A geological hazard assessment for the lower Fox Valley, anno 1994

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Introduction

The section of Fox Valley between the terminus of Fox Glacier and the outlet of the Fox River at the front of the mountain range is, at present, one of the fastest eroding areas on the western side of the Southern Alps. Within the valley, three sites can be recognised, that have recently been affected, or are affected at present by large scale slope instability processes. These are Undercite Creek, Yellow Creek, and the Straight Creek/Boyd Creek complex. A large number of smaller erosion scars can also be recognised in the valley.

Fox Glacier is one of the main tourist attractions of the west coast of the South Island. Most days, large numbers of people visit the lower part of the glacial valley, travelling by car, bus, bicycle, or on foot. Most traffic is using the access road on the true righthand side of the valley. A smaller number of visitors are using the road on the true lefthand side of the valley, which doesn't give direct access to the glacier.

Visitor traffic along the true righthand side of the valley has been affected by erosion of the steep valley side above the access road and track. The visitor carpark has had to be relocated on two occasions since construction of the road, due to rockfall and debris flow activity, and the access road itself was blocked on many occasions by rockfall and avalanche debris. Increased erosion of the Undercite catchment since the winter of 1992 has made it necessary to divert the road away from the valley side, onto the active floodplain of the Fox River. Most problems have been caused by debris sourced from the higher parts of Yellow Creek and Undercite Creek. These two catchments contain a substantial amount of highly fractured and weathered bedrock, and may therefore be expected to continue disrupting or threatening the tourist traffic to and from the glacier on a regular basis in the foreseeable future.

This report, commissioned by the Department of Conservation Science and Research Division, provides a geomorphological and geological evaluation of the natural hazards of the lower Fox Valley, with regard to the tourist traffic in the valley. It discusses the erosion sites that pose a direct threat to traffic in the valley in terms of present character and future activity, and addresses the landscape evolution of the valley in the next decades. To conclude, some remarks are made on possible short term and long term solutions to the problem of access to the Fox Glacier.

Site Description

GEOLOGY

Central South Island contains a zone of active oblique continent-continent collision, involving the Australia and Pacific plates. The Alpine Fault is the locus of much of the oblique plate motion and in its central segment facilitates ramping of continental Pacific crust over continental Australian crust. The Southern Alps are the manifestation of uplift of the leading edge of the Pacific plate crust, which was initiated soon after anomaly 5 (9.8 Ma). In the central segment of the collision zone, modern rates of uplift close to the Alpine Fault are around 8-10 mm/yr, decreasing towards the southeast. A larger part of the oblique convergence is accommodated by dextral strikeslip motion along the Alpine Fault, present rates of movement being around 35 mm/yr.

Alpine schist crops out in a narrow belt immediately to the east of the Alpine Fault. It contains garnet, biotite, and chlorite zones of greenschist facies. These rocks have been deformed during the late Cenozoic as a consequence of the distributed strain of collision and dextral transform movement across the plate boundary.

The main deformational feature, the Alpine Fault, is thought to be located close to the mountain front. In outcrops in nearby valleys, large faults, thought to be part of the main fault strand, are dipping between 45° and 60° towards the southeast. Immediately to the east of the main fault, the Alpine schists are heavily sheared, and dissected by a large number of smaller faults, most of which are running parallel to the main structure.

In the Fox Valley, several zones can be distinguished where the schists have been sheared extensively. These zones are trending northeast-southwest, dipping 70° or steeper towards the southeast.They are characterized by a closer spacing of planar discontinuities than in adjacent rocks. Each of the zones is over 100 meters wide, and contains open planar joints with a spacing of centimeters to decimeters. The joints are up to over ten meters in length.

Between the highway bridge and Yellow Creek there are no indications of intense brecciation of the bedrock, indicative of large scale faulting. However, large quantities of brecciated schists, showing green, crop out in Straight Creek, Boyd Creek, and the upper part of Yellow Creek. The fault zones marked by these breccias are low angle, indicating recent thrusting within the frontal part of the mountain belt.

GEOMORPHOLOGY

The Fox Valley is a glacial valley, with a markedly U-shaped profile of the lower half of the valley sides. The sides are very steep, in many places close to vertical. Above these steep sections, slopes with a smaller scale ruggedness extend upwards to the drainage divides. Glacial striations are present on many bedrock surfaces exposed in the steepest parts of the valley. Elsewhere, post-glacial exfoliation of the dissected schists has produced unstable conditions in highly weatherable rock. Extensive moraine deposits are present in many parts of the valley. Where moraine is exposed in steep valley sides extremely unstable situations exist.

