QUEENSTOWN-LAKES DISTRICT FLOODPLAIN REPORT

Otago Regional Council

November 1999

Report prepared by
Neil Johnstone
Investigations Engineer

Table of Contents

Table of Figures

Table of Photographs

1 Introduction

This Floodplain Report for the Queenstown-Lakes District has been prepared by the Otago Regional Council in accordance with the Council's mission to promote the sustainable management of the region's resources. This report identifies areas at risk from flooding within the Queenstown-Lakes District and the nature and extent of the flood hazards.

The report supersedes the 1993 publication "Floodplain Management Report, Queenstown-Lakes District". Since 1993, the district has experienced two significant flood events. These were in January 1994 and December 1995. Data from those floods has been utilised in reviewing areas at risk from flooding.

1.1 Floodplain Mapping

Floodplain maps have been produced for catchments within the Queenstown-Lakes District. Maps were originally produced for the 1993 edition with the aid of aerial photographs, discussions with locals and field visits. In this document the maps have been reproduced and updated in digital form using 1:50,000 NZMS topographical base maps.

The floodplains reported in this document are based on the maximum known historical levels, dating back to the massive flood of 1878. Waterway works, aimed at mitigating the flood hazard, have been undertaken in some areas, reducing the frequency and severity of flooding. However, a flood risk still remains and should be taken into account in planning and development

Minor changes have been made because of the availability of additional information from the 1994 and 1995 floods and to ensure the maps are accurate at a scale of 1:25,000.

2 Floodplain Management

The objectives of floodplain management are to enhance social well being and environmental quality within an area. These objectives are met by delineating the flood hazard zone, quantifying the flood risk where possible and identifying options to mitigate flood damage.

Flood hazard information provides the basis for deciding what flood mitigation measures should be applied to minimise flood losses as well as providing the criteria for planned development on the floodplain.

European settlement often took place on floodplains in New Zealand. This made economic sense as the ground was flat, the soils fertile, access was easy and there was an available supply of water. Although the settlers quickly gained an understanding of the flood patterns of the river, it was not possible to envisage future developments or extreme flood events.

Flood protection works, such as flood banking and channel improvement works, have subsequently been required in areas where development did not fully consider the flood risk. Flood protection works are often expensive and their effectiveness limited by economical and physical constraints. It is imperative that additional options, including not developing an area at all, are assessed when planning for floods.

There are three basic methods that can be applied to reduce loss caused through flooding. These are outlined below:

Adjusting the actions of people to flooding- land use planning, building requirements and flood warning are all examples of influencing the actions of people.

Reducing flood loss effects- this method includes such measures as post-disaster relief and flood insurance. It is argued, however, that such relief tends to further encourage the increased development on the floodplain despite the flood risk.

Adjusting the flood event- This modifies the flooding from a given rainfall. The size of the flood flow can be reduced by the construction of dams and reservoirs or maintaining appropriate ground cover zones. Floodbanks can be constructed or channels can be modified to eliminate or reduce the frequency of overflow into at-risk areas.

3 The Queenstown-Lakes District

The Queenstown-Lakes District covers approximately 8,500 sq km. It ranges from the Hunter and Makarora Rivers in the north at the head of Lakes Hawea and Wanaka respectively, to Kingston at the southern end of Lake Wakatipu; from the Banner Range in the Southern Alps in the west to Luggate in the east.

The district is predominantly rugged mountainous country which experiences periods of heavy precipitation both as rainfall and snow. The district is a major centre for tourism and includes three major lakes that feed New Zealand's largest river system, the Clutha.

The region is only sparsely populated. Queenstown and Wanaka are the largest centres and there are a number of smaller settlements including Arrowtown, Hawea, Albert Town, Luggate, Kingston and Glenorchy. The high country river catchments such as the Matukituki, Makarora, Shotover, Rees, Dart and Cardrona support small populations sufficient to manage the remote high country runs, and the lower Cardrona valley also supports a number of horticultural units and small farmlets.

Most of the farmland situated on the floodplains of the high country rivers forms parts of much larger pastoral properties extending into the surrounding hills and mountains. These properties all run sheep and cattle. The higher lands tend to be held under pastoral lease while the floodplains are commonly in freehold tenure.

The land within the floodplains is in many cases vital for year-round viability of high country farming operations. Stock are grazed on the higher country during the summer (typically November-mid April) and on the lower fans and floodplains for the balance of the year. Large quantities of winter feed are grown on the flats.

