersed with significantly reduced flows (eg, at night) during which sediments are dumped with little sorting.

Evidence previously cited (sections 3.1 & 3.2 "Lower Level Alluvium") suggests that the Southwood Spur existed as an isolated spur prior to deposition of the sediments which eventually overtopped and mantled the spur crest (this further implies that the Huon Valley itself was roughly as deep as the present valley prior to being filled with the sediments). This requires that those sediments were part of a valley-filling sequence which filled (aggraded) the Huon Valley to a depth of about 70 metres in the Southwood part of the valley, and was subsequently almost completely removed (degraded) by later fluvial incision and erosion. A phase of high sediment supply followed by a phase of greatly reduced sediment supply allowing river waters to erode and flush the sediment pile out of the valley section is indicated. This behaviour is characteristic of glacial erosion and outwash phases followed by non-glacial fluvial phases with greatly reduced catchment erosion.

Thus, the best explanation available for the coarse-grade Southwood Terrace sediments is that they are glacio-fluvial outwash sediments deposited on a broad glacial outwash plain that filled the Huon Valley to the level of the Southwood Terrace. The lack of evident cross-bedding or imbrication in the coarser Southwood Terrace sediments is further interpreted as indicating that the sediments observed were not channel deposits, but flood deposits rapidly dumped across broad areas of outwash plain during diurnal and/or seasonal meltwater flood pulses.

Granular sand facies
In contrast to the lower coarse units that form the bulk of the sediments capping the Southwood Spur, the uppermost granular sand facies shows considerably better grain sorting, and its much smaller grainsize suggests a lower energy depositional environment. Colhoun & Goede (1979, p. 378) described similar medium grained quartz sands with granules overlying glacio-fluvial outwash (of possibly the same age as that at Southwood) at Blake's Opening. On the basis of pollen and other plant remains in the sands, they interpreted those sands as having been deposited in the still waters of a back swamp.

The granular sand facies overlies the coarse glacio-fluvial sediments at Southwood, and is clearly the youngest and last-deposited sediment preserved at the site. The facies is here interpreted as having been laid down as overbank floodplain sediments during the final waning stages of the glacio-fluvial outwash episode, but before major reduction of sediment supply had permitted the river to begin incising significantly into the outwash plain (which would have eliminated any sediment supply to remaining higher floodplain surfaces, and would have drained those areas of water). The deposition of sand grade sediment at the Southwood Site may be due to an overall reduction in the calibre of sediment being supplied by the waning outwash waters, or may be due to a more localised effect of the main river channels having moved away from the northern side of the valley, so that only fine calibre sediment reached the Southwood site as overbank flood waters spread across the floodplain away from the main channels. The lack of observed cross-bedding in the granular sands at Southwood is indicative of overbank deposition away from river channels, although it is noteworthy that similar and possibly correlated sands deposited over outwash a few kilometres to the west near the Weld-Huon confluence (see section 4.3) show apparent cross-beds, which may be indicative of channel deposition of parts of the sand facies.

Sediment composition and implications

Lack of dolerite clasts

A prominent feature of the Southwood Terrace sediments is their complete lack of dolerite clasts. This is surprising because many parts of the Huon Catchment upstream of the Southwood site include dolerite bedrock, both on mountain tops (eg, Mt Picton, Mt Weld), and in valley floors (eg, Picton Valley, Huon Valley near Pear Hill, ~3km upstream of the Picton confluence) which would have been glacially eroded and supplying sediment to outwash flowing down the Huon Valley, at least during parts of the glacial episode. Colhoun & Goede (1979, p.389) noted that dolerite was present in tills and at the base of overlying outwash deposits at Blake's Opening and near the Huon-Picton junction, but in both areas is less evident in higher outwash deposits and (at Blake's Opening) higher morainal deposits. This appears to suggest that dolerite formed a significant component of glacial and glacio-fluvial sediments early in the glacial episode (i.e., lower in the sedimentary deposits), but became less prominent later.

Kiernan (1989a, p. 221 etc) noted varying clast compositions in glacial sediments of the Franklin River valley (western Tasmania), which he attributed to changing provenances (i.e., source areas) related to changing glacier configurations and extents at different times. The explanation proposed here for the lack of dolerite in the Southwood glacio-fluvial deposits similarly assumes changing sediment provenances during the course of the glacial episode, and in particular is based on the inference (from their height in the landscape and other evidence provided in this report) that the Southwood sediments represent the final stages of glacio-fluvial outwash deposition in the recessional phase of a major glacial episode.

It is proposed that dolerite comprised a significant proportion of glacial and outwash sediment in the Huon Valley when the valley glaciers were relatively extensive and were eroding extensive dolerite bedrock areas. However during later stages of the glacial episode the main glaciers retreated up-valley from the dolerite bedrock areas in the valleys, and the mountain top cirque glaciers were greatly reduced or disappeared, which resulted in greatly reduced erosion of dolerite, and consequently a greatly reduced supply of dolerite clasts in the outwash sediment. The deposition of the high-level Southwood sediments occurred in the final stages of glacial retreat shortly before a major decline in sediment supply caused the outwash plain to cease aggrading altogether, and this was evidently a time when very little dolerite was still being glacially-eroded and transported from the catchment areas that were still occupied by the retreating glaciers.

The furthest upstream area of dolerite bedrock that would have been directly eroded by the main trunk of the Huon Valley glacier occurs in the narrow river gorge north of Pear Hill[3], about 3 km upstream of the Huon-Picton confluence. Once the glacier had receded up-valley from this gorge the supply of eroded dolerite in the glacial outwash would have

[3] Current 1:25,000 scale geological mapping (Picton sheet) shows little dolerite bedrock in this gorge, but the presence of dolerite bedrock at low levels in this part of the valley was previously noted by Colhoun & Goede (1979, p. 389), and Sharples (1994a, vol.2, p. 67).

diminished markedly. The only significant potential source of dolerite further upstream is the upper slopes of Mt Picton. Although cirque glaciers are considered to have been present on Mt Picton and may have been confluent with the Huon Glacier below at the maximum extent of the glacial ice, Colhoun & Goede (1979, p. 389) considered that the Huon Glacier received little contribution from the dolerite – capped Mt Picton during the deposition of moraines at Blake's Opening, which are presumably recessional features formed when the glacier had receded to Blake's Opening (well upstream of the Pear Hill gorge). Thus, it is proposed that once the glacier had retreated up-valley from the Pear Hill gorge, the supply of dolerite to the glacier and its outwash sediments would have greatly diminished, resulting in the outwash being dominated by the Precambrian quartzites, silicified dolomites and Permo-Triassic sedimentary rocks present in the areas further upstream that were still being eroded by the glacier.

Since large quantities of dolerite would also have been eroded from both mountain top and valley floor locations in the Picton and Weld Valley at the maximum extent of the tributary glaciers in those valleys, it must be assumed that similar mechanisms during glacial retreat resulted in significant reduction in dolerite erosion and transport in those valleys also. The extensive occurrence of dolerite in some high-altitude areas of the Weld and Picton Valley that late stage glaciers would have retreated to (eg, on the South Picton Range at the head of Cook Creek) may imply that the glaciers must have disappeared altogether or become largely moribund in the Weld and Picton Valleys at the same time as the retreating Huon Glacier was still sufficiently substantial as to be eroding enough Precambrian quartzites and Permian mudstones in the headwaters of Manuka Creek to supply outwash that was still aggrading as far downstream as the Southwood Terrace.

Change in clast and matrix composition between facies

There is a notable reduction in clay content and increasing silica (quartz) content going upwards through the Quaternary sedimentary sequence at the Southwood Terrace. Whereas the lower silty-clay pebble/cobble facies contains abundant mudstone and siltstone clasts (weathered to soft clay) and a clayey matrix, the overlying sandy pebble/cobble facies has a predominantly sandy (siliceous) matrix with dominantly quartzite pebble and cobble clasts and few mudstone or siltstone clasts.

Whereas the causes of changes to matrix compositions alone could lie partly in local processes such as channel migration across the outwash plain changing local hydrodynamic processes so as to result in increased winnowing of the higher sedimentary facies, it is difficult to account for the major reduction in proportions of coarse-grade mudstone and siltstone clasts in this way. As with the distinction between dolerite-bearing and dolerite-free sediments discussed above, a change in sediment provenance may be a more likely explanation. Permian sedimentary bedrock (interpreted as one of the two main components of the silty-clay pebble/cobble facies, along with Precambrian quartzites) is present up to about 400m ASL in the Huon Glacier source area at the headwaters of Manuka Creek (Calver 1997), however above that altitude only Precambrian quartzite bedrock is present. It is possible that the transition from the lower siltstone/mudstone and quartzite – bearing silty-clay pebble/cobble facies to the overlying quartzite-only sandy pebble/cobble facies may be related to the recession of the retreating Huon Glacier to areas above 400m ASL in the head of Manuka Creek. Since this transition occurs only a few kilometres below the cirque headwalls at Gallagher Plateau to which the Huon Glacier probably receded in its final waning stage, this scenario is again consistent with the proposal that the sediments deposited on the Southwood Terrace were probably being deposited at a very late stage in the recession of that glacier.

Age of the Southwood sediments

Absolute age testing of the sediments at the Southwood Terrace has not been undertaken, although it may be possible to constrain their age by means of palynological , thermo-luminescence or other means. However, a suite of samples has been collected with a view to undertaking such tests in the future, and these samples are listed in Appendix 3.

In the absence of absolute dating tests, the following weathering, post-depositional modification and topographic criteria provide some constraints on the ages of the sediments:

Regolith development

The sediments rest on a Permian siltstone bedrock surface which is deeply weathered to soft silty clay regolith for a depth of 14 – 20 metres below the terrace sediments (section 3.1, see Figure 14). In contrast bedrock which has not been covered by the sediments for a considerable period (eg, at sites 2 and 31) is relatively unweathered and hard in surface outcrops. This indicates that a considerable period of weathering and regolith development has taken place since the bedrock surfaces have been protected from erosion by an intact mantle of Quaternary sediments. Where such a mantle has been removed (as at sites 2 and 31), normal erosion processes have removed bedrock as it has weathered, preventing the preservation of a deeply weathered soft regolith layer at the bedrock surface. Whilst the depth of regolith development in bedrock beneath a protective surface sediment mantle can be expected to bear a proportional relationship to the period over which the bedrock surface has been protected from erosion, little data is available which would give an indication of the absolute ages implied by varying regolith thicknesses, under particular environmental conditions, for Tasmania. Hence, whilst the depth of bedrock weathering at the Southwood site gives an impression of considerable antiquity, it is not possible to suggest absolute dates for that antiquity on presently available information.

Weathering of sedimentary cobbles

Similarly, mudstone and siltstone (but not meta-sedimentary quartzite) clasts up to 20 cm diameter in the coarse outwash sediments have everywhere been uniformly weathered throughout to a soft clay, which in the silty-clay pebble/cobble facies appears to have contributed significantly to the clayey matrix of the sediment. Given that these cobbles were deposited in a high energy fluvial environment it can be assumed the clasts were hard and unweathered at deposition; hence their degree of post-depositional weathering provides a measure of the time elapsed since deposition. Weathering rind thicknesses on dolerite clasts in Tasmanian Quaternary deposits have been used to identify deposits of differing relative ages (Kiernan 1983, 1990a), and under some circumstances can be calibrated to provide rough constraints on absolute ages. Whereas subsurface dolerite cobbles deposited during the most recent glaciation typically have weathering rinds only a few millimetres thick (Kiernan 1983), Colhoun & Goede (1979) found that dolerite cobbles up to 300mm diameter in the tills at Blake's Opening were completely rotted, which is consistent with tills deposited during the maximum Cainozoic glaciation (Kiernan 1983). However, little comparable data is available for rates of post-depositional weathering of sedimentary clasts in Tasmanian Quaternary deposits. It seems reasonable to assume that clay-rich sedimentary rocks such as siltstone and mudstone will typically weather more rapidly than dolerite, hence whilst the deeply weathered nature of the mudstone and siltstone cobbles at Southwood probably constrain them to an age greater than the Last Glaciation, they would be consistent with ages both younger and older than the maximum Cainozoic glaciation.

Iron pan development
Well developed iron pans ("coffee rock" B horizon development) occur at about one metre depth in sandy sediments at the Southwood Terrace, and also in probably equivalent sediments north of the Huon-Weld confluence (see sections 3.2 above and 4.3). B-horizon iron pan development becomes more pronounced with age and so also provides a relative age indicator. The degree of iron pan development at the Southwood Terrace site is likely to be indicative of a pre-Holocene (>10,000 years) age, however comparison with iron pan development in similar sediments of known age in similar environments elsewhere in Tasmania is necessary to evaluate the degree to which iron pan development can constrain the age of the Southwood sediments.

Position in the landscape
As discussed previously (section 2.2), the Southwood Terrace sediments are the highest glacio-fluvial outwash sediments known in the Huon Valley landscape, and this suggests they are likely to have been deposited by the most extensive glacial episode that has affected the valley. It is reasonable (but by no means certain) to suppose that this episode may have been that correlated with the Linda Glaciation and other equivalents of the maximum Cainozoic glaciation known from other parts of Tasmania (section 2.2).

Pre-depositional landscape form
Evidence cited above (section 3.1 and "lower level alluvium" above) suggests that the depth of the Huon Valley and the form of the Southwood Spur prior to deposition of the glacio-fluvial outwash sediments was not greatly different to their present depth and morphology today. This suggests a very rough constraint on the maximum ages of the sediments, in that a valley and spur topography not greatly dissimilar to today implies a likely age of only a few million years at most, and probably a Quaternary (i.e., within the last two million years) age.

Summary – age constraints
In summary, in the absence of any form of absolute age testing, the available evidence allows only rough age constraints to be placed on the Southwood Terrace sediments. Those constraints suggest that the sediments are older than the Last Glaciation (circa 19,000 years BP), but probably no older than a few million years. Weathering criteria and the position of the sediments in the landscape appear consistent with correlation to the Linda Glaciation (>730,000 years BP) and other equivalents of the maximum Cainozoic Glaciation.

With additional study, it may be possible to provide more rigorous indicators of relative age using post-depositional modification parameters at the Southwood site (see Kiernan 1990a), however time and resources did not permit more detailed studies of this sort to be attempted.

3.3 Glacio-fluvial terrace landform morphology and preservation at the Southwood site

Pre-glacial bedrock surface

Evidence from surface exposures and drill-holes shows that the bedrock surface upon which the Southwood Terrace sediments sit slopes down gently from north to south, and also slopes down on the eastern side of the spur (Figure 14). This surface represents the pre-glacial topography of the spur crest, and if the pre-glacial bedrock surfaces are interpreted as ridge crest and side slopes declining towards the pre-glacial Huon River channel, then a similar topography to the present is implied, with the Huon Channel passing around the southern and eastern sides of the spur.

Highest surface

The highest part of the Southwood Terrace sediments occurs at the northern end of the spur (near sites 18, 24, 39 & 40 – see Figure 15), where the sediment pile reaches 110m ASL in a distinct rise. This high area is underlain by the silt-clay and sandy pebble/cobble facies, but not the granular sand facies. Quartz pebble lags and colluvium mantle the top and sides of this rise, indicating that it has undergone some erosional dissection (see Figure 14), and there is no evidence that an original terrace surface is preserved in this area.

Main terrace surface

The main part of the Southwood Terrace is a distinct surface between 100-105m ASL in the area encompassed by sites 8, 9, 13 and 38 (see Figures 14, 15, 16 & 17). Most of this surface is nearly flat, with slopes in the range of 0º to 3º only (Figure 16). A slight rise to a maximum elevation of about 106m occurs between sites 6 and 9 (Figure 15). The flat surface ends at distinct breaks of slope on the western, south western and north-eastern sides (at sites 9, 10 & 11 on the western side, near site 8 on the southwest side, and between sites 13 and 14 on the north-eastern side). The flat surface of the main terrace is poorly drained, with swampy button-grass areas in the region around site 27 (Figure 15). The poor drainage is due to a combination of the very flat topography which impedes surface drainage, and the presence of iron pans at about 1 metre depth which inhibit groundwater drainage.

This main terrace level is largely (but not entirely) mantled by the granular sand facies which overlies both the sandy and silty-clay facies (see Figures 13 & 14). In virtue of its uppermost stratigraphic position, the granular sand facies is interpreted as the youngest sedimentary facies, and it is noteworthy that this younger facies has been deposited on a flat surface at slightly lower altitude than occurrences of the older coarse facies on the rise immediately to the north (see Figure 14). Gentle channel cross-sections eroded into the top of the underlying sandy pebble/cobble facies at site 13 on the main terrace (Figure 11) indicate that a phase of fluvial incision occurred after deposition of the coarse facies. The main terrace level on which the granular sand was deposited is thus interpreted as a degradational fluvial terrace incised into the older sediments prior to deposition of the granular sand, leaving a slightly higher residual portion of the older deposits at the northern end of the spur. The granular sand facies evidently filled shallow channels eroded into the degradational terrace, covering most of the terrace surface but probably leaving a few areas (eg, site 12) uncovered.