The valley bottom is occupied by a glacier, the Fox Glacier, currently extending downward to about 260m a.s.l. Immediately downstream of the glacier terminus, a 250 meter wide floodplain accommodates the braiding Fox River. At the lower end of the 2.5 km long floodplain, the river enters a more confined section, and spreads out again downstream of the highway bridge.

A little less than a kilometer downstream of the present glacier terminus, a body of dead ice, covered by a layer of coarse sediment, marks the glacier stand of the early 1960's. Hugging the true righthand side of the valley, the dead ice body forces the river to the lefthand side of its floodplain, where it remains until it enters the more confined section downstream (Photo 1).

Three large sediment bodies are built out onto the floodplain. On the true righthand side, a steep rock avalanche cone is present underneath Undercite Creek, and a debris fan is fed by Yellow Creek. On the true lefthand side of the valley, a debris fan, currently being overriden by the glacier, forms the lower end of Straight Creek. These three sediment bodies mark the three most important erosion areas within the Lower Fox Valley.

Except for Mills Creek, and the uppermost part of a nameless stream to the northwest of Yellow Creek, other parts of the Lower Fox Valley have been relatively stable during the past 50 years. On various series of aerial photographs (1948, 1965, 1975, 1981, 1984, 1985), only traces of minor debris avalanches, landslides, and debris flows can be seen in the catchments of Caution Creek and Broken Creek. Rockfall in the upper part of the White Creek catchment has not affected the lower valley sides to a large extent.

Appendix 1 is a geomorphological map of the Lower Fox Valley, giving an overview of the recent erosion features present in the area.

LOCATION OF THE MOST IMPORTANT EROSION SITES

Figure 1 gives an overview of the most important erosion sites in the lower Fox Valley with respect to visitors traffic. These sites are:

1 Undercite Creek
2 Yellow Creek
3 the Straight Creek/Boyd Creek complex
4 the nameless creek immediately to the northwest of Undercite Creek
5 the nameless creek crossing the righthand access road at 1.9 km from the highway 6 turnoff
6 the lower valley side between White Creek and the glacier terminus
7 the north facing side of the Cone Rock ridge
8 Mills Creek

Hazard Assessment Individual Sites

UNDERCITE CREEK

Undercite Creek drains a very steep section of the righthand valley side below the spur that forms the western boundary of the Yellow Creek catchment over a height of 600 meters (Photo 7, 8, 9, and 11).

Since August 1992, the catchment has experienced an increased rate of erosion. Several large slips, occurring during times of prolonged intense rainfall, have stripped a substantial part of the drainage basin of its vegetation cover, topsoil, and underlying fractured bedrock. Debris sourced from the catchment blocked the access road on several occasions. Finally, in January 1994, collapse of the eastern side and part of the western side of the basin, produced between 1 and 1.35 x 10^6 m^3 of material, most of which was deposited on the debris cone directly underneath the catchment (Photo 9 and 11).

Figure 2 shows the situation before and after the January 1994 event. Increased thickness of the deposits caused the access road to be covered on part of the cone. The apex of the cone was heightened by 45 meters, while increase of thickness decreases down slope. The present angle of the enveloping surface of the talus body is **38°** approximating the critical slope angle for material of this coarseness.

The large rock avalanche of January 1994 affected the lower valley side directly to the southeast of the Undercite catchment (Photo 9). Over a width of around 250 meters, a thin layer of regolith came off the sheer cliff face, exposing glacially striated, relatively compact schists. Most of the material derived from the face was deposited on the talus slope below the cliff, although some larger boulders breached their way through the shrub covering the lower part of the slope, crossing the access road in the process.

The axial zone of the Undercite catchment, occupied by the main creek, is incised into highly fractured schists. However, the present line of the valley bottom cuts the bedrock foliation at oblique angles, thus indicating that the general trend of the foliation cannot be regarded as the cause of incision in the first place. It is more likely that the presence of more intensely fractured bedrock in the upper part of the southeastern side of the basin caused the onset of valley formation. In this part of the catchment, the discontinuities are spaced at smaller intervals than in the adjacent bedrock. Joints are slightly buckled, and open. This makes for highly weatherable rock, and indeed, weathering and disintegration have progressed tens of meters into the subsurface. Part of this highly erodible material was removed during the erosion episode in January 1994. The remaining part of the body has an estimated volume of 0.6 to 0.75 x 10^6 m^3, the largest part of which is no longer protected by a cover of topsoil and vegetation (Photo 11).