During the past three decades considerable development has occurred on the floodplains. Improved drainage, fencing, the establishing of windbreaks, pasture improvement and appropriate management practices have boosted stocking levels.

Flooding of high country floodplain areas within the Queenstown-Lakes District tends to occur moderately frequently because of the extreme climatic conditions. This can cause loss of pasture via erosion and gravel deposition, damage to drainage and irrigation channels and fencing, damage to farm buildings (although these are mostly situated clear of the floodplain), and loss of stock. Disruption to amenities such as road access, telephone and power supply can also create major difficulties.

Urban flooding within the study area is largely confined to the major population centres of Queenstown and, to a lesser extent, Wanaka. Extreme levels in the mountain catchment-fed Lakes Wakatipu and Wanaka respectively have inundated low-lying parts of these towns on several occasions. Queenstown is also at risk from Horne Creek. Intensive development adjacent to Horne Creek has necessitated a major flood protection scheme that minimises the risk and impact of flooding to a substantial part of the built up area.

Floodplain information has been based on field inspections, personal accounts, file records and reports, historical and photographic records. In many areas, particularly the more remote ones, information is quite limited. Consequently the flood hazard maps produced in this report will continue to require some refinement as further information (especially from future flood events) becomes available to the Otago Regional Council. The maps, for regulatory or planning purposes, should not be used in isolation. Reference to the accompanying text would be prudent, and detailed site-specific investigation will be essential in many cases. Additional data is, in many cases, held by the Otago Regional Council.

Major catchments of the Queenstown-Lakes District are shown in **Figure 1**.