However, there is no evidence that significant further erosion of the main terrace surface has occurred following deposition of the granular sand facies over the degradational terrace surface incised into the underlying coarse sediments. This assertion is supported by the following grounds:

- Residual surface lag deposits are not evident on the main terrace surface, which implies that erosion resulting in lowering of the surface has not occurred. This is particularly apparent in small portions of the surface, such as at Site 12, where the granular sand facies has not covered the underlying sandy pebble/cobble facies (see Figure 9). Where surface erosion of this facies has occurred elsewhere, a residual lag concentration of quartz pebbles is generally evident (e.g., see Figure 8).

- The main surface is a flat un-dissected surface mantled by highly erodible sediments which are still in place, and bounded by distinct breaks of slope. This is characteristic of erosion by scarp retreat, whereby erosion of landforms occurs from the edges inwards, without significant top-down lowering. Scarp retreat erosion is typical of fluvial denudation processes under current climatic conditions in Tasmania. This implies that the flat main terrace is slowly being reduced in lateral extent, but provides no evidence that top-down erosion is also occurring.

- Evidence of erosion of the flat surface, or lack of it, would be provided by truncation of sedimentary structures in the uppermost sedimentary facies. However, no structures such as bedding were identified, hence this criterion cannot be applied on current knowledge of the sediments.

This evidence implies that the upper surface of the granular sand facies on the main terrace is probably a more-or-less intact depositional surface, preserved as it was at the time deposition of the granular sand facies ceased (see Figure 17). If this is so, the next phase of fluvial incision following the deposition of the granular sand evidently failed to affect the main terrace level, leaving it as a residual landform standing above river level. However, the unconsolidated sediments of the main terrace would have remained vulnerable to erosion by river channels migrating across the outwash plain until the level of fluvial incision dropped below the upper level of the bedrock underlying the sediments. The fact that a significant thickness of sediments have been preserved on the spur crest attests that this degree of incision must have occurred relatively quickly for the sediments to have escaped such erosion.

Given that no further sediments were deposited over the granular sand facies, and that incision to below bedrock level on the Southwood Spur must have occurred rapidly to prevent migrating river channels from eventually eroding the sandy sediments of the main terrace, it follows that a major reduction in sediment supply - sufficient to allow the river waters to begin incising substantially and progressively into the outwash plain sediment pile - must have quickly followed deposition of the granular sand facies. This implies that the granular sand facies was deposited at or close to the end of the glacial outwash episode.

Indeed, one explanation for the unusual preservation of a significant sediment sequence and depositional terrace surface on the crest of the Southwood Spur - whilst equivalent high level sediments and terraces have been removed from valley sides in most other parts of the Huon Valley - may be that the fortuitous occurrence of a high pre-glacial bedrock

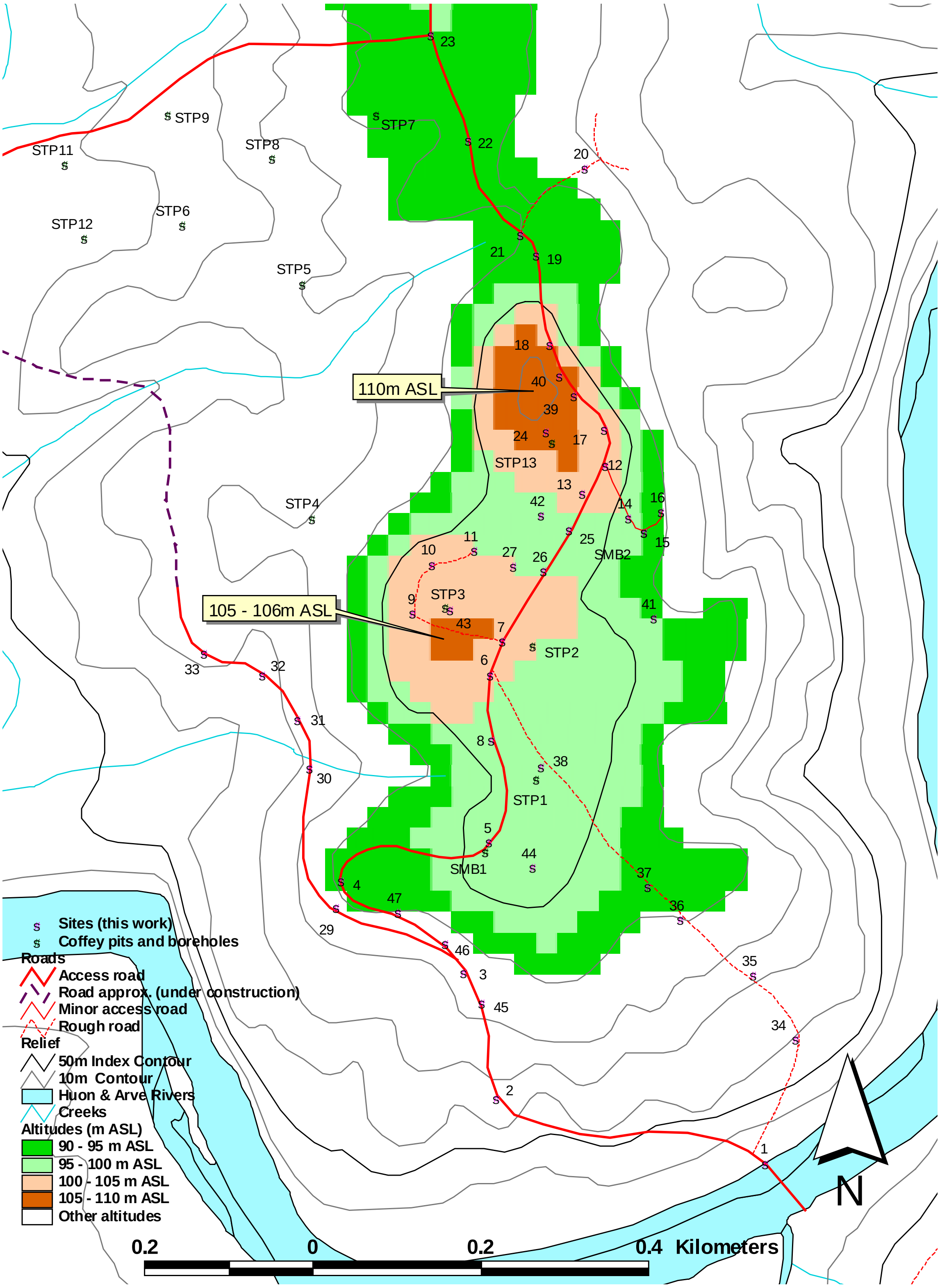

Figure 15: Altitude ranges at the Southwood site. Derived from 25m Digital Elevation model (2nd edition 2002).

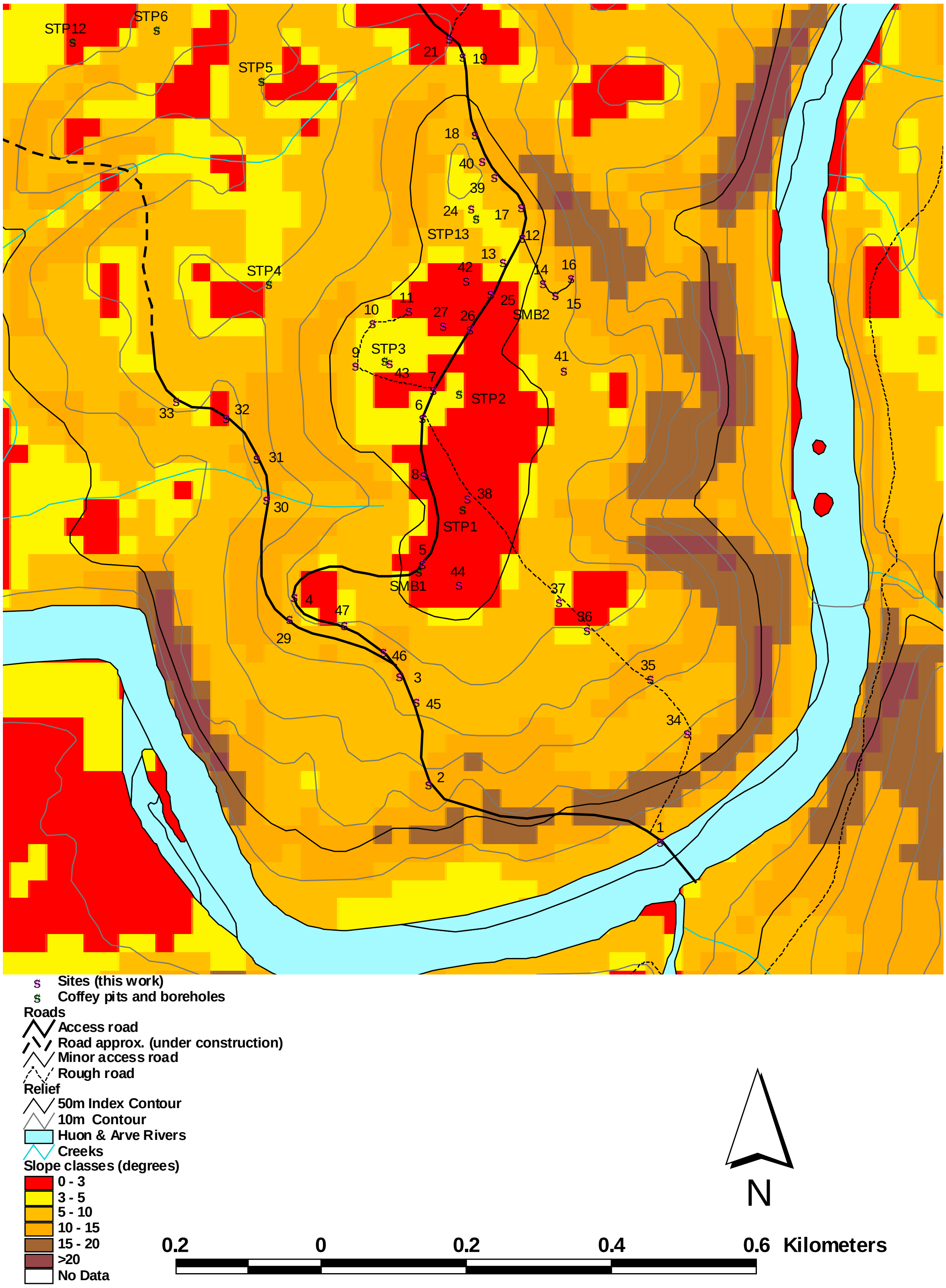

Figure 16: Slope classes (in degrees) at the Southwood site. The main glacio-fluvial terrace is highlighted as the area of 0° - 3° slopes at the ridge crest. Large flat areas west of the Southwood ridge are lower level river floodplains and terraces. Derived from 25m Digital Elevation model (2nd edition 2002).

spur overtopped by glacial outwash deposits only in the final stages of the glacial episode, and capable of protecting that cap of sediments from further fluvial erosion during post-glacial incision of the outwash plain, is not known to be replicated elsewhere in the valley.

If, as suggested by the evidence provided above, the main terrace surface has not been significantly eroded since it was deposited this raises two possibilities which may contribute to scientific dating of the Southwood Terrace sediments, namely:

- The sandy peat soils that have developed on the surface (eg, at site 13) may be of greater than Holocene age, and this could be tested by radiocarbon dating techniques (albeit it is possible that the peaty terrace soils could have periodically been destroyed by fire, so that the peat need not necessarily be older than Holocene age).

and:

- The depositional age of the granular sandy sediment may be susceptible to testing by methods based on measuring the duration of their surface exposure to cosmic rays, since it is implied that the sandy sediments have constituted the exposed upper surface of the main terrace level since they were deposited. Testing by such means would constitute a further test of the assertion that they represent an original depositional surface, since an obviously too-young exposure age (eg, a Holocene age) would tend to disprove the assertion.

Lower incised surfaces
Following incision of rivers below the level of the main Southwood terrace, continued post-glacial incision ultimately removed most outwash sediment from the Huon Valley, eventually returning the river channel to its base level bedrock channel. A stepped series of degradational fluvial terraces would have been produced during this incision process, and residual alluvial deposits at lower levels on the slopes of the Southwood spur, together with extensive low level terraces at Weld Plains, are considered remnants of these terraces (see section 3.2 "Lower Level Alluvium" above). These features have not been examined in detail during this work.

Steep eastwards dips
Evidence from outcrops around the edges of the main terrace surface and in the road cuttings along the spur crest show that the base of the granular sand and the underlying sandy pebble/cobble unit are flat to only slightly undulating beneath most of the terrace surface (Figure 14). However, on the eastern side of the main terrace between sites 13 and 16, the bases of these units abruptly descend steeply towards the east (Figure 14), and mapping elsewhere on the eastern slopes of the Southwood spur indicates a similar steep descent of all the Quaternary units towards the east (Figure 13).

The descent of the base of the basal silty-clay pebble/cobble unit towards the east conforms with a slope on the underlying bedrock surface, and this slope can be attributed to a pre-existing valley slope towards a pre-glacial Huon River channel in roughly the same position as the present channel. The similar slopes on the bases of the overlying units is more difficult to explain, although a possible explanation is that significant scouring by a major river channel intervened between deposition of each of the sedimentary units.

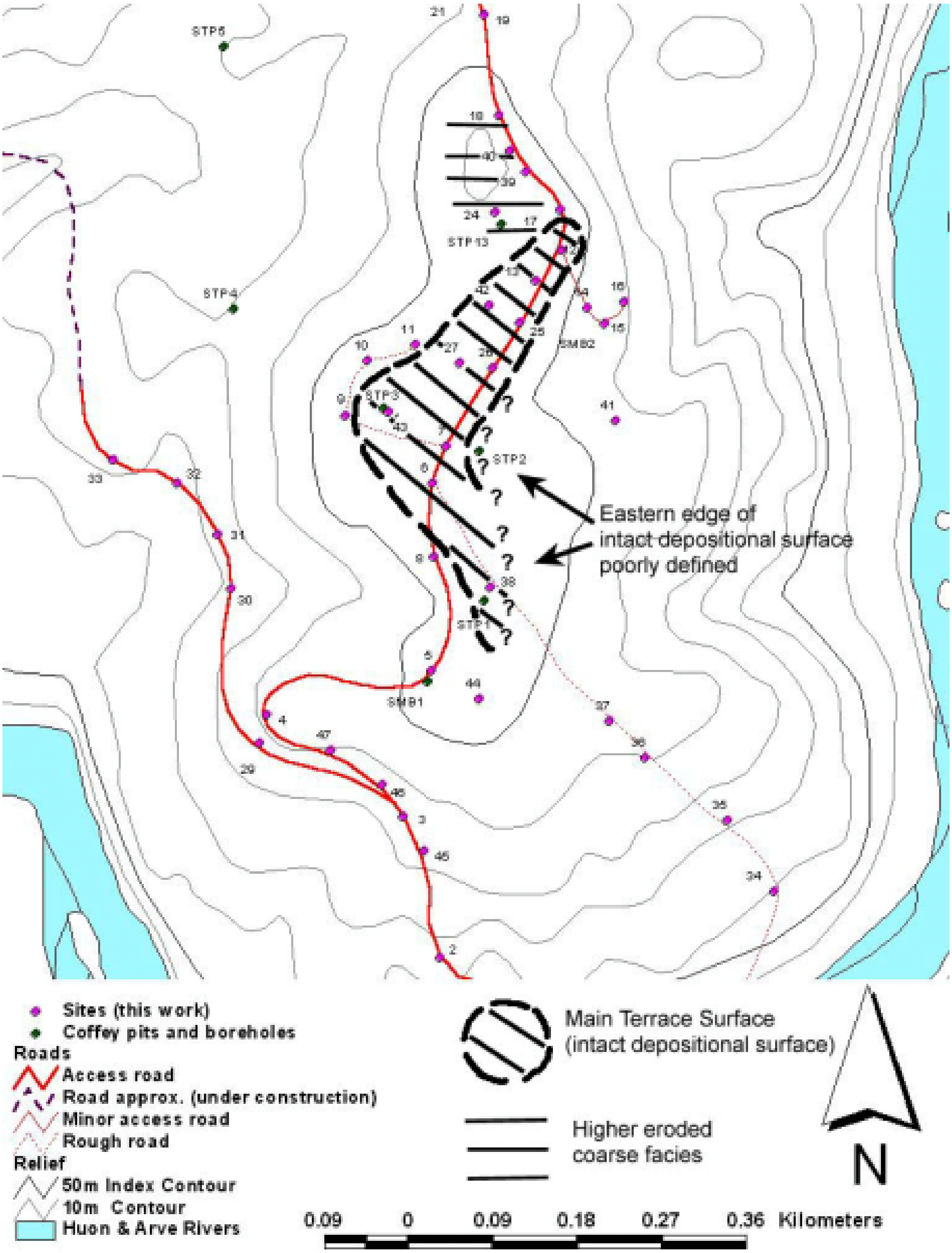

Figure 17: Interpretive geomorphic map indicating the extent of the main terrace surface on the Southwood Spur crest, which is interpreted as an intact original depositional surface formed at the final stages of deposition on the glacio-fluvial outwash plain, immediately prior to rapid incision of the outwash plain sediment pile (see text). The eastern and south-eastern sides of the intact depositional surface are poorly defined due to a lack of substrate exposure combined with difficulties in interpreting the eastwards dip of the Quaternary sedimentary units in this area.