Although the largest part of the debris involved in the January 1994 event was derived from the southeastern side of the Undercite catchment, some erosion occurred in the middle part of the northwestern side of the basin. Large slabs of bedrock came off this side of the catchment in at least two places, producing very coarse debris. These rock avalanches made use of the overall trend of the foliation of the bedrock (Photo 11).

From comparison of photographs taken before and after the main erosion events that took place over the past two years (Photo 7, 8, 9 and 11), an important conclusion can be drawn with regard to events preceding the collapse of large segments of steep valley sides in this region. Shortly (in terms of years) before wholesale collapse, an instable valley side will start showing elongate, arcuate streaks in which weathered bedrock is exposed, due to the occurrence of minor debris avalanches. An erosion scar of this sort formed in the steep rock face directly to the southeast of the Undercite catchment between February and June 1993 (Photo 7 and 8), and may well have been a precursor of larger events to come. A similar pattern has been recognised in many other sites in the Alpine zone between Haast and Hokitika, that have produced landslides and debris avalanches involving large amounts of material.

The Undercite catchment is most likely to continue debouching large amounts of debris in the form of rock fall, rock avalanches and possibly debris flows. Erosion may be expected to affect both the presently exposed part of the basin, and increasing parts of the adjacent, oversteepened valley sides.

Within the present catchment, both the southeastern and the northwestern sides may produce large amounts of debris. Smaller amounts of rock may fall off both sides of the basin at any time, but especially during times of intense precipitation. A large rock avalanche, involving at least several hundred thousand cubic meters of debris, is likely to be triggered by an episode of prolonged intense rainfall within the next few years.

The rock face to the southeast of the Undercite catchment has already been stripped of vegetation, and is likely to produce rock falls at any time. As the face is undercut over much of its width, it may be expected to collapse at some stage. It is not possible to predict timing and size of such an event at present. A site which is of particular concern is the loose standing flake, immediately to the southeast of the stripped part of the cliff face (Photo 10). This flake has been undercut on its eastern side, and is poised to collapse, involving yet another part of the valley side in the Undercite erosion complex.

The vegetated rock face directly to the northwest of Undercite Creek shows a number of vertical streaks in which the vegetation has been removed (Photo 9). The easternmost of these streaks has increased in size during the erosion episode of January 1994, and now has an arcuate shape, connected with recent rock avalanche scars in the northern side of the Undercite catchment. It is very likely that the part of the rock face enclosed by this feature will collapse within the foreseeable future, thus expanding the catchment.

Most material produced by the Undercite catchment will be deposited on the debris cone and adjacent talus slopes that are already in place. Individual boulders may have enough momentum to reach and travel over the floodplain of the Fox River. During episodes of precipitation, the Undercite Creek may cut into the head of the debris cone, re-eroding part of the sediment. One or several debris fans or small scale alluvial fans are likely to form at the base of the cone over the next few years, thus increasing the area influenced by erosion of the Undercite catchment.

NAMELESS CREEK IMMEDIATELY NW OF UNDERCITE CREEK

This creek originates from the same spur as Undercite Creek. It runs down one of the steepest parts of the sheer rock face adjacent to the Fox River, over a height of about 800 meters. Two tributaries make the nameless stream drain a much larger part of this section of the true righthand valley side than the neighbouring Undercite Creek (Photo 7 and 9).

A debris cone of some 40 meters height lies directly underneath the lower end of the nameless catchment. Although this cone is considerably smaller than the Undercite cone, it illustrates the capacity of the basin to produce large amounts of very coarse material, mainly in the form of rock fall and rock avalanches. The cone must have been deposited since the start of this century, and lack of vegetation shows ongoing debris input.

Most of the catchment is covered by dense vegetation. Thus, it is hard to assess the relative stability of the bedrock which is present at or close to the surface in many parts of the basin. Where rocks are visible over some distance, they display fracturing patterns similar to those in the northwestern side of the Undercite catchment. No intensely fractured schists have been observed.

The present state of this nameless catchment is comparable to the situation in Undercite Creek, prior to 1992. The apparent absence of large amounts of highly shattered bedrock may make it unlikely that an erosion event of similar importance to that of the January 1994 event in the Undercite catchment will occur. Nevertheless, this drainage basin may have the potential to produce large rock avalanches that will hit the access road as it was used until early this year. Telling from vegetation disruption markers, the lower end of the ridge which forms the western boundary of the funnel shaped catchment may be an area of future instability.