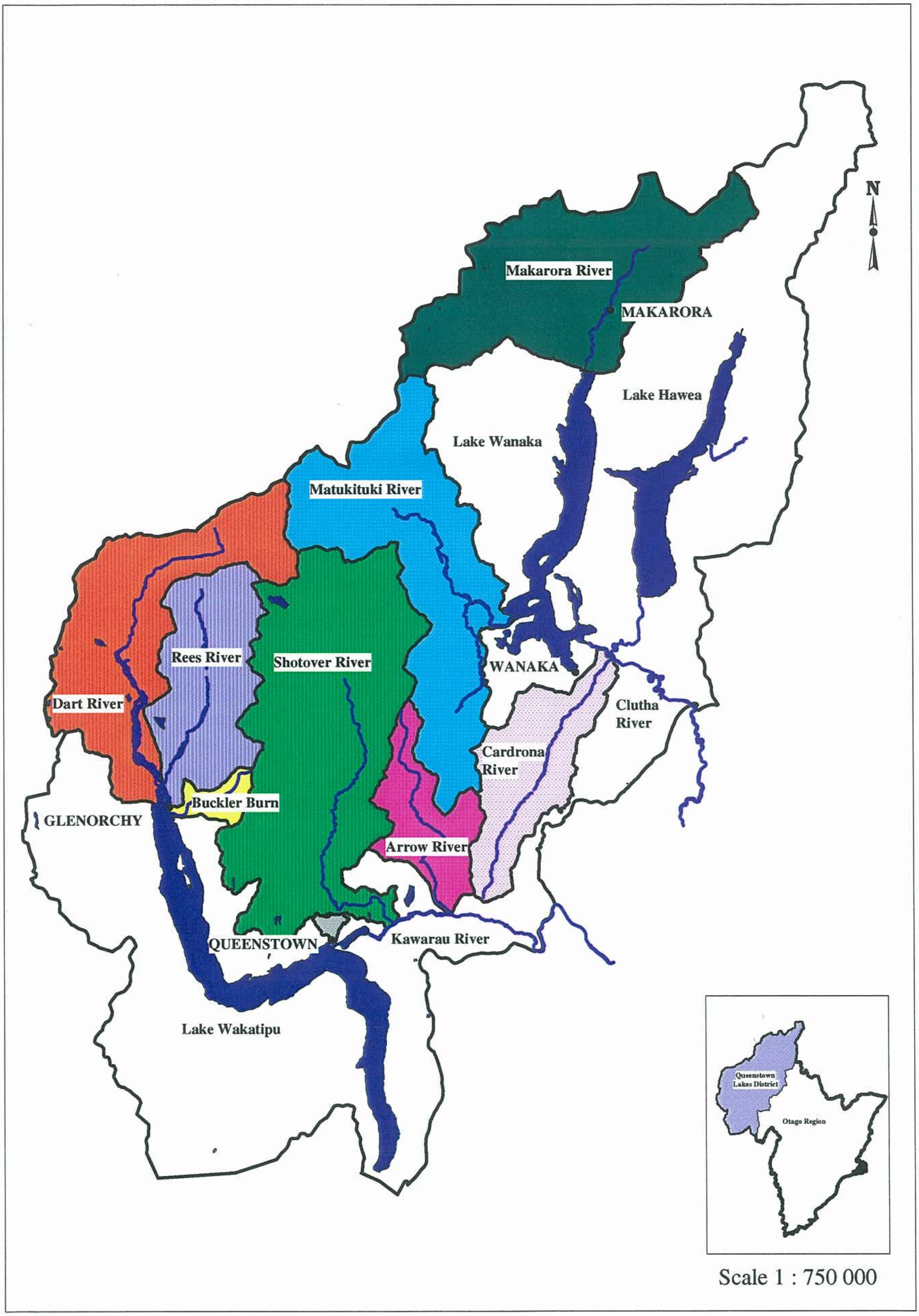


Figure 1
Major Catchments in the Queenstown Lakes District

4 Floodwarning in the Queenstown-Lakes District

The Otago Regional Council, as part of its function to minimise damage by floods, distributes MetService heavy rainfall warnings to the Queenstown-Lakes District Council and rural communities in the catchments of Lakes Wakatipu, Wanaka and Hawea. The information is disseminated by fax with telephone backup. Council also maintains a publicly accessible telephone service (Flow Phone) which provides up-to-date weather warnings.

Rainfall and lake and river level information is available from a number of telemetered sites on the Dart, Shotover, Kawarau and Clutha Rivers and the three main lakes. The majority of these sites are managed by NIWA. Up to date data from these sites can be accessed by the Otago Regional Council and used to assess the likelihood of flooding, particularly in respect of Queenstown and Wanaka. No formal warning systems are in place but under flood conditions there is close liaison with the Queenstown-Lakes District Council. The rainfall and level information is also available on the Flow Phone.

5 Dart and Rees Rivers – General

The Dart and Rees Rivers drain a combined area of 1,044 sq km and discharge into the head of Lake Wakatipu. Most of the catchments lie in Mount Aspiring National Park with indigenous forest dominant below the snow line. The great U-shaped valleys have been forged by glacial action. At its peak some 18,000 years ago, the Dart glacier extended to Kingston at the southern extreme of Lake Wakatipu. Its terminus has receded some 135km to its present location upstream of the road bridge.

The Dart River catchment covers some 632 sq km and is contained by the Barrier Range to the north and by the Humboldt Mountains to the west. The Forbes Mountains, which include Mount Earnslaw (2,819m) form the boundary between the Dart and Rees catchments. The Rees catchment (412 sq km) is bounded further to the east by the Richardson mountains. The majority of these catchments consist of finely foliated schists of varying hardness and high erodibility if shattered. **Figure 2** shows the Rees and Dart catchments.

European settlement commenced in the latter half of the 19th century with forest being cleared around Lake Wakatipu for farmland. A small number of sawmills were established in the region but these have long gone, leaving agriculture and recreational pursuits such as tramping, climbing, hunting and fishing as the major activities in the region.

The roads from Glenorchy into the Rees and Dart Valleys have made the area more conveniently accessible, but these roads are subject to inundation and damage from the major rivers as well as from local mountain streams.

Flash floods of enormous proportions can occur frequently in high country catchments such as these. The floods of January 1924, February 1952, October 1978, January 1983, January 1994 and December 1995 would appear to rank as the greatest experienced in the Dart and the Rees this century. In January 1924 the Otago Witness reported that "the Dart and Rees Rivers at the head of the lake were in high flood, and joined up below Mount Alfred, thus submerging the whole county in this locality." In 1952 the Otago Daily Times reported that the Rees and Dart "joined forces and became one raging torrent". Ken Lloyd in his account of the October 1978 Clutha River flood reported that "292mm of rain fell within a 24 hour period at Routeburn. The Dart River flowed bank to bank and stock grazing on the river flats were swept away and drowned. Tommy Thomson of Mount Earnslaw Station (Rees) lost over 200 ewes. Richard Bryant of Kinloch had similar losses". In 1994 288mm of rain was recorded at Routeburn Station between January 7-9 and another 230mm between January 21-23. The Queenstown-Glenorchy Road was closed by numerous slips and washouts, the most notable being at Stoney Creek where the road culvert disappeared into the lake.