Clear interpretation of the causes of the eastwards descent of each sedimentary unit on the eastern side of the Southwood Spur is hampered by a lack of good substrate exposures in that side of the ridge, which has resulted in incomplete mapping of the sedimentary units there (Figure 13). Further mapping of these sediments is required to allow more informed interpretation of the form of the sedimentary units there. This is an area in which further mapping in the course of excavations associated with the Southwood development may be of scientific value.

Irrespective of the interpretation of the descent of the sedimentary units on the eastern side of the Southwood Spur, it is evident that the original depositional surface of the upper granular sand unit is unlikely to be preserved intact where that unit descends the eastern slopes, as it has there been exposed to erosion by scarp retreat.

3.4 Conclusions: Interpretation of the Quaternary geomorphic development and history of the Southwood site

Based on the preceding data and discussions, the interpreted geomorphic history and development of the Southwood Terrace Quaternary sediments can be summarised as follows; note that this interpretation includes assumptions which have been suggested by the available data, but which require more rigorous testing before being accepted:

1. The Southwood site was a pre-glacial bedrock spur which stood above the level of a broad glacio-fluvial outwash plain during the main phases of a very extensive glaciation preceding the Last Glaciation. The exposed upper surface of the Permian bedrock forming the spur sloped south and eastwards, towards the pre-glacial Huon River channel.

2. The outwash plain sedimentary pile aggraded to the level of the Southwood spur top at a late stage of glacier retreat, when dolerite was no longer being contributed to outwash sediments in significant amounts.

3. Coarse boulder-grade glacial outwash material (including quartzite boulders) was initially deposited on the lower (southern) part of a bedrock surface sloping southwards along the crest of the Southwood Spur.

4. This was followed by deposition of finer, but still coarse cobble-grade material (the "silty-clay pebble/cobble facies"), with abundant clasts of both Precambrian quartzite and predominantly Permian siltstones, mudstones and sandstones, perhaps derived from the upper Manuka Creek valley to which the Huon Glacier is interpreted as having by that time receded. These deposits over-topped the entire bedrock spur crest, aggrading up 110m ASL and perhaps higher.

5. An episode of fluvial erosion followed, perhaps due to migration of braided channels across the outwash plain, scouring a terrace surface with shallow channel scours (eg, site 39) a little above 100m ASL across the main part of the preserved area of sediments but leaving a higher surface at the northern extremity of the deposits.

6. Cobble-grade alluvium with a predominantly sandy matrix (the "sandy pebble/cobble facies") was then deposited on the scoured surfaces, aggrading again to at least 110m ASL. A significant reduction in mudstone and siltstone clasts in this facies compared to the underlying facies may be due to continued retreat of the source glacier to areas of quartzite bedrock upstream of the Permian sedimentary bedrock areas at the head of Manuka Creek.

7. Another fluvial erosion event then occurred to form a broad terrace surface at 100 - 105m ASL with shallow channel scours as at site 13, but again leaving a residual area of higher sediments at the northern end of the preserved deposits. This erosion event may again have been due simply to channel migration across the outwash plain, however the fact that the overlying fine sediments are the final sedimentary unit deposited on this part of the outwash plain suggests that it may have been partly due to a reduction in outwash sediment load associated with the terminal waning of glacial erosion. This would have permitting fluvial processes to begin incising the outwash plain sediment pile as the dominant fluvial processes switched from aggradation to degradation.

8. In a final outwash depositional phase, fine granular quartz sand was deposited on the main terrace surface at 100 – 105m ASL, as overbank floodplain sediments which infilled channel scours as at site 13. There is no evidence that similar sediments were deposited on the highest northern parts of the Southwood Spur, which may by that time have been above the level of normal floodplain deposition.

9. A substantial reduction in sediment supply associated with the end of glacial erosion then allowed rivers to start rapidly incising into and terracing the outwash plain. Incision of the outwash plain to below the top of the Permian bedrock underlying the outwash sediments on the crest of the Southwood Spur occurred rapidly, before channel migration could scour the outwash sediments off the crest of the spur.

10. Progressive incision of a stepped series of lower degradational terraces followed, with the bedrock spur continuing to protect the outwash sediments on its crest from fluvial erosion, until the Huon River ultimately regained its base level bedrock channel. Residual fragments of lower degradational terraces remain at a number of levels on the side slopes of the Southwood Spur, and the Weld Plains west of the Southwood Spur - just above present river level - may at least in part represent the lowest level degradational terraces from this glacial outwash episode.

11. No subsequent glacial outwash accumulated to the same level, suggesting that subsequent glaciations were less extensive, and did not again fill the valley with outwash sediment to the same height.

12. A long subsequent period of weathering, post-depositional modification and erosion ensued up to the present, during which:

    - siltstone cobbles up to 20 cm diameter in the sediments on the Southwood Terrace weathered completely to clay, and the underlying bedrock weathered to soft clayey regolith 14 - 20 metres deep where-ever it was protected from erosion by the Quaternary sediments.

- The alluvium-capped bedrock spur slopes eroded by river attrition, scarp retreat, colluvial slope erosion and transport processes and side-slope slumping, but the main terrace surface at 100 – 105m ASL on the ridge crest remained intact although its area has decreased as the relatively sharp break of slope separating it from the inwards-retreating side slopes of the spur have retreated laterally inwards. Inside the break of slope, the flat terrace surface remains sufficiently broad that it has not been subject to slope erosion processes nor to significant fluvial erosion. There is no evidence that erosion has lowered the terrace surface vertically, and the upper surface of the granular sand facies on that surface is interpreted as an original depositional surface.

- Peat soils developed on the flattest (poorly draining) parts of main terrace, and iron pan ("coffee rock") B-horizons developed in the sandy sediments.

4.0 POTENTIAL GLACIO-FLUVIAL TERRACES EQUIVALENT TO THE SOUTHWOOD TERRACE ELSEWHERE IN THE MIDDLE – LOWER HUON VALLEY

4.1 *Introduction – the purpose of this section*

An essential part of assessing the geoconservation significance of a particular landform is to determine whether it is a rare or unique feature – which if degraded will result in a loss of scientific and intrinsic values which cannot be replicated elsewhere – or whether comparable features are replicated elsewhere, that can provide equivalent evidence of past geomorphic processes. In the case of the Southwood glacio-fluvial terrace, this amounts to determining whether other glacio-fluvial terraces exist in the middle Huon valley which can be attributed to the same glacial event, and can provide equivalent evidence as to the extent, altitudes and gradients of the original outwash plain, equivalent evidence of the sediment composition and sources, and of the nature of the glacio-fluvial processes and subsequent fluvial incision processes which operated to produce the terraces.

Other terraces equivalent to the Southwood terrace have not previously been identified in the Huon valley. The purpose of the assessment described in this section is to determine whether equivalent terraces can be identified, or be shown to be likely to be present[4].

Ideally, the identification of equivalent glacio-fluvial terraces elsewhere in the Huon Valley would proceed by means of extensive field exploration, leading to the identification, inspection, description, sampling and testing of a wide range of apparent remnant terrace sites throughout the valley. By this means, terraces of equivalent absolute or relative age and origin to the Southwood site terrace could be positively identified by means of fieldwork and other tests, and their relative positions and altitudes in the landscape could then be mapped in order to reconstruct the size, morphology (shape) and gradient of the original glacio-fluvial outwash plain of which they would be dissected remnants.

Unfortunately, the lack of extensive previous geomorphic surveys of this kind in the Huon Valley precludes this approach for the present brief project. In the present case the terrace

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[4] **Note:** it is likely that other glacio-fluvial sediments deposited by outwash from the same glacial episode are preserved in the Huon valley, however many of these are likely to be simply dissected exposures of sediments formerly buried within the final outwash plain. A key aspect of the Southwood terrace is not only that it contains glacio-fluvial sediments, but also that its surface form – its terrace morphology – may represent a fragment of the original outwash plain surface as it existed close to the time deposition ceased on the outwash plain. The preservation of the terrace surface form is important since it can yield information on the original altitude, extent and gradient of the outwash plain, and hence provide insights into the glacial processes that cannot be deduced simply from the sediments contained within the outwash plain/terrace (albeit these provide other types of scientifically useful information too).

Consequently, the simple identification of other sediments of the same age as those in the Southwood terrace would not be sufficient to say that, for geoconservation purposes, a replicated feature equivalent to the Southwood terrace had been identified. What is also needed is replicated examples of both:

- an equivalent high level original terrace surface;
- composed of glacio-fluvial outwash sediments of equivalent age

fragment under consideration is one for which no other equivalents have previously been identified. The morphology and gradient of the outwash plain of which it originally formed a part is consequently unknown. Thus, in order to determine the likely locations of any equivalent features, one has to make "best guess" predictions of what the form and gradient of the outwash plain might have been, and then use those predictions as a guide to searching for candidate sites. Eventual identification and dating of equivalent sites by this means would confirm the predictions made; however on the other hand, failure to identify equivalent sites by this approach could be due *eithe*r to no equivalent sites existing (i.e., no other remanent parts of the same outwash plain being preserved elsewhere in the valley), *or* simply to the wrong assumptions having been used in attempting to predict their possible location.

4.2 *Prediction of equivalent glacio-fluvial terraces elsewhere in the Huon Valley*

Given that no other terrace remnants thought to be of equivalent age to the Southwood Terrace have previously been identified elsewhere in the Huon Valley, it is not possible to reconstruct the extent, altitudes and gradients of the original outwash plain by interpolation between identifiable remnants. Hence, and in the absence of sufficient time to conduct thorough and extensive field exploration, an initial search for possibly equivalent fragments of the same outwash plain must (as discussed above) be based on a predictive modelling of the possible outwash plain's form, using on the most reasonable assumptions available.

The following assumptions have been made in conducting this predictive modelling exercise, based on conclusions reached in the preceding sections of this report:

- that the Southwood terrace is a dissected fragment of a former outwash plain deposited by glacial meltwaters downstream of a glacier terminus during a major Cainozoic glaciation prior to the Last Glaciation, and possibly during the most extensive Cainozoic glaciation in Tasmania (given that no evidence of higher glacio-fluvial terraces that might relate to even larger glaciations has been identified in the Huon Valley). The Southwood terrace is thought to be a remnant fragment of an outwash plain that would have formerly filled the Huon valley to the same level, and that was subsequently incised and dissected by post-glacial river flows, leaving only a few remnant fragments of the original surface preserved as high level terrace fragments; and

- that the main glacier which generated the outwash plain was sourced on the south-eastern side of Gallagher Plateau, and flowed down the Manuka Creek valley to Blake's Opening, and thence down the floor of the main Huon Valley. At its maximum extent, available evidence suggests the glacier may have extended down -valley to Tahune Bridge (Colhoun & Goede 1979), and further down-valley extent cannot be ruled out. Tributary glaciers from Mt Picton and the Picton and Weld valleys may or may not have been confluent with the main glacier at it's maximum extent, but meltwater streams from tributary glaciers would have provided sediment to the main outwash plain during at least part of the glacial recession phase. As the glacial climatic phase waned, it is assumed the main glacier receded back up the Huon and then the Manuka Creek valley towards its source cirques; and

- that the outwash plain continued to aggrade (build upwards) by addition of glacial outwash sediment until a relatively late stage in the recession of the glacier. Thus, the final outwash plain depositional surface would have graded up to higher altitudes going up the valley, to a point near the glacier terminus at a relatively late stage in the recession process. On the assumption that the Southwood terrace relates to a more extensive phase of glaciation than the last, there is evidence to suggest that the glacier involved reached at least as far down the valley as Tahune Bridge at its maximum extent (Colhoun & Goede 1979). The Southwood Terrace, at 100 - 105m ASL, is higher than Tahune Bridge (~50m ASL), thus if the outwash plain graded only from the maximum glacier extent to the Southwood terrace, it would have to slope upwards going down the valley, which is impossible! Again, even if the outwash plain surface was perfectly flat below the glacier snout, it would still have had to originate from a point on Manuka Creek over one kilometre upstream of the Huon River / Manuka Creek confluence, which is at ~80m ASL. However the outwash plain would not have been flat over such a long distance down valley to the Southwood Terrace, but rather would have sloped down-valley. The upshot is that simple topographic considerations require that the outwash plain of which the Southwood terrace (at 100 - 105m ASL) forms a remnant fragment, must have sloped down-valley from an origin somewhere significantly above the 100m ASL contour in Manuka Creek valley, and this in turn implies that it was continuing to aggrade until well into the glacier's retreat from its maximum extent which is presumed to have been at or below Tahune Bridge; and

- that tributary outwash plains generated by glacier systems in tributary valleys (Picton valley, Weld valley/Eddy Creek, Snowy Range glaciers via Little Denison River valley) would have graded down to the main Huon valley outwash plain without significantly altering the long profile gradient of the main Huon valley outwash plain from the gradients modelled by this exercise.

- that no significant tectonic disruption or tilting of the outwash plain or incised fragments of it occurred subsequent to deposition; and

- that any other remnant terrace fragments will have similar surface form (mainly flat surfaces in the 0º - 3º slope class range) to that at the Southwood site. Note that remnant sedimentary deposits from within the same outwash plain may be preserved at a range of altitudes below the original surface of the plain, and be exposed on a range of erosional slope angles, but these will not preserve remnant portions of the final outwash plain surface. The search for equivalent examples of *both* the sediments and the original terrace surface at Southwood is the focus of this exercise.

Based on these assumptions, two alternative models have been applied to predict the possible gradient and altitudes of the original outwash plain. More sophisticated models than these are likely to be closer to the truth, but are difficult to generate given the lack of adequate field data currently available. The two models used here, although relatively crude, constitute initial hypotheses to give direction for a scientific process of information collection aimed at ultimately generating better models of the actual glacio-fluvial processes that occurred.

The two models applied in this exercise were:

Model (1)
That the present day river channel has incised to a constant depth below the former outwash plain surface; that is, that the long profile gradient of the original outwash plain was similar (parallel) to the long profile of the present day river bed.
This model suggests that remnant fragments of the original outwash plain surface are likely to be found at about 70 metres altitude above the present river at any given point in the valley, as is the case at Southwood. This is a simplistic "first pass" model which is unlikely to be fully accurate for a variety of reasons including that:

- The main Huon River channel has adjusted its bed, not to the gradient of Manuka Creek (which is only a small tributary of the river today), but rather to a gradient responding to geomorphic controls affecting the main channel of the Huon River which rises in the (artificially flooded) Huon Plains area west of Mt Anne (see figure 18). Thus it is unlikely that the present day Huon River gradient below Manuka Creek would be entirely consistent with former outwash processes that originated in Manuka Creek valley, and which produced a depositional plain graded not to the headwaters of the Huon River, but rather to some point in the Manuka Creek valley.

- The long profile gradient of Manuka Creek is significantly steeper than that of the Huon River at the confluence of the two watercourses (see figure 18). It is unlikely that the original outwash plain would have abruptly changed its gradient at this point in a similar fashion.

- At least one – and possibly more – lesser glacial episodes have occurred subsequent to the episode that formed the Southwood terrace. This means that glacio-fluvial sediments have accumulated in the Huon and Manuka valleys (albeit to lesser depths) and have then been again removed by fluvial incision, on possibly several occasions subsequently. These subsequent events would also need to be accounted for in relating the river's present day gradient to past glacial outwash processes.

It is unlikely that this simplistic "first pass" model would be true for the entire outwash Plain if it extended up the Manuka Creek valley as assumed; however this model could approximate the truth at least for those parts of the Huon Valley well downstream of the Manuka Creek junction (eg, below the Picton / Huon Rivers confluence), where the abrupt change of gradient from Manuka Creek to the Huon River (see Figure 18) becomes less of a problem for the model.