YELLOW CREEK

Yellow Creek drains the true righthand side of the Fox Valley over its entire height, debouching onto the main valley floor within 500 meters of the present glacier terminus.

On aerial photographs flown in 1948, the Yellow Creek catchment shows as a large white area within a heavily vegetated region, indicating intense erosion of the basin. During the 1960's and 70's, erosion activity in the catchment was subdued, and a visitors carpark was constructed near the lower end of the creek when the access road was first built. Increased erosion in the Yellow catchment since the late 1980's caused a debris fan to cover an increasing part of the Fox River floodplain (Photo 1), necessitating a relocation of the carpark. Various degrees of lichen coverage of rocks on the fan indicate regular reoccurrence of debris flows and fluvial processes, depositing new material on the fan surface. Yellow Creek has cut a channel with a width of several tens of meters and a depth of greater than five meters into the fan surface (Photo 3). This channel is shifting regularly, feeding and eroding different parts of the sedimentary body. As a result, the foot track, used by most visitors to the valley, which crosses the fan, is a temporary feature, requiring regular maintenance.

The position of Yellow Creek is determined by the presence of a large planar structure, trending NNW-SSE, dipping some 55 degrees towards the WSW. This structure separates intensely fractured and deeply weathered schists to the west from more compact and resistant bedrock to the east. In the upper part of the catchment, low angle shear zones are visible within the highly fractured schists.

Most material transported by Yellow Creek, is eroded from the western side of the catchment. The largest part of this side of the basin bears marks of extensive erosion by sheetwash, rillwash, and gullying. In the upper part of the catchment as well as in its lower part, headscarps of deep seated landslides are visible. These landslides, with a width of up to over 100 m, and a depth of several tens of meters, involve tens to hundreds of thousand cubic meters of material, made available to the axial fluvial system during periods of prolonged intense precipitation. The uppermost part of the eastern side of the drainage basin has also been affected by recent denudational events.

Many million cubic meters of deeply weathered bedrock are still sitting in the western side of the Yellow catchment, being virtually unprotected from the denudational influences of atmospheric, runoff, and gravitational processes. Thus, the catchment is likely to continue delivering large quantities of debris onto the Fox River floodplain. Most material will be liberated during high intensity rainfall events, and may therefore not pose a direct threat to visitors traffic across the Yellow Creek fan.

Although the present situation on the Yellow Creek fan is relatively harmless at most times, in terms of rockfall, there are some minor hazards to tourist traffic across the fan. The most important of these is formed by instability of the sides of the river channel cut by the Yellow Creek. Visitors have to descend into this channel, and climb out of it, via narrow, steep tracks. Many people wander into the channel bed, and try to climb the channel sides in places where no track is available. In doing so, they expose themselves to the danger of falling off the steep sides, or, in a worse case, being buried under a collapsing part of the channel side. Constructing a clearly marked and easy track through the channel sides should solve most problems.

Over the past few years, the growing Yellow Creek fan has forced the Fox River to shift to the true lefthand side of its floodplain. At times, the river erodes the distal end of the fan, generating steep, instable banks. Keeping visitors away from the distal end of the fan should therefore be an objective of traffic management.

The valley side between Yellow Creek and the easternmost end of the Undercite Creek complex shows traces of one recent (early 1990's), and one less recent slip. Both events occurred during large storm cycles. Debris from the larger, more recent of the two scars reaches the valley floor close to the visitors track, and may pose a hazard to visitors traffic during rain storms.

The bedrock exposed in the upper part of the slope is relatively compact and does not show the characteristics which promote the extreme erosion rates in the Undercite and Yellow Creek catchments. At present, it seems unlikely that this particular part of the valley side will be subject to large scale instability in the near future. However, smaller scale slips may occur during major storm cycles.

THE STRAIGHT CREEK/BOYD CREEK COMPLEX

Although not of any direct importance to visitor traffic in the lower Fox Valley at present, the Straight Creek/Boyd Creek complex possibly is the largest erosion feature in the lower part of the valley. It is situated on the true lefthand side of the valley, adjacent to the present terminus of the Fox Glacier. Between Boyd Creek and Straight Creek, the lower 800 meters of the valley side have been affected by massive slope instability in subrecent times (probably 1930's). Over a width of almost one kilometer, the valley side slumped over a vertical distance of 300 meters, along a listric plain of failure, producing an arcuate headscar. The surface area of the slumped mass amounts to around **1.3 km^2**, its maximum thickness being over 100 meters. In all, close to 50 x **10^6 m^3** of material may be involved in this enormous landslide (Photo 4).

Both sides of the slumped mass have been excavated by more recent erosion processes. Extensive influence of sheet whash, rill wash, gullying and minor sliding, can be seen in the lower parts of both the Straight Creek and the Boyd Creek catchments. Material derived from Straight Creek is being deposited on a debris fan adjacent to the present end of the glacier.

NAMELESS CREEK CROSSING ACCESS ROAD AT 1.9 KM FROM HIGHWAY 6 TURNOFF

The headwaters of this nameless creek are situated adjacent to the upper end of the Yellow Creek catchment. For over 1.5 km the stream runs parallel to the Fox River, and then turns sharply to the southwest, to join the main river.

The catchment of the nameless stream is almost entirely covered by dense forest vegetation. A narrow, elongate erosion scar marks the upper part of the main stream. Apart from that, only few minor erosion scars have been generated over the past 50 years. The large central scar, which results from a single event in the early 1990's, has produced an amount of material which has been deposited near the apex of an old fan shaped sedimentary body, at the outlet of the mountainous part of the catchment. From there, a small channel has conducted minor amounts of debris across the road and into the Fox River.

As the orientation of the main stream is almost at right angles to the trend of the foliation of the underlying bedrock, it seems unlikely that large landslides or rock avalanches will occur in this nameless catchment. Smaller scale debris flows may occur on a more regular basis. However, these flows will have lost most of their erosive power by the time they reach the access road, so that they are not likely to cause any structural damage to the road.

LOWER VALLEY SIDE BETWEEN WHITE CREEK AND GLACIER TERMINUS

In the recent past, the Fox river has been undercutting the scree deposits on the true righthand side of the valley between the terminus of the glacier and the lower end of White Creek. As a result, several small landslides occurred, affecting the visitors track, which is constructed about 15 meters above the valley floor. In two places, the track has been interrupted, and was only restored temporarily. Many tourists find the track hard to negotiate. A warning sign should be in place, and a diversion of pedestrian traffic onto the floodplain at the mouth of White Creek might be a safer and easier way of access to the glacier terminus, for as long as the river does not occupy the extreme righthand side of the valley floor.

NORTH FACING SIDE OF CONE ROCK RIDGE

Cone Rock Ridge is situated in the central part of the lower Fox Valley, separating Mills Creek from the Fox River. The ridge runs parallel to the main river in a southeasterly direction for over a kilometer, and then joins a steep section in the true lefthand valley side, leading into the Straight Creek catchment (Photo 6).

The ridge consists of schists, dissected by an almost vertical, NE-SW trending set of discontinuities. Two parts of the northeastern side of the ridge, where the spacing of discontinuities is closer than elsewhere, have produced large rockfalls in the recent past (reputedly the 1930's), shedding debris onto the floodplain of the Fox River. These events may be attributed to stress unloading after the retreat of the glacier front from this part of the valley. The two culminations of the ridge, Cone Rock itself, and an adjacent bluff, are made up of more compact, less fractured bedrock (Photo 5 and 6).

Although the current position of the Fox River on the extreme lefthand side of its floodplain prevents any rockfall from the Cone Rock Ridge from posing a serious threat to visitors of the valley, minor slope instability may influence the safety of people using the Cone Rock track, which follows the crest of the ridge for much of its length. In many places, small, unofficial side tracks lead from the Cone Rock track to view points on the edge of the cliffs. Especially where the schists are highly foliated, the top edge of the cliffs can be extremely instable. In many places, uprooted, and fallen trees testify of the potential hazards involved in standing close to the edge. Visitors should be warned about and kept away from fragile edges.

Between the Chalet lookout track and Straight Creek, the Cone Rock Ridge and its southeasterly extension are topped by a layer of moraine material. The jump in permeability between the porous moraine and the underlying schists may be the cause of many of the small scale landslides that have occurred in the steeper part of this particular section of the valley side. The Chalet lookout track has been affected by slides on several occasions, as artificially undercut slopes are especially vulnerable to this type of instability.

MILLS CREEK

Mills Creek drains the true lefthand side of the Fox Valley between Fork Creek and Broken Creek. At its lower end, the stream is turning towards the west, to flow around the Cone Rock Ridge before joining the Fox River.