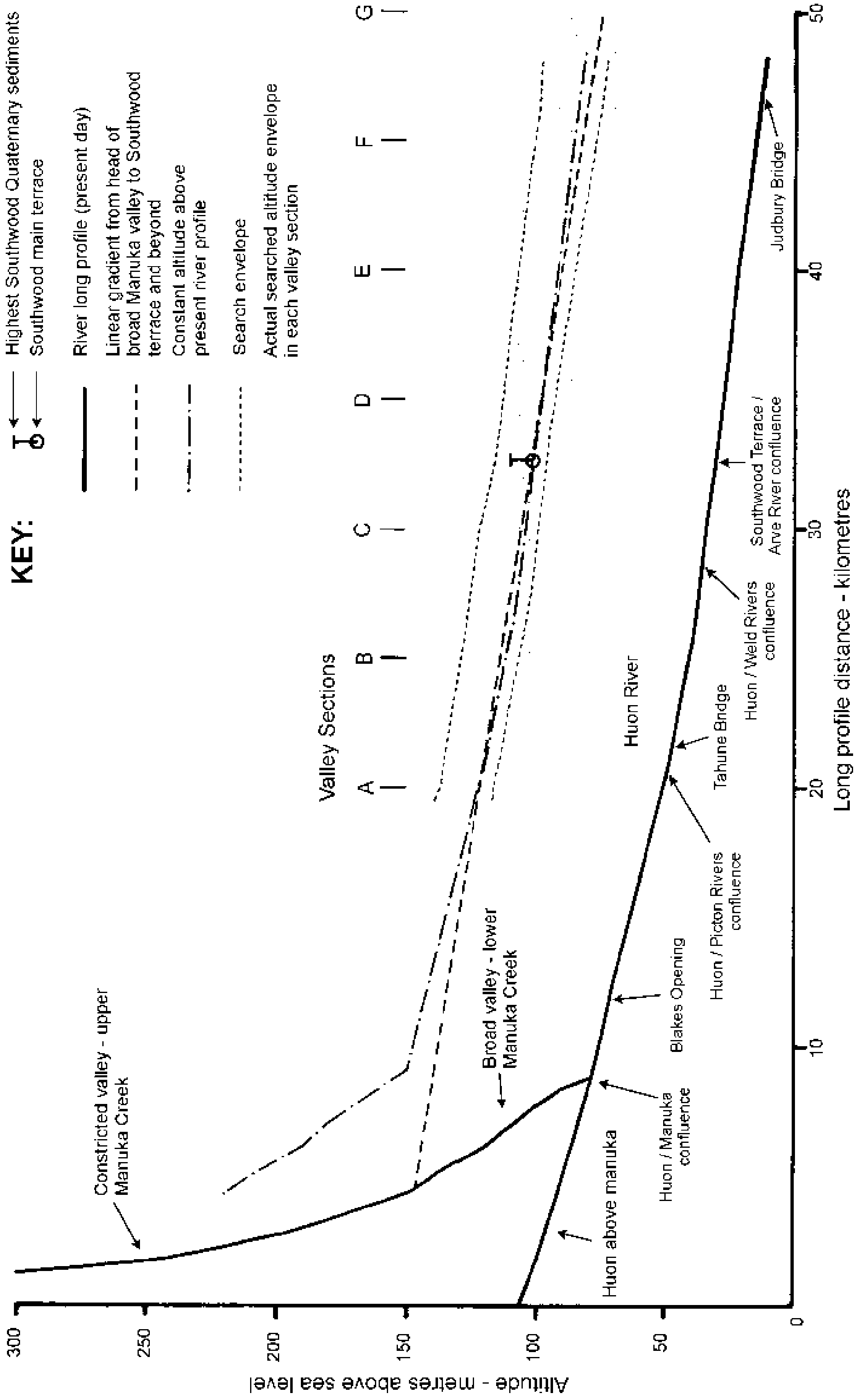

Figure 18: River long profiles and modelling of possible terrace profiles (see text explanation).

Model (2)
That the former outwash plain surface graded down-valley in a constant linear fashion from a point at the head of the broad Manuka Creek Valley, to the Southwood Terrace and beyond.
This model assumes that the outwash plain continued to aggrade (build up) until a relatively late stage in the glacier's retreat from its maximum extent, when the amount of continuing glacial erosion became insufficient to continue supplying large quantities of sediment to be carried long distances down the valley by meltwaters emanating from the retreating glacier's snout. From the discussion of model assumptions (above) it is clear that the final outwash plain surface must have graded up the valley to at least a point well over a kilometre above the Huon / Manuka confluence, but how far above that point is difficult to determine.

It is noteworthy that the Manuka Creek valley is relatively broad and flat-floored for about 4 km above its confluence with the Huon, but above that point (at 150m ASL) the valley down which the glacier must have flowed from the cirques on Gallagher Plateau narrows significantly. There is also a significant steepening of the valley long profile gradient above this point (see figure 18). In the absence of better information to base model assumptions on, it is assumed as a working hypothesis that the final outwash plain surface of which the Southwood Terrace formed part graded upstream at a linear gradient from Southwood to roughly a point at 150m ASL at the head of the broad part of the Manuka Creek valley (at about AMG grid reference 465 000mE 5232 300mN, AGD66 datum) [5]. This assumption implies that the glacier terminus had retreated this far or even further up the valley when the outwash plain surface assumed its final form and gradient as represented by the Southwood Terrace. It is possible that the glacier could have retreated further up the valley than this point by the time the plain assumed its final form, but given the steepened valley gradient above this point, it is likely that outwash sediment from higher glacier terminal positions would be washed steeply down slope and would only accumulate in an outwash plain at or below the distinct flattening in the valley long profile at 150m ASL, which may thus have been the final head or point of origin of the main final outwash plain regardless of further glacier recession above that point.

Although the assumptions behind placing the head of the final outwash plain at about 150m ASL in the Manuka valley are tenuous, it is noteworthy that the modelled outwash plain gradient based on this assumption is closely similar to the gradient implied by Model (1) from the Huon / Picton confluence downstream (see figure 18), which as noted above is the part of the Huon Valley where Model (1) is most likely to approximate reality.

As a "caveat", it should be noted that Model (2) assumes a linear (i.e., straight line) gradient on the long profile of the outwash plain from its original source at the head of the broad Manuka Creek valley to the Southwood terrace location. It is unlikely that this assumption is strictly correct, however in the absence of more detailed information about the Huon Valley glacial system it is difficult to improve on the assumption. Given the lack of more detailed information, a linear gradient is assumed to be the best available assumption to work with and, as noted above, is closely similar to the long profile gradient

[5] Although Calver (1997) has mapped Quaternary alluvial terraces in the more constricted upper Manuka Creek valley above this point, these relatively well preserved terraces are likely to relate to Last Glaciation outwash rather than to the older glaciation implicated for the Southwood Terrace and equivalents.

of the present Huon River in the region below the Picton / Huon confluence which suggests that it may have some predictive power.

Search criteria based on the adopted models

The two predictive models described above yield predictions of likely terrace heights which are closely similar (± 4 metres altitude difference) from roughly the Huon – Picton Rivers confluence down-valley to Judbury (Figure 18). Above and below this section of the valley the terrace altitudes predicted by the two models begin to diverge significantly. As noted above, assumptions of outwash plain gradients (and thus altitudes) based on Model (1) become increasing unlikely and increasingly divergent from the predictions of Model (2) above the Picton River junction (closer to the Manuka Creek - Huon River junction where present river gradients change sharply).

Partly for these reasons, and also because of available time constraints, the search for equivalent terraces was limited to the 28 km section of the Huon Valley between the Huon – Picton junction and Judbury, where correspondence between the two models suggest reasons for confidence.

Based on the predicted terrace altitudes yielded by the two models, a "search envelope" of most likely altitudes within which equivalent terraces may exist was defined by first defining a "prediction envelope" as being - for any given point down the valley - the range of altitudes between the lowest of the two predicted altitudes for the main terrace at that point, and an altitude 10m higher than the highest of the two predicted altitudes for that point (this latter is because some glacio-fluvial sediments occur up to 10m higher than the main terrace level at the Southwood site – see section (3.3) for discussion of this and it's possible explanations). The prediction envelope so defined was then expanded by 5 metres altitude above and below, to allow for uncertainties inherent in the models being used, which yielded a final "search envelope" defining the altitude ranges within which equivalent terrace surfaces are most likely to occur at any given point in the valley, based on the models and assumptions employed in this exercise (see Figure 18).

A 25 metre digital elevation model (DEM)[6] of Tasmania was then analysed using ESRI Arcview 3.2a / Spatial Analyst GIS software to identify all flat surfaces in the same slope class range (0º – 3º) as the main Southwood Terrace, that fall within the "search envelope" altitude ranges. The identified flat surfaces that resulted constitute potential outwash terrace fragments equivalent to the Southwood terrace, and are shown on figures 20 to 25.

A problem arising with this exercise was that the GIS analysis method used only identifies surfaces within a constant altitude range in all parts of the map area being analysed; however the search envelope actually slopes gradually downwards as one moves down-valley (see figure 18). The (slightly crude) method adopted to deal with this problem was that the stretch of the Huon Valley being searched was split into six short (5 kilometre) sections, within each of which the change in altitudes of the search envelope is relatively small (6 – 8 metres). Within each such valley section the altitudes searched were defined

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6 Digital Elevation Model (DEM) of Tasmania, 2nd Edition (2002), produced by Landinfo (Canberra) for the Information and Land Services Division, DPIWE, using Arc/Info TIN modelling. The original source data was derived from 1:25,000 scale 10m contours, watercourse and waterbody information, and limited spot height data. The DEM essentially comprises a 25 metre grid dataset tagged with an altitude (metres ASL) for the centre of each 25m grid square.

to be from the highest limit of the search envelope at the upstream end of the valley section, to the lowest limit of the search envelope at the downstream end (these "actual searched altitude envelopes" for each valley section are indicated by the shaded areas on Figure 18). This approach meant that the effective search envelope was again widened by several metres altitude and varied in a stepwise fashion between valley sections, such that discrepancies could occur between flat surfaces identified at the limits of the search envelopes in different adjoining valley sections. However, this method ensures that all flat surfaces falling within the (sloping) search envelope would be identified throughout the search area, and in practice it was found that discrepancies between flat surfaces identified near the margins of adjoining valley section were only minor (see figures 20 – 25).

The locations of the six valley sections are indicated on Figures 18 and 19, and details are listed below:

Valley Section	**Extent** (wrt Huon River long profile)	**"Actual searched altitude envelope" over valley section (m ASL)**
A - B	From 0.5 km above Huon / Picton confluence to 3.4 km below Tahune Bridge (3.5 km above Huon / Weld confluence). See Figure 20.	107 - 137
B - C	From 3.5 km above Huon / Weld confluence to 1.4 km below Huon / Weld confluence (2.7 km above Huon / Arve confluence) See Figure 21.	100 - 130
C - D	From 2.7 km above Huon / Arve confluence to 2.3 km below Huon / Arve confluence. See Figure 22.	93 - 122
D - E	From 2.3 km below Huon / Arve confluence to Huon / Little Denison River confluence. See Figure 23.	85 - 113
E - F	From Huon / Little Denison River confluence to 1.7 km above Judbury Bridge. See Figure 24.	77 - 107
F - G	From 1.7 km above Judbury Bridge to 3.3 km below Judbury Bridge. See Figure 25.	70 - 100

Finally, field inspections were made of as many as possible of the potential equivalent terrace sites identified by the search process described above. The outcomes of the field inspections are documented in the Section (4.3). In selecting potential equivalent terrace sites for field inspection, no account was taken of whether available geological mapping indicates the presence or absence of Quaternary sediments at that site. This is because most available geological mapping in Tasmania – and particularly older mapping – provides more or less inconsistent mapping of Quaternary sediments, showing them in some places and omitting them in other places where they are equally thick or extensive. Equally, no potential sites were eliminated from consideration simply on the grounds that known geology suggested that they flat surfaces indicated might simply be structural benches on flat – lying sedimentary bedrock. Whether or not this is the case, the surfaces may still be mantled with glacial outwash sediments and have outwash terrace surfaces plastered over the underlying structural benches (indeed this is likely to be the case at the Southwood site).

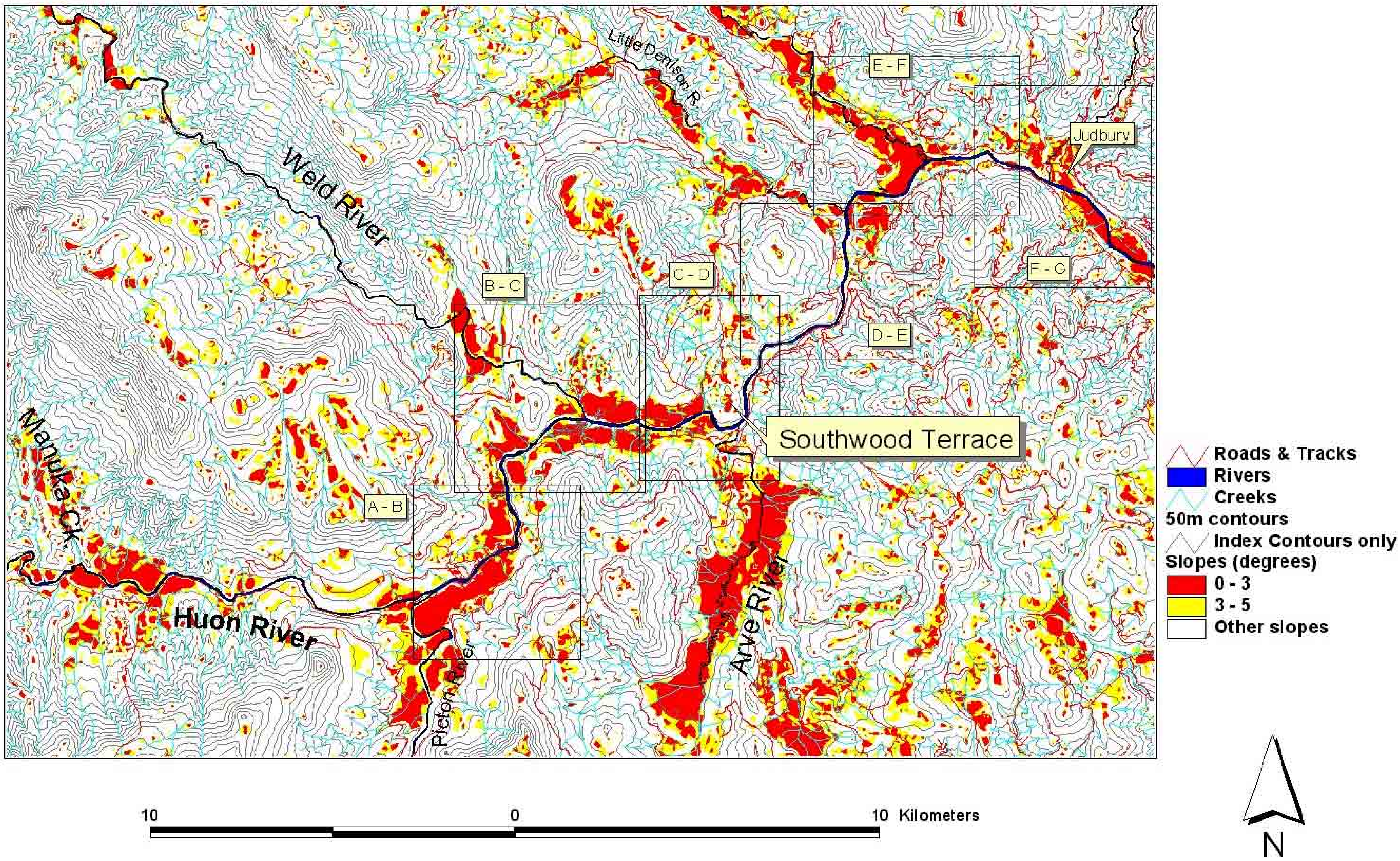

Figure 19: Flat surfaces (all altitudes & all types) in the middle Huon Valley, indicating valley sections (A – B to F – G) shown on figures 20 to 25 (following). The flat surfaces (0º - 3º slopes and marginal 3º - 5º slopes) shown here include recent floodplain terraces, probably older glaciofluvial terrace fragments, higher erosion surface fragments, structural benches, and probably other types of surfaces. The aim of the analysis reported in this section is to identify, amongst all these, which flat surfaces may potentially be equivalents of the Southwood glacio-fluvial terrace.