Mills Creek produced small amounts of erosion material, until several landslides occurred in the upper central part of the catchment, in September 1993. Large amounts of material, sourced from these slides, were deposited in the central channel in the lower part of the drainage basin, destroying part of the Mills Creek track. A second episode of erosion and deposition in Mills Creek took place during the storm cycle of early January 1994.

The landslides from which most material was derived were caused by undercutting of the valley side by fluvial incision. At present, one medium sized, and three smaller erosion scars are visible within the central part of the catchment (Photo 2). On aerial photographs, the outline of a much larger mass that may become instable in the near future, can be distinguished. This outline is marked on the geomorphological map.

In the near future, the upper central part of the Mills Creek catchment is likely to produce more erosion material. The terrain seems more vulnerable to high intensity rainstorms than adjacent drainage basins. It would therefore be advisable to relocate the part of the Mills Creek track between Broken Creek and Mills Creek, which is directly affected by erosion and deposition in the central channel. The shallow valley between the parallel parts of Broken Creek and Mills Creek, which is defined by two adjacent moraine ridges, may be a suitable location for this section of the Mills Creek track.

Future landscape development in the lower Fox Valley

The most important dynamic landscape elements in the lower Fox Valley are the Fox Glacier, the floodplain of the Fox River, the three sites of large scale slope instability, being Undercite Creek, Yellow Creek, and the Straight Creek-Boyd Creek complex, and their respective sediment accumulation sites, and the body of dead ice occupying part of the floodplain below the Cone Rock Ridge. Any scheme for future management of visitor traffic in the lower Fox Valley will have to take the development of each of these geomorphologic entities into account. Here, a possible scenario for the evolution of each of the aforementioned elements will be discussed briefly. A discussion of the movements of the Fox Glacier is outside the scope of this report, as they are determined by meteorological rather than geomorphological factors.

The outlines of the floodplain of the Fox River will not change much in the next few decades. Only the length of the plain may vary, as a result of the shifting position of the glacier terminus. Yet, the floodplain is likely to accommodate a substantial part of the material being put into the fluvial system by various types of glacial and non-glacial erosion processes. The way in which the erosion material is deposited on the main valley floor, is determining to a large extent which part of the floodplain is actually available for discharge of water by the main river.

If no limitations were imposed on the fluvial system, the Fox River would alter its course on a regular basis, shifting to a different part of the valley floor as soon as aggradation of the riverbed would make an alternative position of the channel more efficient in terms of runoff and sediment transport. However, sedimentary bodies and man-made structures occupying part of the Fox River floodplain may constrict the position of the fluvial channel substantially. This may lead to rapid aggradation of parts of the riverbed, giving rise to unstable fluvial conditions.

An example of this type of situation is the confined position of the Fox River resulting from the construction of a stop bank directly downstream of the body of dead ice, in January 1994. Since construction of this bank, the river bed in place has aggraded 50-100 cm. As a result, the channel bed has been raised to a position close to, or above the level of the adjacent floodplain. Breaching of the stop bank would lead to a sudden shift of the Fox River to the central or true righthand side of the floodplain, which is currently being used to accommodate the access road and visitor carpark.

Another limit to the movement of the river channel across the floodplain is formed by the body of dead ice that currently sits on the valley floor just down stream of the Yellow Creek debris fan. The ice was separated from the main glacier in the early 1960's, and has since molten only slowly due to the debris cover that protects the core form solar radiation. The dead ice hugs the true righthand side of the valley, forcing the Fox River into a position at the far left of the valley floor. Thus, the righthand side of the floodplain immediately downstream of the obstacle has been sheltered form fluvial activity for a prolonged period of time.

During recent storm cycles, the Fox River has eroded part of the debris cover of the southeastern side of the ice core. The exposed ice is melting rapidly, a process which is unlikely to slow down. Thus, it may be expected that the dead ice body in the Fox valley will not last another decade, opening the way for the main river to migrate more unrestrictedly across its floodplain.

As was discussed earlier, Yellow Creek is likely to go on debouching large amounts of sediment in the foreseeable future. The Yellow Creek debris fan will remain an active feature, building out onto the Fox River floodplain. According to the balance between sediment input and erosive power of the main river, its size may change considerably over the years, but its presence will force the main river into a lefthand course for a prolonged period of time.

The Undercite debris cone is much less likely to build out over a large part of the floodplain width, regardless of the degree of erosion activity in the overlying catchment. However, the Undercite drainage basin, and the adjacent steep cliff faces will remain a considerable hazard to tourist traffic on the true righthand side of the valley. The catchment is likely to expand sidewards by means of large scale slope collapse.

The Straight CreekBoyd Creek complex probably is the most underestimated feature in the lower Fox Valley in terms of erosion. Currently, the slumped mass is kept in place by the lower end of the glacier, but if the glacier terminus would retreat upstream, a tremendous amount of material may be sitting on the true lefthand side of the valley, ready to go. A large earthquake, as has occurred along the Alpine Fault in historic times, may trigger wholesale collapse of the valley side in question, thus liberating many million cubic meters of material. A mass movement of this scale would alter the profile of the valley completely.

Conclusion and recommendations

The Fox Glacier is one of the main tourist attractions on the west coast of the South Island. Visitor traffic to and from the glacier terminus is mainly on the true righthand side of the Fox Valley. The access road on this side of the valley is exposed to the following natural hazards:

1. large rock avalanches from the Undercite catchment and adjacent steep rock faces
2. reoccurring debris flows and mud flows from the Yellow Creek catchment
3. instability of channel sides on and below the Yellow Creek fan

4 slope instability between White Creek and the glacier terminus
5 occasional debris flows from the nameless catchment to the northwest of the upper Yellow Creek basin
6 debris avalanching from the lower valley side between Undercite Creek and Yellow Creek.

Hazards 5 and 6 do not pose a serious threat to visitors of the valley, as long as the respective sites are cleaned and marked appropriately.

Hazard 4 can be negated by reinforcement of the existing track, the placing of a clear warning sign immediately upstream of the White Creek bridge, and by diverting visitor traffic onto the floodplain immediately upstream of the White Creek bridge whenever the itinerary of the Fox River permits such.

Hazards 2 and 3 could be reduced through a relocation of the track across the Yellow Creek fan, and maintenance of a wide and easy track crossing the channel cut into the fan surface. The safest itinerary for the track would climb along the northwestern margin of the fan to its apex, then cross the fanhead channel, where its position is most stable, and descend across the vegetated slopes to the east of the active fan.

Hazard 1 is the most serious and should be met by a permanent relocation of the main access road. The true righthand valley side between the lower end of the floodplain and the present location of the dead ice body is oversteepened and extremely unstable. Keeping visitor traffic away from this valley side should be one of the prime objectives of future valley management.

Three alternatives are suggested with regard to solving the problem posed by instability in the Undercite catchment and adjacent rock faces:

1 keep the access road in its present position on the central floodplain
2 construct a carpark at the lower end of the floodplain and maintain a wide foot track from the carpark further into the valley, keeping to the central or true lefthand side of the floodplain as much as possible
3 direct the main traffic stream along the access road on the true lefthand side of the valley and build this road out to a place from where the floodplain can be reached easily.

Solution 1 may work as a short term solution. However, it should not be considered as a longer term option. Floodplain dynamics are such that maintenance of the access road in the dry river bed would require substantial repairs after each storm cycle, as soon as the dead ice body currently sheltering part of the floodplain has ceased existing.

Both solutions 2 and 3 should require only moderate amounts of maintenance work, once the initial construction of the necessary infrastructural elements has been completed. Although both options imply an increase of the walking distance between the carpark and the glacier terminus, they should be regarded as the only realistic options for a longer term solution to the slope instability hazard caused by Undercite Creek.

If solution 3 is considered, the slope instability in the upper central part of the Mills Creek catchment should be taken into account. Debris sourced from this area has reached the lower slopes underneath Cone Rock on several occasions, and a future large scale erosion event would be likely to affect a provisional extended road on the true lefthand side of the lower Fox Valley.

Sediment liberated by large landslides in the upper central part of the Mills Creek Catchment may be deposited on the Mills Creek track where it is situated in or nearby the streambed of the Creek. As reoccurrence of such landslides is likely, it is recommended to relocate the section of the track between Broken Creek and the crossing of Mills Creek to a slightly higher position, where it would be sheltered by old moraine ridges.

The Cone Rock track provides access to the in places dangerously unstable upper edge of the north facing rock faces of the Cone Rock Ridge. Users of the track should be warned about the fragile quality of the edge, and the track should be maintained in such a way that access to cliff edge view points is only possible where no great danger of slope instability exists.