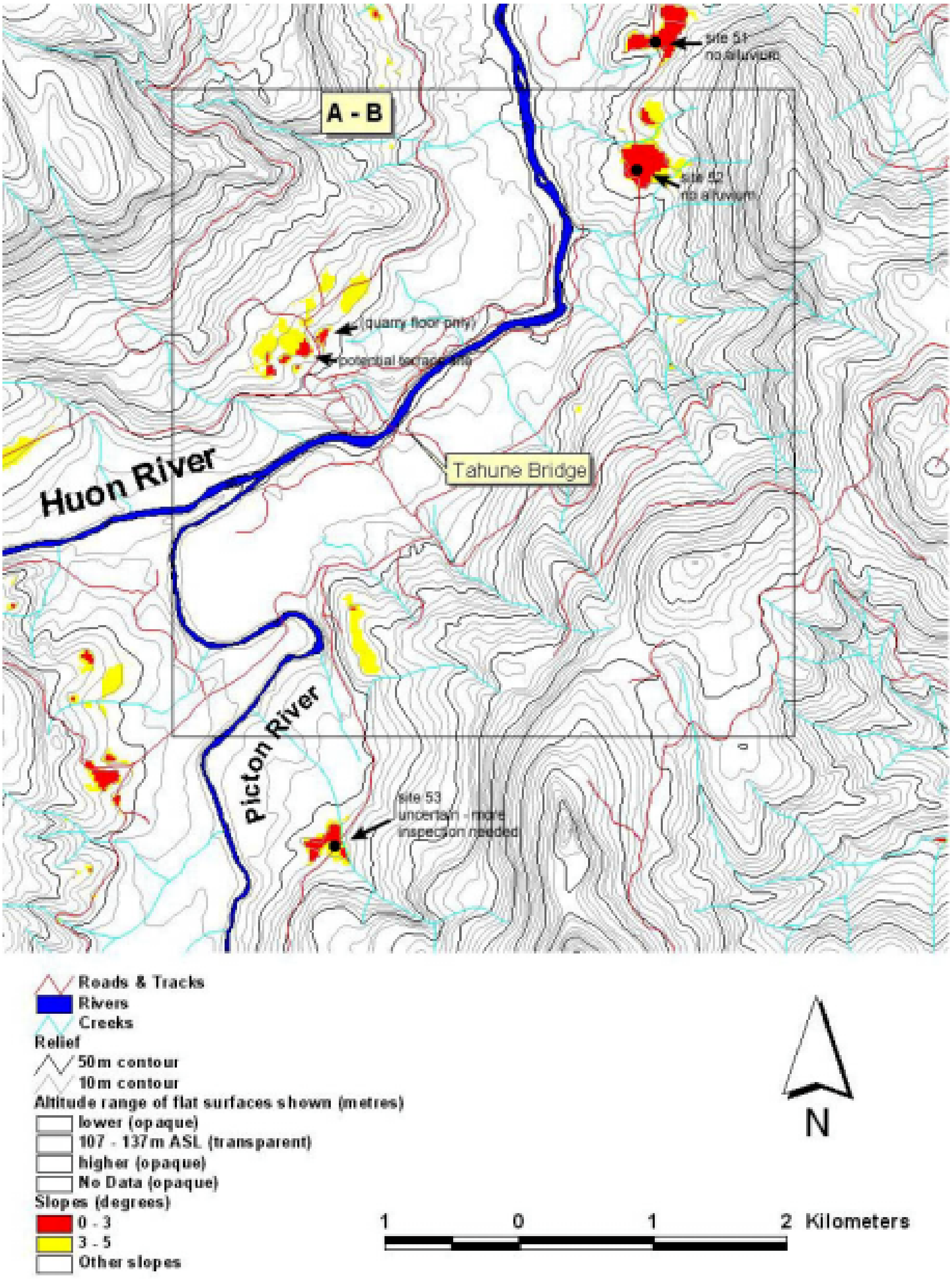

Figure 20: Valley section A – B, showing flat surfaces (0º - 3º and marginal 3º - 5º slopes: possible glacio-fluvial terrace remnants equivalent to Southwood terrace) in the 107 – 137 m ASL altitude "search envelope" for the Picton / Huon Junction – Tahune Bridge region. Sites 51, 52 & 53 (shown) have been inspected, and are described in section (4.3) following.

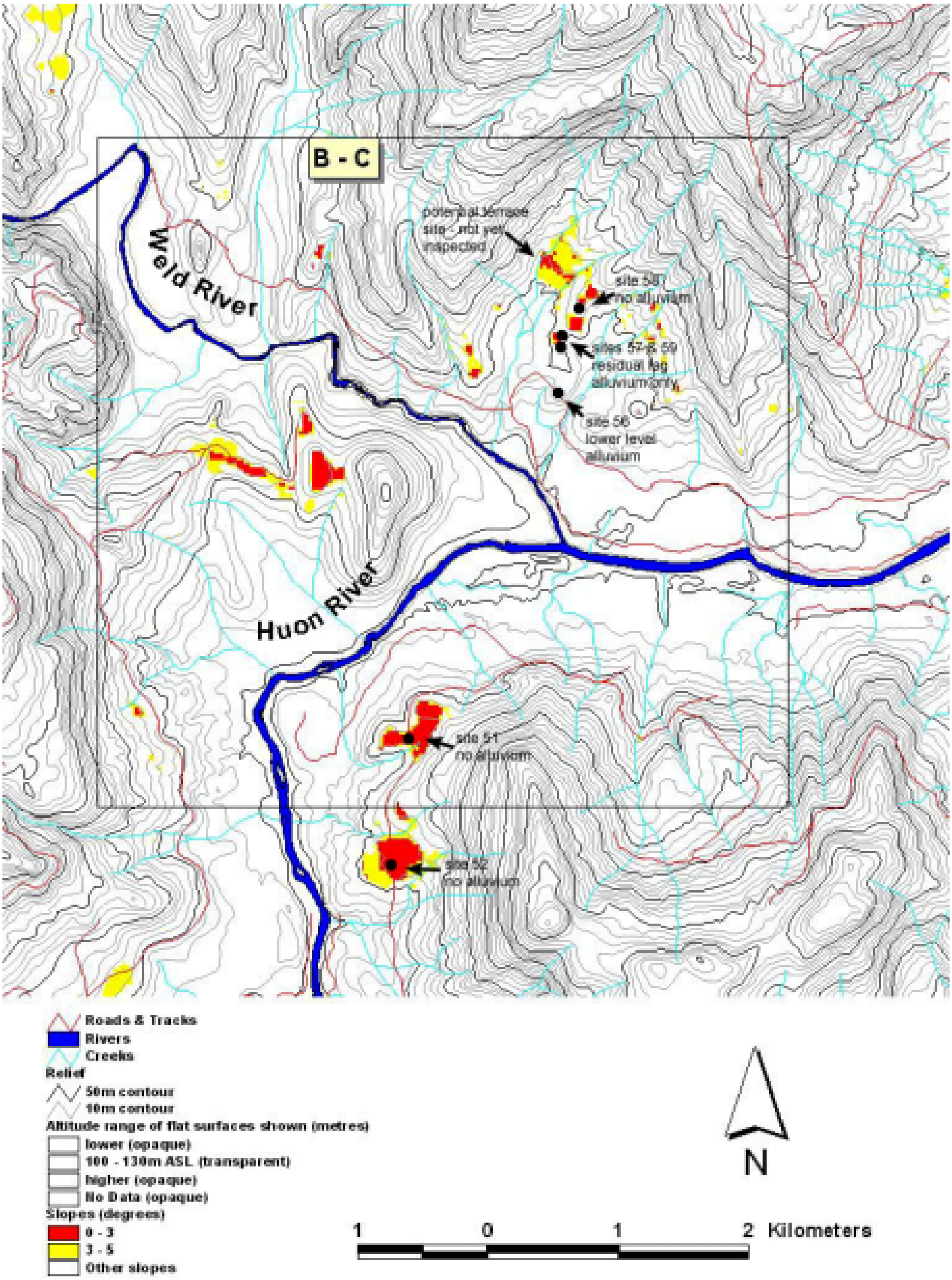

Figure 21: Valley section B – C, showing flat surfaces (0º - 3º and marginal 3º - 5º slopes: possible glacio-fluvial terrace remnants equivalent to Southwood terrace) in the 100 – 130 m ASL altitude "search envelope" for the Weld / Huon Junction region. Sites 51, 52, & 56-59 (shown) have been inspected, and are described in section (4.3) following.

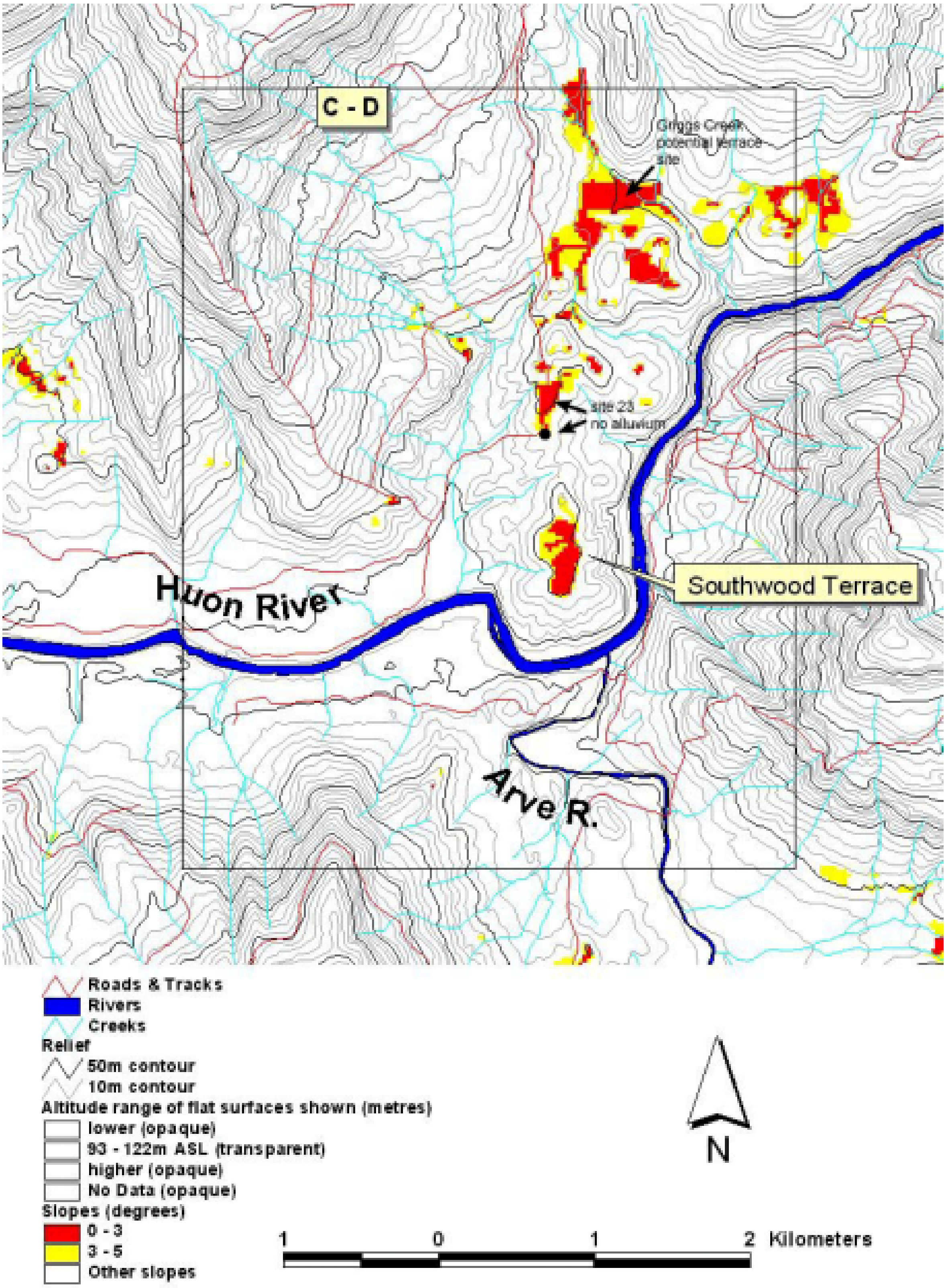

Figure 22: Valley section C – D, showing flat surfaces (0º - 3º and marginal 3º - 5º slopes: possible glacio-fluvial terrace remnants equivalent to Southwood terrace) in the 93 – 122 m ASL altitude "search envelope" for the Southwood terrace region. Site 23 (shown) has been inspected, and is described in section (4.3) following.

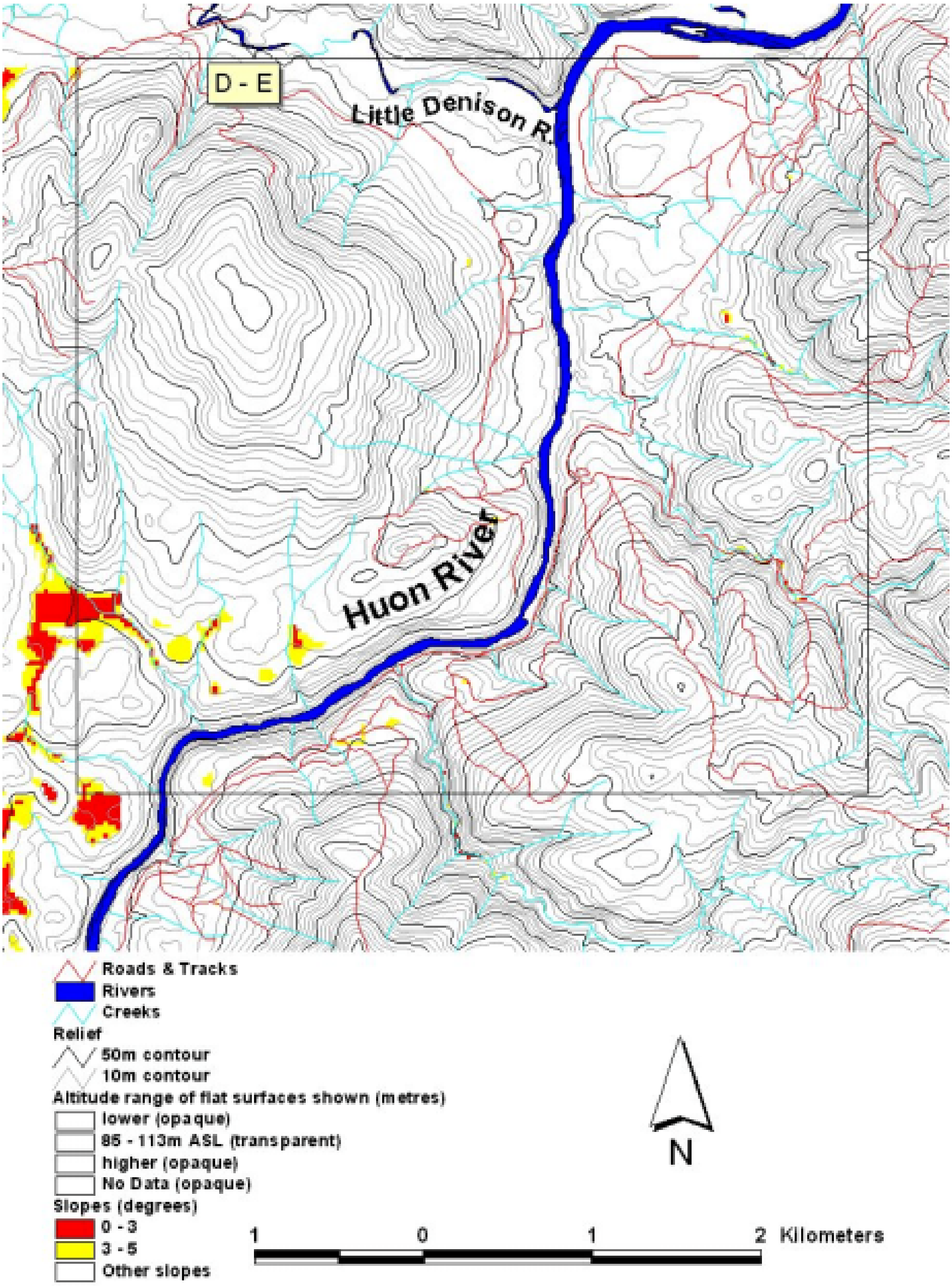

Figure 23: Valley section D – E, showing flat surfaces (0º - 3º and marginal 3º - 5º slopes: possible glacio-fluvial terrace remnants equivalent to Southwood terrace) in the 85 – 113 m ASL altitude "search envelope" for the Huon above Little Denison confluence region. No sites in this valley section have yet been inspected.