List of illustrations

MAP OF THE GEOMORPHOLOGICAL HAZARDS OF THE LOWER FOX VALLEY

A geological hazard assessment for
the lower Fox Valley anno 1994

Niels Hovius
March 1994

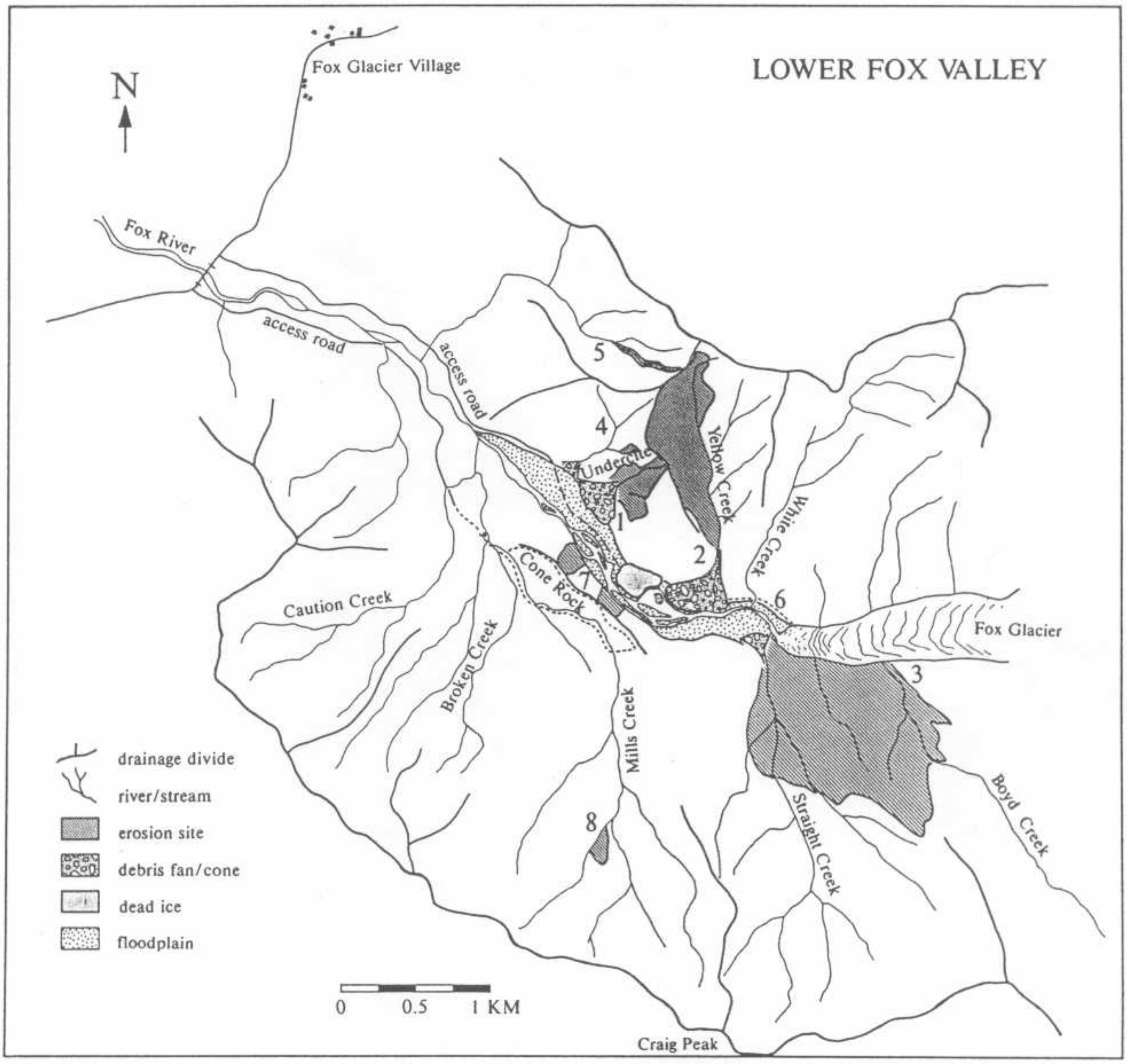

Fig. 1 Location map of the lower Fox Valley

EXPLANATION

GLACIAL ICE

DEAD ICE

RIVER/STREAM

LARGE GULLY

SHEET AND RILL WASH

LANDSLIDE EROSION SCAR

ROCK FALL

LARGE BOULDERS

DEBRIS FAN/CONE

SEDIMENT LOBE

FLOODPLAIN

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