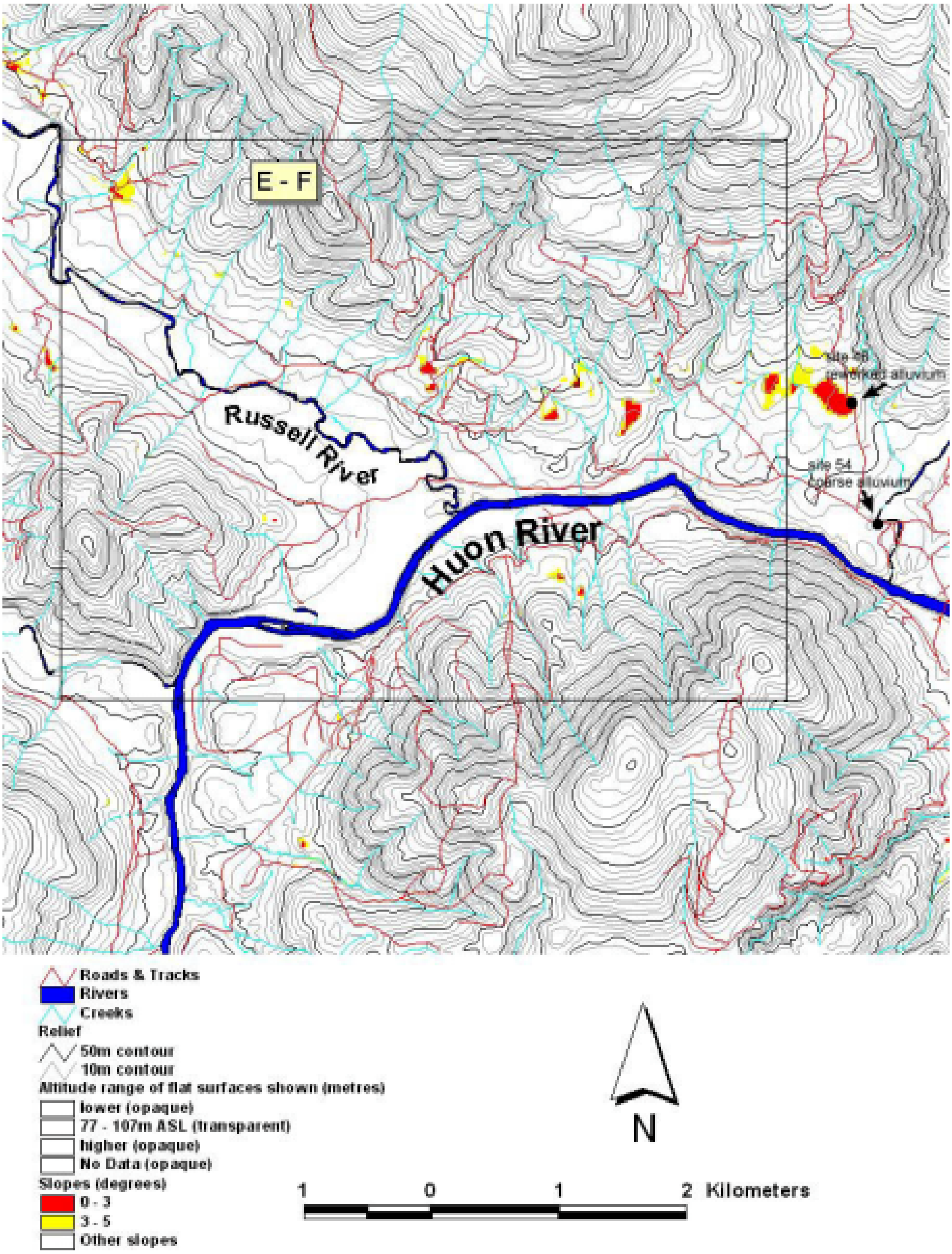

Figure 24: Valley section E – F, showing flat surfaces (0º - 3º and marginal 3º - 5º slopes: possible glacio-fluvial terrace remnants equivalent to Southwood terrace) in the 77 – 107 m ASL altitude "search envelope" for the Little Denison confluence to above Judbury region. Adjacent sites 48 and 54 (see also figure 25) have been inspected and are described in section (4.3) following.

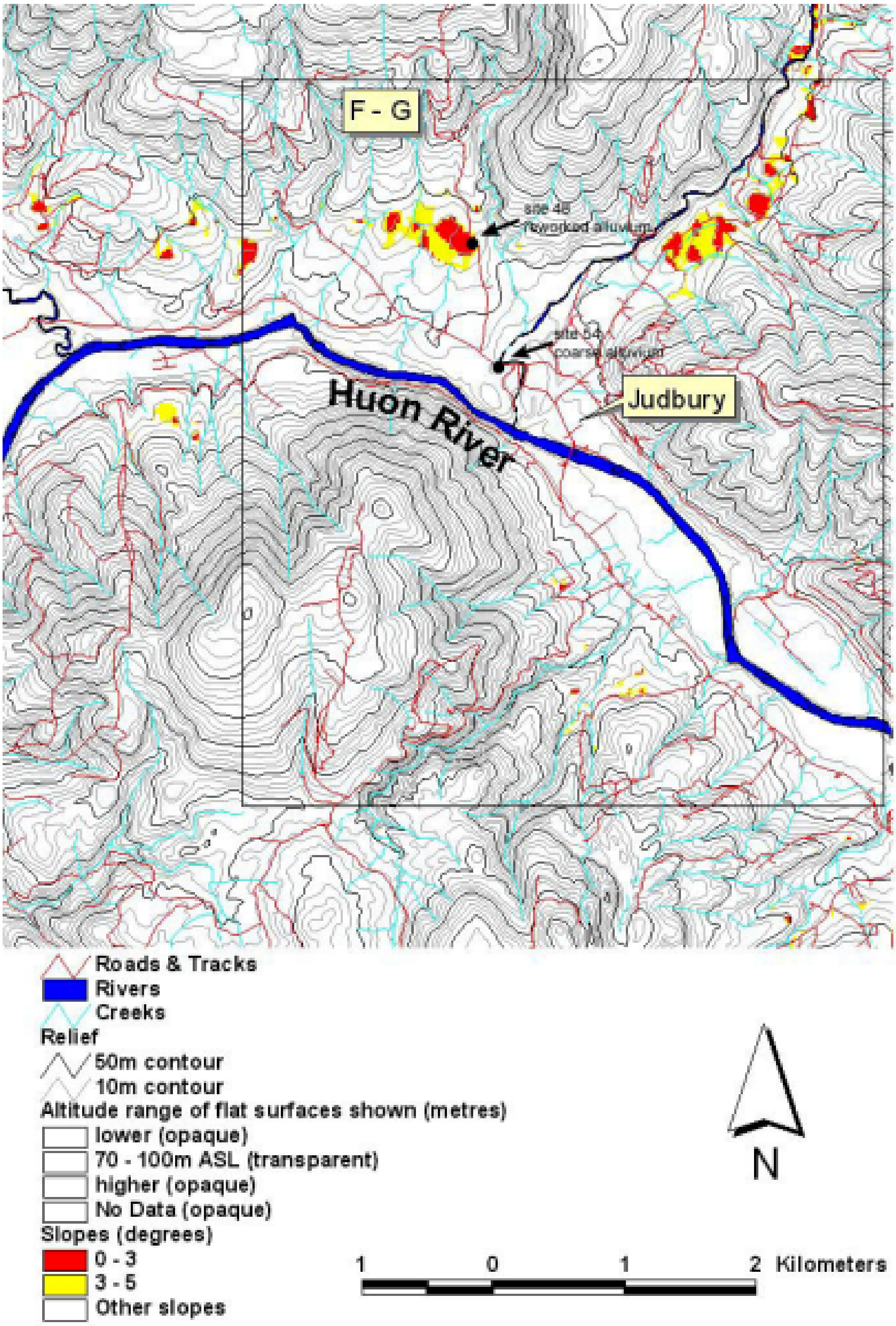

Figure 25: Valley section F – G, showing flat surfaces (0º - 3º and marginal 3º - 5º slopes: possible glacio-fluvial terrace remnants equivalent to Southwood terrace) in the 70 – 100 m ASL altitude "search envelope" for the Judbury region. Sites 48 and 54 (shown) have been inspected, and are described in section (4.3) following.

4.3 Assessment of potential equivalent glacio-fluvial terraces elsewhere in the Huon Valley

This section provides details of the predicted glacio-fluvial terrace sites, potentially equivalent to the Southwood Terrace, that have been field-inspected in the course of this project. Two sites (site 48 near Judbury and sites 57/59 north of the Huon/Weld confluence) yielded evidence of alluvial sediments in the predicted altitude ranges, and may be degraded remnants of high-level glacio-fluvial terraces. A number of other potential sites yielded no evidence of alluvial sediments and are probably surfaces of other types, although they could have possessed glacio-fluvial sediment covers in the past. Details of the inspected sites are provided below. Other potential sites indicated on the predictive maps (Figures 20 – 25) could not be inspected in the time available, and it remains possible that some of these may be glacio-fluvial sites equivalent to the Southwood Terrace.

Judbury

Site 48 – Reworked terrace remnant?
Site 48 (see map figure 25) is situated at 493 324mE 5240 683mN, at 80m ASL, which is 60 – 65 metres vertically above and north of the Huon River and lies within the predictive "search envelope" for this section of the valley. The site is a flat to gently sloping valley-side shelf roughly 150 metres wide which is private freehold pasture used for grazing. The shelf was inspected at it's eastern end adjacent Jacobson's Road.

The shelf is underlain by Jurassic dolerite bedrock (Forsyth *et al.* 1995), which outcrops in places on the shelf. Most of the shelf is mantled by angular and sub-angular boulders and cobbles of dolerite, which are probably a combination of bedrock lag and colluvial (slope) deposits which are likely to have moved down the valley slopes during the arid, sparsely vegetated conditions of the Last Glacial climatic phase. Pre-existing older deposits on the shelf are likely to have been both partly reworked and buried by these slope deposits.

However, a one metre high road cutting in the outer part of the shelf (at the specified grid reference, in the south part of the shelf well out from the higher valley slopes) exposes a brown silty-clay soil containing common well rounded to sub-rounded pebbles and granules of quartz and quartzite (see Figure 26). No coarser quartzite material was observed, however some significantly larger weathered dolerite cobbles are also present in the soil. The soil is dominated by the fine silty-clay matrix, and the quartz pebbles do not form a clast-supported conglomerate but are dispersed through the soil.

The quartz and quartzite pebbles are interpreted as a remnant of a Quaternary alluvial deposit, whose high level on the valley sides implies deposition at a time when rivers were depositing sediment at a level 60 – 65 metres above the present river level, which is the altitude predicted (previous section) for the highest (final) surface of a glacio-fluvial outwash plain of which the Southwood Terrace formed a part.

Permian and Triassic sedimentary rocks outcrop over 300 metres away from and upslope of site 48 (Forsyth *et al.* 1995), and could be considered a potential local source for the

Figure 26: Road cutting at site 48 (493 324mE 5240 683mN) showing rounded quartz pebbles (eg, above hammer head) and granules in abundant brown silty-clay soil. Larger dolerite cobbles are also present (eg, on surface above hammer), and the whole is interpreted as a soil derived from slope deposits which include reworked remnant alluvial quartz and quartzite pebbles.

quartz pebbles, via erosion and slope (colluvial) transport of residual dropstones or alluvial pebbles derived from the Permo- Triassic rocks. However, the topography of the slopes immediately above the site 48 shelf is that of a gentle spur ridge, which implies that colluvial material from the Permo-Triassic rocks upslope would be shed from slopes above site 48 into adjacent gullies, and would be unlikely to reach site 48. Given the lack of any likely local source for the quartz pebbles, the strong probability is that they are derived from Precambrian quartzite areas well upstream in the Huon Valley, and have been transported to the Judbury area by alluvial or glacio-fluvial processes.

Dolerite cobbles associated with the quartz pebbles at site 48 are of a consistently larger size and are probably unrelated, locally derived colluvial material which has been mixed with the quartz pebbles during slope transport and reworking of the alluvial deposits in the last glacial climatic phase. The dolerite cobbles at site 48 are not thoroughly weathered through to clay, in contrast to dolerite cobbles in a nearby, lower-level, glacio-fluvial deposit at site 54 (see below). The possibility that alluvial dolerite pebbles were deposited along with the quartz pebbles at site 48, and have subsequently been completely weathered to clay and mixed with the soil materials during later reworking of the deposit cannot be ruled out, however no evidence for alluvial material other than quartz and quartzite pebbles was identified.

In summary, rounded quartz and quartzite pebbles at site 48 are interpreted as alluvial pebbles deposited at a time when similar sediments filled the Huon Valley near Judbury to a level 60 – 65 metres above present river level. The necessary scale of such a valley fill, and the fact that the altitude of the sediments is that predicted for sediments equivalent to those at the Southwood Terrace, supports the possibility that the site 48 pebbles were deposited on a glacio-fluvial outwash plain surface equivalent to the Southwood Terrace. However, no absolute or relative dating tests have been attempted on the site 48 materials. Subsequent interglacial valley incision probably later removed most of the sediment fill from the valley, following which remnant glacio-fluvial terrace sediments at site 48 have been reworked and mixed with younger dolerite slope deposits by periglacial and mass movement processes during the last glacial climatic phase. As a result, any original terrace morphology has been lost, leaving only remnant pebbles from the original glacio-fluvial deposit.

Site 54 – Lower level glacio-fluvial sediment

A contrasting but possibly related glacio-fluvial sediment is exposed in a road cutting at site 54, directly down-slope from site 48, at 493 610mE 5239 749mN (see Figures 25, 27 & 28). This deposit has previously been noted by Sharples (1994a vol. 2, p.22), and may represent an earlier, lower stage of deposition in the same glacio-fluvial episode that the site 48 alluvium is inferred to have been deposited in.

Site 54 is situated at 30 metres ASL, several hundred metres north and about 15 metres vertically above the present day Huon River. The deposit comprises an unlithified conglomerate deposit 2 – 3 metres thick mantling Jurassic dolerite bedrock, and has an undulating upper surface with no indication of flat terrace surfaces. The sediment is a very poorly sorted clast-supported conglomerate comprising well-rounded quartzite and dolerite pebbles and cobbles up to 20cm diameter, in a pale brown silty-clay matrix with quartz sand and granules. The quartzite cobbles (~ 40% by volume of the cobbles) are hard and unweathered, whilst the dolerite cobbles (~ 60% by vol.) are thoroughly weathered to clay throughout. No indication of reworking of the deposit subsequent to its initial deposition was identified.

The clast rounding and distant (middle-upper Huon River region) provenance of the quartzite clasts imply alluvial transport and deposition, whilst the poor sorting and high matrix content are consistent with glacio-fluvial sedimentation. The deeply weathered nature of the dolerite clasts implies a depositional age significantly older than the Last Glaciation (Kiernan 1983, 1990a,b, 1991), indicating that the deposit is not a Last Glaciation outwash deposit, and is consistent with deposition during the maximum Cainozoic glaciation (>730,000 years BP), or potentially earlier. This implies that an age similar to the Southwood Terrace sediments (and the higher site 48 sediments) is possible.

Relationship between Judbury site 48 and 54 sediments

As noted above, the available evidence is consistent with the sediments described at sites 48 and 54 both being glacio-fluvial outwash deposits older than the Last Glaciation, potentially related to the maximum Cainozoic glaciation, and potentially having both been deposited during the same glacial outwash episode as the Southwood Terrace sediments. Whilst this latter possibility cannot currently be demonstrated, in the absence of more detailed absolute or relative age testing, the possibility arises that:

- the lower, coarser quartzite + dolerite sediment at Judbury (site 54) represents an earlier stage in the glacial phase when coarser material, eroded by extensive

Figure 27: View of coarse unlithified Quaternary sediment in road cutting at site 54 (493 610mE 5239 749mN), just west of Judbury, which is interpreted as glacio-fluvial outwash. The exposure shows unweathered quartzite cobbles and deeply weathered and ("rotten") dolerite cobbles (e.g., immediately to left of hammer handle).

Figure 28: Another view of the same exposure of probable glacio-fluvial sediment at site 54, also showing underlying dolerite bedrock exposed in the roadside drain at the base of the road cutting.

glaciers from both dolerite and quartzite bedrock source areas, was being carried down the meltwater rivers and deposited in the outwash plain; and that:

- the higher, finer grained quartzite–only (?) sediment at Judbury (site 48) represents a much later (waning?) phase of the same glacial phase, after an additional 50 metres thickness of outwash sediments had been deposited over the site 54 sediments. By that stage, only material from quartzite source areas was being eroded and carried downstream, and was travelling greater distances from the retreating glacier source, to be deposited on the outwash plain towards the end of its aggradational history.

Such a scenario implies that dolerite was present in the outwash sediments at earlier stages of the glacial phase, but had disappeared from the sediments by the time later outwash was being deposited at both Southwood and Judbury during the waning glacial outwash phase, for reasons possibly related to changes in sediment provenance as the source glacier retreated (see also discussion of "sediment composition and implications" in section 3.2).

If the site 54 and 48 sediments do both relate to the same period of glaciation, it is implicit that later (interglacial) fluvial incision of the Huon Valley outwash plain removed most of the deposits from the valley, leaving a remnant patch of low – level early-stage outwash sediment at site 54, and removed virtually all of the higher final outwash plain surface except for a few marginal remnant patches clinging to the higher valley sides, which remained intact at Southwood but were degraded and reworked by later slope processes at site 48.

Huon / Weld Confluence

Extensive deposits of high-level unlithified Quaternary glacio-fluvial sediments about one kilometre north of the Huon – Weld Rivers confluence were previously documented by Sharples (1994b, p. 12). See Figure (29). These sediments were identified at up to 90 metres ASL altitude (about 50 – 55 metres above the present river channels), which is a little lower than the Southwood Terrace.

The predictive modelling exercise conducted during this project indicated the existence of flat surfaces upslope from the sediments previously examined at this location, in the altitude range predicted for original final outwash plain surface fragments comparable to the Southwood Terrace (see Figure 21). Several of these have been examined (sites 57 – 59) and are described below. The lower sediments documented previously were also re-examined at one location (site 56) for comparison with the Southwood Terrace sediments.

Summary

In brief, although no absolute or relative age tests have been performed, the high level glacio-fluvial sediments north of the Weld-Huon confluence are considered probable correlates of those in the Southwood Terrace on the basis of strong lithological similarity (especially to the sandy pebble/cobble and granular sand facies – see section 3.2) and a closely similar high level position in the landscape. Terraces are present at various levels within the deposits, which appear to be degradational fluvial terraces eroded into the sediments during post-glacial down-cutting by the Huon and Weld Rivers. However, the

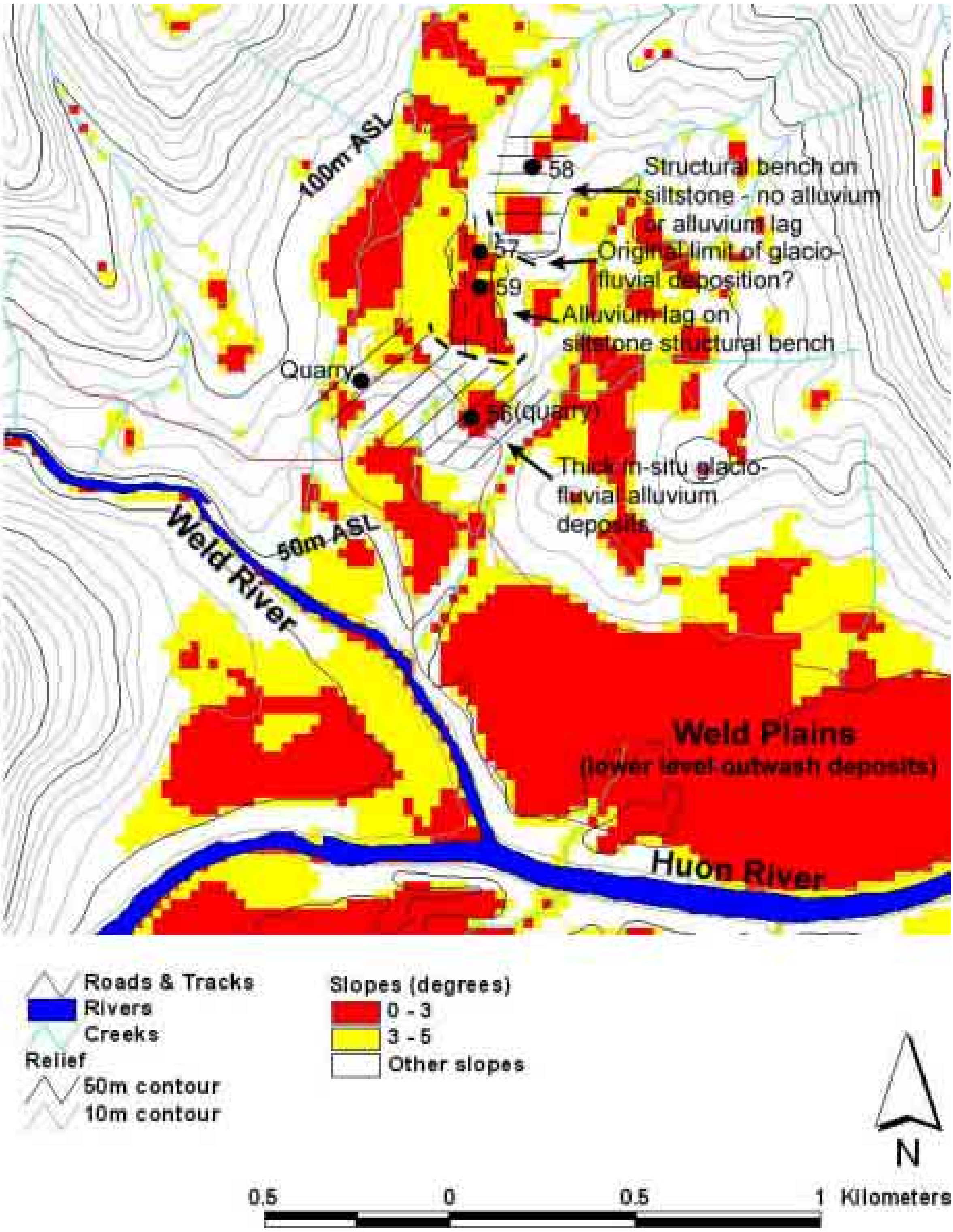

Figure 29: Flat surfaces and Quaternary glacio-fluvial sediments immediately north of the Huon – Weld River confluence. Sites numbered as per text. Flat surfaces are shown for all altitudes, not only those within the "search envelope" for terrace surfaces equivalent to the Southwood Terrace (as shown on Figure 21). A stepped series of surfaces or benches is clearly evident, and is probably due to two differing causes: whereas many of the surfaces below 100m ASL (i.e., at site 56 and below) are probably fluvial terraces incised into glacio-fluvial outwash sediments, those above 100m ASL are at least partly structural benches on flat-bedded Permian siltstone bedrock. The bench between 100 – 110 m ASL (at sites 57 & 59) is a structural bench upon which the highest glacio-fluvial sediments were previously deposited.

uppermost levels of the sediments have also been subject to post-glacial erosion in all locations where they have been examined. Thus, although lag deposits of alluvium occur on flat surfaces at the altitudes predicted for original final (uppermost) outwash plain surface remnants equivalent to the Southwood Terrace, these are not intact original surfaces, but rather comprise residual alluvium lags on bedrock structural benches upon which the highest level (final) glacio-fluvial sediments were originally deposited, and from which they were subsequently mostly eroded. Nonetheless, some further flat surfaces at the same altitudes remain to be inspected, and it is still possible that these may include some intact fragments of original outwash plain surfaces.

Significantly lower level sediments in the same area, close to the present Huon and Weld River levels, were not examined but may be outwash sediments deposited earlier in the same phase of glaciation – that have been exposed by subsequent deep incision of the final outwash plain - and/or may include outwash from more recent glacial episodes including the Last Glaciation. In either case, they are likely to include sediments of differing composition to the older high level sediments described here.

The sites examined north of the Huon-Weld confluence are indicated on figures (21 & 29) and are described below.

Existing reconnaissance – level geological mapping (Forsyth *et al.* 1995) indicates that Jurassic dolerite bedrock underlies these sites, however this is incorrect: although bedrock outcrops were not identified during this work, pale silty-clay soils with common angular lag fragments of siltstone occur throughout the area of the flat surfaces examined around sites 57 – 59, and these are indicative of Permian siltstone bedrock. No dolerite fragments or dolerite – derived soils were identified in the area of these sites. Roughly one kilometre to the SSE of these sites, at site 55 (481 433mE 5233 448mN) which is also a location that interpretation of current geological mapping suggests is underlain by dolerite, a recent road cutting exposes well-lithified Permo-Carboniferous tillite, comprising matrix supported rounded pebbles and cobbles of quartzite and schist (but no dolerite).

Site 56 and adjacent areas – Glacio-fluvial sediments previously identified below the highest original surface altitudes

Sharples (1994b, p. 12) previously described the glacio-fluvial sediments at site 56 and in another quarry 300m further to the west (both sites are indicated on Figure 29). The western quarry (at 480 600mE 5234 000mN) exposes a 3 metre thickness of unlithified poorly-sorted pebble/cobble conglomerate dominated by Precambrian quartzite clasts, with no Jurassic dolerite clasts. This site also includes a lens of moderately sorted sand/granule sediment displaying crude inclined laminations that are probably cross-beds. The sand/granule lens is comparable to the uppermost granular sand facies at the Southwood Terrace (see section 3.2), and the presence of cross-bedding is notable since these have not yet been identified at the Southwood site.

At site 56, which is also a quarry pit exposure at 90m ASL on the outer edge of a flat terrace surface at 480 905mE 5233 888mN, unlithified glacio-fluvial alluvium over 3 metres deep (base not seen) is exposed. The sediment is a very poorly sorted clast -

Figure 30: View of glacio-fluvial sediment exposed in an artificial face at site 56 (480 905mE 5233 888mN), about a kilometre north and 50 metres vertically above the Huon – Weld River confluence.

Figure 31: View of fallen tree root ball at site 59 (tree trunk lying on ground at top) showing a section of the upper soil profile at this site. A distinct rounded quartz pebble layer 10-15 cm thick at the top of the soil profile is interpreted as a residual alluvium lag, and is underlain by yellow-brown silty-clay soil having only rare quartz pebbles.

supported massive conglomerate lacking obvious bedding or clast imbrication (see Figure 30). The larger clasts comprise well rounded pebbles and cobbles (up to 20 cm diameter), mainly consisting of meta-sedimentary quartzite but including minor grey silica agates, silica with characteristic "boxwork" holes, and some deeply weathered ("rotten") mudstone clasts. The agates and boxwork silica are characteristic of dolomite-replacement silica known from the Weld Valley and Blakes Opening (Huon River), whilst the "rotten" mudstone clasts may be Permian or Triassic-age mudstones similar to those found in the glacio-fluvial alluvium at the Southwood Terrace. As at Southwood, no dolerite clasts were identified. The sediment matrix is silty quartz sand with quartz granules. Well-developed brown iron pans ("coffee rock") are exposed about one metre below the ground surface, in the quarry pit.

In terms of its sedimentological texture and fabric, clast composition, degree of lithification and iron pan development, the sediment is indistinguishable from the "sandy pebble/cobble" facies at the Southwood Terrace (see section 3.2), and given its occurrence at a similar high level in the landscape, is likely to be an equivalent, or correlate, of the latter.

A concentrated surface layer of quartz pebbles is interpreted as lag, and implies that the surface of the deposit has been eroded subsequent to deposition. A flat surface immediately above the exposures (see Figure 29) is about 10 metres lower than the probable highest level of local glacio-fluvial sedimentation (near site 57 – see below and Figure 29), and is probably a degradational fluvial terrace incised into the deposit during down-cutting by the Weld and Huon Rivers after glacio-fluvial sedimentation ceased.

Sites 57, 58 and 59 – Original highest outwash plain surface levels (and above)

About 10 metres vertically above the thick glacio-fluvial sediments at site 56, a flat bench at 100 – 110m ASL was identified by predictive modelling as potentially equivalent to the Southwood Terrace (see Figure 21). This surface was inspected at and around sites 57 & 59 (see Figure 29), which are located at 480 918mE 5234 389mN and 480 897mE 5234 300mN respectively.

Rounded cobbles and pebbles of meta-sedimentary quartzite are sparsely visible on the ground surface around sites 57 & 59. No bedrock outcrops were identified. Fallen tree root-balls provide exposures of the soil to up to a metre depth. The soil is a grey-brown to yellow-brown silty-clay containing common angular pebble and cobble size fragments of siltstone, which are interpreted as residual lag from underlying Permian siltstone bedrock . Scattered rounded quartzite pebbles and cobbles (up to 20 cm diameter) are moderately common in the upper 10 – 15 cm of the soil profile, but occur only rarely or not at all below that depth (see Figure 31).

Further upslope, higher flat surfaces in the "search envelope" for Southwood Terrace equivalents (see Figure 21) were inspected between 110 and 120m ASL, up to site 58 at 481 052mE 5234 592mN. Above 110m ASL, no further rounded quartz pebbles and cobbles were seen in the soil, which is predominantly a grey silty-clay soil with common angular pebbles of siltstone, which are again interpreted as residual lag fragments of underlying Permian siltstone bedrock.

It is conceivable that at least some of the rounded quartz pebbles and cobbles in the soil around sites 57 & 59 could be residual dropstone lags weathered out of the underlying Permian siltstone bedrock, rather than being derived from Quaternary alluvium. However, the fact that these pebbles are noticeably absent above 110m ASL, despite the bedrock evidently being Permian siltstone both above and below that altitude, strongly suggests that the pebbles are not primarily derived from the bedrock itself, but rather constitute a residual lag from a Quaternary alluvial deposit which was originally laid down up to 110m ASL, but not above that altitude. This suggests that the final level of the outwash plain surface here reached 110m ASL altitude, which is very close to the upper limit of the Southwood Terrace, and within the range predicted for the outwash plain surface near the Huon-Weld confluence (see section 4.2 and Figure 21).

The quartz pebbles and cobbles on the flat surface below 110m ASL, around sites 57 & 59, occur widely dispersed ("matrix – supported") through a soil which also contains angular siltstone fragments, and are evidently not intact *in situ* alluvial sediments, as at site 56. On the available evidence, these pebbles and cobbles are interpreted as a residual lag remnant of an alluvial (glacio-fluvial) sediment related to the sediment down-slope at site 56, which was originally deposited at altitudes up to 110m ASL, but has now been largely removed by erosion, leaving only a few residual remnants in a soil that is predominantly derived from the underlying siltstone bedrock. This is in contrast to areas further down-slope (i.e., below 100m ASL), where patches of original glacio-fluvial sediments – that were formerly buried within the outwash plain sediment pile - remain *in situ* but now exposed on the valley sides.

Whereas many of the flat surfaces identified below 100m ASL (see Figure 29) are incised into thick deposits of *in situ* glacio-fluvial sediments, and are probably fluvial terraces form by river incision and erosion after glacio-fluvial sedimentation ceased, the prominent series of stepped benches or terraces above that altitude are cut into bedrock at and extending well above the final level of glacio-fluvial deposition. These latter benches are likely to be the result of slope erosion processes etching out structural (bedding-controlled) benches in the flat-lying Permian sedimentary bedrock[7].

Other sites inspected

Sites 51 & 52 (Edwards Road)

Two broad flat shelves on the east side of the Huon Valley upstream of the Weld River confluence lie in the predicted altitude range for sites equivalent to the Southwood Terrace (Figures 20 & 21), and were inspected where they are traversed by Edwards Road (at grid references 479 742mE 5231 343mN and 479 611mE 5230 390mN).

The northernmost site (51) is underlain by areas of both Jurassic dolerite and Permian sedimentary rocks (Forsyth *et al.* 1995), but is mostly mantled by dolerite slope deposits).

[7] It is of interest to note that, at least in the areas examined, the thick *in situ* glacio-fluvial sediment deposits support predominantly low heathy or moorland vegetation, whereas the higher surfaces with only residual alluvium lags support forest vegetation. Although this may be partly related to fire history, it is likely that a controlling factor is that the siliceous alluvial sediments are a very nutrient-poor soil parent material, whereas the areas of only residual alluvium lag are dominated by siltstone-derived soils with a higher nutrient status that is better suited to supporting forest vegetation.

No evidence of alluvial deposits was found. A single rounded quartz pebble noted in the soil is likely to be a residual lag from weathering of underlying Permian bedrock.

The southern site (52) is underlain by Permian sedimentary rock which outcrops in road cuttings, and is partly mantled by dolerite slope deposits. No indication of alluvial sediments was identified.

If any significant glacio-fluvial sediments have existed at these sites in the past, it is evident that they have been reworked and removed by erosion, and by slope mass movement processes during the Last Glacial Phase. The flat shelf topography at these sites may be structural benches resulting from exposure of flat-lying bedding planes by erosion.

Site 23 (immediately north of Southwood Terrace)
A flat area surrounding the road at and north of site 23, immediately north of the Southwood Terrace site, lies in the same altitude range as the Southwood terrace (see Figure 22). Permian sedimentary rock outcrops and forms residual lag boulders on this surface, and no significant alluvial deposits were identified in the surface (rare quartz pebbles are likely to be residual dropstone pebbles weathered from the Permian bedrock). The flat surface in this area is probably a structural bench resulting from exposure of flat-lying bedding planes by erosion.

Any glacio-fluvial sediments formerly present on this structural bench have evidently been removed by erosion.

Site 53 (East Picton Road)
At this site (477 339mE 5225 230mN) a flat bench occurs on the east side of the lower Picton River valley about three kilometres upstream of the Picton / Huon confluence. It is probable that a broad outwash plain deposited by a Huon Valley glacier would have extended this far up the tributary Picton Valley, where it would undoubtedly have also received an outwash contribution from glaciers in the Picton Valley itself.

Unfortunately, road construction at this site has utilised quartzite glacio-fluvial sediments from a quarry in the low level outwash terraces adjacent the Huon / Picton confluence, hence it is difficult to identify *in situ* glacio-fluvial material in roadside exposures, if any such exists. A brief reconnaissance away from the roadside revealed poor substrate exposure within the forest, and it is evident that it will require more extensive exploration of the area, and perhaps test pits, to determine whether glacio-fluvial sediments, and terrace surfaces equivalent to the Southwood Terrace, are present at this location.

Priorities for further inspections

Due to time limitations, the fieldwork undertaken during this project has not exhausted the target sites identified as potentially equivalent to the Southwood Terrace. In addition to a more detailed inspection of site 53, all remaining potentially equivalent sites identified (Figures 20 – 25) are worth inspecting. Of particular note are:

- Although potentially equivalent sites 57 & 59 (north of the Huon / Weld confluence – Figure 21) proved to retain only a residual lag of the glacio-fluvial sediments, these lie at the upper limit of an extensive deposit of intact glacio-fluvial sediments, and it is still possible that better preserved terrace remnants preserving the original top surface of the deposit could exist nearby. An identified "target" flat area about 500 metres north of, and at the same altitude as site 57 would be worth inspecting (figure 21).

- Only two kilometres north of the Southwood Terrace, a flat area on the southwest side of Griggs Creek, centred around 485 183mE 5235 522mN, is at the same altitude as the main part of the Southwood Terrace. Although this flat area lies a little way up a tributary valley, it is likely the Huon outwash plain would have in-filled this re-entrant, which is therefore worth an inspection.

Considering the Huon glacio-fluvial outwash system more broadly, possibly equivalent glacio-fluvial sediments are known as far down-river as Franklin and Randalls Bay, in the Huon estuary (see section 2.2). Further investigation of these sediments would be of considerable scientific interest, particularly in respect of attempting to determine whether they may be chrono-stratigraphic correlates of the Southwood Terrace sediments. If they can be shown to be of likely equivalent age, the identification of remnant upper terrace surfaces – or even simply of the highest altitude of residual equivalent sediments - would be of considerable value in testing and improving the models of the outwash plain long profiles discussed in section (4.2) above.

5.0 GEOCONSERVATION SIGNIFICANCE ASSESSMENT OF THE SOUTHWOOD DEVELOPMENT SITE

Geoconservation is "the identification and conservation of geological, geomorphological and soil features, assemblages, systems and processes (geodiversity) for their intrinsic, ecological or heritage values" (Eberhard 1997, p. v). Geoconservation is based on the idea that geological features, landforms and their ongoing processes (geodiversity) are as important a part of our natural heritage, and as worthy of conservation, as is biodiversity. This idea is now a well-established conservation principle in Tasmania (DPIWE 2001).

One basic aim of geoconservation is to conserve well-developed and well-expressed representative examples of important elements of the geodiversity found in a region. In some cases, the goal is to conserve the integrity of the ongoing geomorphic processes, such as fluvial, karst or coastal processes, which form the basis of natural ecosystems. However in a case such as that of glacial landforms in Tasmania, the goal is to conserve representative relict or fossil features which provide important information about Tasmania's past development, and which thus constitute aspects of our geological or geomorphic heritage ("geoheritage").

An assessment of the geoconservation significance of a feature essentially consists of an assessment of:

1. how well the feature displays or exemplifies the important characteristics of its type, in comparison to other examples of the same class of feature; and

2. whether or not other equally good examples of the same class of feature are rare or common within the same geomorphically-defined region ("georegion"), which in the case of the Southwood glacio-fluvial terrace can be taken to be the Huon Glacial System region.

Such an assessment can lead to a feature being identified as being somewhere on a spectrum between – at one extreme – the best available example of a rare class of feature (and thus highly significant), or – at the other extreme – an mediocre or poorly expressed example of a common type of feature (and thus of low significance). Features assessed as being of geoconservation significance may be conventionally classified as *Outstanding* or *Representative* at levels ranging from *Local* to *World* (Sharples 1995). Thus, an feature judged "Outstanding at a World Level" would be one of the best examples of its type in the world, whereas a feature judged "Representative at Local Level" would be a good representative example in a local context, but equivalent features may be relative common at a world level.

Outcomes

The Southwood Terrace is a well-developed and well-expressed example of a glacio-fluvial outwash plain surface and sediments relating to a major – possibly the most extensive – glaciation preceding the Last Glaciation in Tasmania. It can be considered well – developed and expressed because it preserves a portion of the original final outwash plain surface more or less intact, and because it contains a well-preserved suite of differing late-stage outwash sediment facies (see sections 3.2 & 3.3).

These latter aspects are significant because:

- preservation of a portion of the final outwash surface allows reconstruction of the altitude, extent and form of the broader outwash plain, and permits inferences to be made about the extent of the glacial episode which produced the outwash plain. These inferences become less certain where only residual contents of the outwash plain are preserved without their original intact surfaces.

- preservation of sedimentary materials, particularly where these show compositional and textural variations between facies, allows interpretation of glacier source areas (from the clast lithological types, and variations of these between facies), changes in source areas allowing interpretation of glacier configurations at different times, and also allows interpretation of the glacio-fluvial outwash processes that operated on the outwash plain.

Although further exploration for equivalent examples is possible and recommended, to date no other equally well-developed and expressed examples of a glacio-fluvial outwash plain surface equivalent to the Southwood Terrace have yet been located in the Huon Valley. Although two potentially equivalent terrace remnants have been identified (see section 4.3), these are considerably eroded and degraded compared to the Southwood Terrace, and do not display a preserved original depositional surface, nor original intact sediment fabrics and textures. Consideration of the unusual position of the Southwood Terrace sediments in the landscape (on the broad crest of a bedrock spur projecting into the valley centre, where the remnant depositional terrace was protected from fluvial incision by the bedrock spur beneath it, and from later slope erosion by the broad nature of the flat ridge crest) suggests that equivalent situations conducive to preservation of an original outwash plain fragment are likely to be rare in the Huon Valley, and none have been located to date (see section 3.3).

In summary, the Southwood Terrace surface and sediments are a well-developed and expressed example of a fragment of the original (final) surface and sediments of a glacial outwash plain formed during a very extensive (possibly the most extensive) Cainozoic glaciation preceding the Last Glaciation. Whilst several degraded equivalent examples have been tentative identified, and further exploration remains to be undertaken, no equally good equivalent examples have yet been identified elsewhere in the valley, and there is reason to think (in virtue of its unusual landscape position) that the Southwood Terrace may be unique in the Huon Valley in terms of its degree of preservation.

Geoconservation significance
On these grounds, the Southwood Terrace and sediments can be considered to be of Representative, and probably Outstanding, significance at a Regional level, where the region is taken to be the Huon Valley Glacial System.

Time has not permitted a thorough review of data on equivalent outwash plain surfaces and sediments relating to the maximum Cainozoic (and other) glaciations elsewhere in Tasmania. It is assumed that similarly well-expressed and preserved outwash surface fragments relating to extensive glaciations preceding the Last Glaciation may exist in other glaciated regions of Tasmania outside the Huon Region. If so, the Southwood Terrace is likely to remain significant at only the Regional, but not the State level. However, if a thorough review of available data were to reveal that no other equally good examples of equivalent features are known to exist elsewhere in Tasmania, then the Southwood Terrace would be the best known example of its type in Tasmania, and hence its geoconservation significance would be upgraded to Representative or Outstanding at State level.

Distribution of sensitive geoconservation values at the Southwood Spur
The geoconservation value of the outwash sediments comprising the preserved outwash plain fragment would be significantly degraded by large-scale excavation and removal of the sediment, however minor excavations (relative to the total extent of the sediment deposit) will provide useful exposures allowing better understanding of the feature.

The aspect of the feature most sensitive to disturbance is the form – the landform morphology – of the intact portion of the original depositional surface on the granular sand facies. This surface is significant as an ancient landscape surface which, on current evidence, remains the only intact example of its type and age known in the Huon Valley. The sensitivity of the surface to disturbance is enhanced by the fact that it is composed of soft unconsolidated sands which are easily disturbed by mechanical means. The extent of this surface is shown on Figure 17. Significant disturbance of this surface, by excavation, heavy machinery or other mechanical impacts, will irreversibly modify it, reducing its intrinsic and scientific value. Recommendations regarding this sensitive landform feature are provided in the following section (6.0).

6.0 RECOMMENDATIONS

In the light of the information and discussions provided in this report, the following recommendations are made:

Southwood Site Development

- Excavation and site development work at the Southwood Terrace should be monitored by a suitably qualified person with a view to recording further scientific data on the glacio-fluvial outwash sediments as sections of these become exposed, in order to improve understanding of the feature and its origin. Data which can usefully collected includes sedimentological descriptions, exposure of relationships between facies units, and measurement and mapping of the form of each unit. Further samples suitable for dating tests and other palaeo-environmental analyses should be collected as appropriate. Sampling of peat and any palaeosols identified for radiocarbon testing is also recommended,

  In particular, recording of new exposures on the eastern side of the Southwood Terrace, and down the eastern slopes, will be valuable in understanding the implications of the abrupt and unexplained descent of each sedimentary unit down the eastern side of the spur.

  Given the geoconservation significance of the Southwood Terrace, and the fact that some of its geoconservation values are likely to be partly or wholly lost through site disturbance, it is recommended that the opportunity to obtain the maximum scientific information from the feature during site development works should be given priority.

- Efforts should be made to preserve at least representative portions of the preserved original outwash plain depositional surface free of mechanical disturbance, in view of the significance of this ancient landscape surface remnant (see section 5.0). The sensitive area of original depositional surface is indicated on Figure 17. The practicality of achieving preservation of remnant portions of this surface in the context of the proposed development should be determined by examination of the site development plans.

Ongoing scientific study of the Southwood Terrace

In addition to the ongoing field data collection recommended above, it is recommended that:

- Previously collected sediment samples (as listed in Appendix 3), together with any further samples collected, should be subjected to dating and palaeo-environmental testing, including thermo-luminescence dating, palynological analysis, and other tests as appropriate, to improve knowledge of the age, depositional environment and glacial process implications of the Southwood Terrace.

Exploration for equivalent terraces

- Continued exploration for potential equivalent outwash terrace sites elsewhere in the valley is recommended. Exploration should commence by completing the examination of all potential sites identified in section (4.2), particularly the priorities for further inspections identified in section (4.3), and might progress through further refinement of the predictive models used in this investigation.

Geoconservation significance assessment

- A thorough review of available data on pre-Last Glaciation outwash terraces elsewhere in Tasmania, together with consideration of any further data obtained through other recommended actions (above), should be undertaken with a view to confirming or revising the assessment of the geoconservation significance of the Southwood Terrace as described in section (5.0) above.

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APPENDIX 1: CONSULTANTS BRIEF

This report has been prepared in accordance with the following brief, which was supplied to John Holland Pty. Ltd. by the Tasmanian Department of Primary Industries, Water & Environment (DPIWE), in September 2002.

Draft consultant's brief for assessment of geoconservation values at the site of the proposed Southwood development

Background

The Southwood development site falls within the Huon Valley Glacial Systems, listed as being of significance on the Tasmanian Geoconservation Database. Copies of the database record and map are attached. The significance of the Huon Valley Glacial Systems is listed as "unknown" because scientific description is at present very incomplete. The gravels and sands of the "main terrace" at the development site are of apparent fluvio-glacial origin. Sharples (1994) notes that this terrace remnant is the highest known (70 m) with respect to the present level of adjacent river. As such it is likely to be the oldest of these deposits and should not be correlated with those of the Weld Plains, which occupy a lower position in the present landscape. The inferred age of the deposit means its scientific values have a special significance within the context of the Huon Valley Glacial System, and potentially within the broader suite of the Southwest Tasmanian Glacial Areas.

The brief:

1/ Establish whether or not it may be possible to correlate the deposit at the development site with any similar features elsewhere within the Huon Valley Glacial Systems, noting that no such features are presently known. If potential correlates are found collect and submit any datable materials as per 4/ below.

2/ Provide a detailed sedimentological description of the nature and distribution of alluvial facies present at the development site, including the relations between the various facies, to the extent that this is possible using existing exposure and logs of boreholes and test pits. Text descriptions should be accompanied by appropriate graphics, including photographs, maps, sections etc.

3/ Determine whether any of the existing geomorphic elements may represent primary (i.e. depositional) surfaces and, if appropriate prepare a geomorphological map.

4/ Collect and submit for analysis appropriate samples for age determination. Such samples might include sands for thermoluminescent dating or, less preferably, palaeosol materials for relative age determination by palynological methods.

5/ Provide an interpretive summary history of the post-Permian geology and geomorphology of the development site.

6/ Use the above work to explicitly identify the nature and distribution of geoconservation values at the development site. Where necessary note the nature and significance of gaps in the data and what influence these might have on this assessment of geoconservation values.

7/ Prepare a report, including the necessary maps and sections etc., that documents the above and where appropriate lodge specimens with organisations that are able to curate these materials.

The report on the above work shall then be referred to a special sub-committee of the Tasmanian Geoconservation Database Reference Group to determine how the geoconservation values of the development site could be best maintained.

APPENDIX 2: SITE DATA

The following list provides the AMG (Zone 55) metric co-ordinates (AGD66 datum) of each site referred to in the text. Co-ordinates were in all cases obtained using a Garmin 12 GPS unit.

Site No	Easting	Northing	Note
1	485100	5232649	
2	484780	5232727	
3	484741	5232877	
4	484596	5232986	
5	484772	5233032	Adjacent coffey borehole SMB1
6	484773	5233232	
7	484787	5233272	
8	484774	5233154	
9	484680	5233305	
10	484704	5233363	
11	484754	5233380	
12	484910	5233481	
13	484883	5233448	
14	484938	5233419	
15	484956	5233402	Coffey borehole SMB2
16	484977	5233426	
17	484909	5233524	
18	484844	5233625	
19	484828	5233732	
20	484886	5233836	
21	484809	5233757	
22	484747	5233869	
23	484702	5233994	
24	484840	5233522	
25	484866	5233404	
26	484837	5233355	
27	484801	5233361	
28	484089	5233664	
29	484589	5232955	
30	484558	5233120	
31	484544	5233178	
32	484501	5233232	
33	484433	5233257	
34	485136	5232797	
35	485086	5232873	
36	484999	5232940	
37	484961	5232979	
38	484834	5233122	
39	484872	5233565	
40	484855	5233587	
41	484967	5233299	
42	484833	5233422	
43	484726	5233309	

44	484823	5233002	
45	484763	5232841	
46	484719	5232911	
47	484664	5232948	
48	493324	5240683	
49	484081	5233653	Junction Weld Plains Rd and new road
50	484138	5233813	Coffey borehole SMB3
51	479742	5231343	
52	479611	5230390	
53	477339	5225230	
54	493610	5239749	
55	481433	5233448	Permian tillite outcrop, Weld Plains
56	480905	5233888	Quarry in outwash, Weld plains
57	480918	5234389	
58	481052	5234592	
59	480897	5234300	Rootball exposing alluvium lag

APPENDIX 3: SAMPLE CATALOGUE

The following seven sediment samples were collected from the Southwood Terrace site during the investigations detailed in this report:

Sample No.	**Site No.** (see Appendix 2)	**Details**
S1	18	Deeply weathered Permian siltstone regolith, from approx. one metre below basal contact with overlying silty-clay pebble/cobble outwash facies. Sample obtained from fresh road-cutting 3 – 4 metres below natural ground surface.
S2	40	Silty-clay pebble/cobble outwash facies, from 1.5m above base of fresh road cutting, approx. 3 metres below natural ground surface.
S3	13	Granular sand facies, from top of sand unit, immediately under sandy peat O-horizon. Sample is a portion of the original depositional surface. Sample obtained from freshly exposed road-cutting.
S4	13	Granular sand facies, from 70 – 80 cm below top of sand unit (measured from base of overlying peat O-horizon), immediately above iron-cemented sand "coffee rock" horizon. Sample obtained from freshly exposed road cutting.
S5	13	Iron-cemented granular sand facies from "coffee rock" horizon, 90 - 95 cm below top of sand unit (measured from base of overlying peat O-horizon) . Sample obtained from freshly exposed road cutting.
S6	12	Sandy pebble/cobble outwash facies, from top of facies unit immediately under sandy peat surface O-horizon. Sample is a portion of the original incised terrace surface on which the adjacent granular sand facies was deposited, and which appears not to have been further eroded since outwash deposition ceased. Sample obtained from freshly exposed road-cutting.
S7	12	Sandy pebble/cobble outwash facies, from base of road cutting 100 cm below top of sandy pebble/cobble facies (measured from base of overlying peat O-horizon). Sample obtained from freshly exposed road cutting.