Such major floods and others, more frequent but of lesser magnitude, not only take their toll of stock but are also responsible for accelerated erosion of river flats, changes of river channel alignments, deposition of gravel over vast areas of otherwise fertile land and disruption of road communication.

The mountainous catchments of the Rees and Dart are subjected to frequent heavy rainfall which can result in widespread flooding especially in spring when snow-melt can boost flows substantially. Rainfall intensities in excess of 100mm/day are not uncommon.

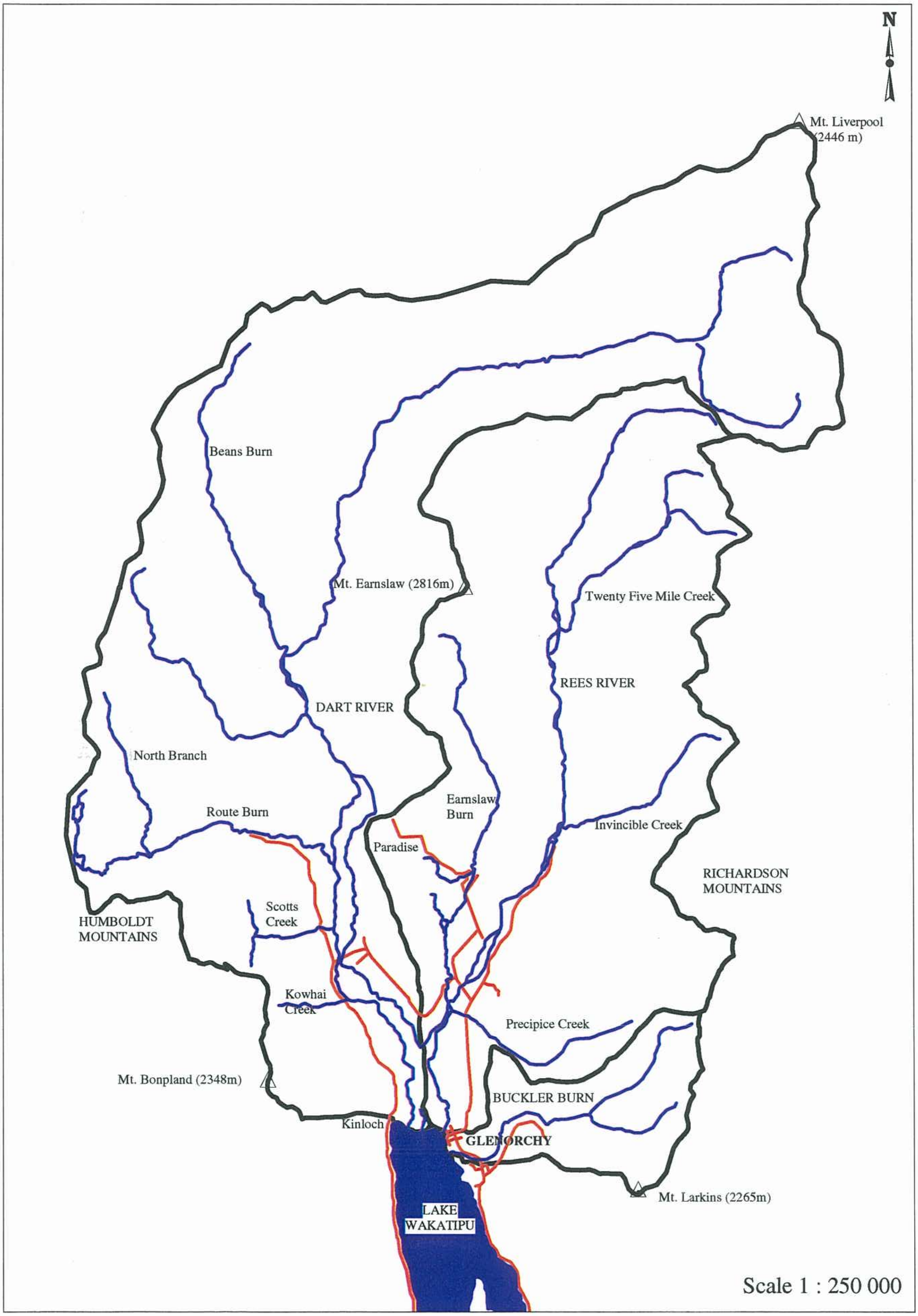


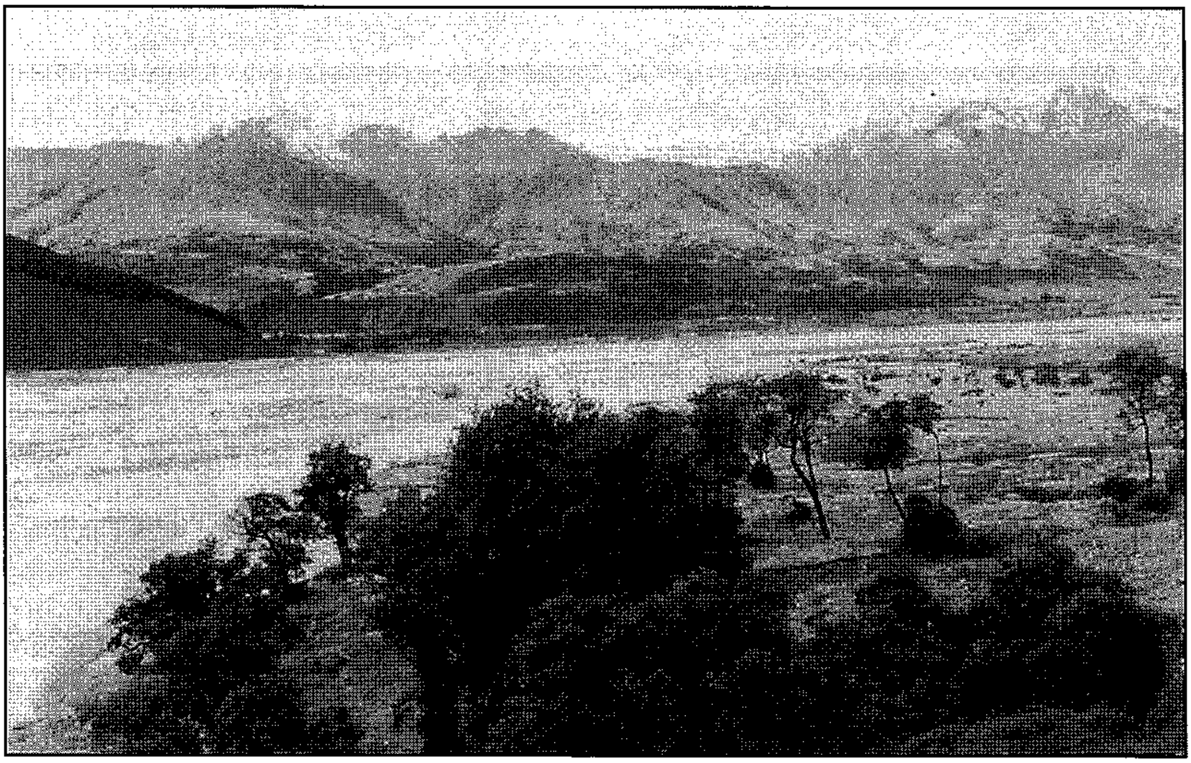
Figure 2
Dart and Rees River and Buckler Burn Catchments

The valley floors through which these rivers flow are, when adequately drained, extremely fertile because of the thick deposits of fine silts brought down by these rivers in the past. The impact of fire, noxious animals, heavy grazing and the clearance of bush has in many areas accelerated bed load movement and increased the supply of coarse material. This increase, together with the normal oscillation of large braided rivers, has resulted in the loss of large areas of fertile flats either by burial or by direct erosion.

5.1 Dart River

Flooding and erosion have been problems for runholders in the Dart Valley throughout the 20th century. Most difficulties have been experienced on the right bank downstream of the road bridge (i.e. towards Kinloch) although there have been instances of significant land loss on the left bank also.

Low stopbanks and log protection were put in place by runholders with Otago Catchment Board and Department of Lands and Survey assistance in the late 1950s/early 1960s, as the river channel attempted to change course in the Kinloch area, a short distance upstream of the lake. Similar works, some involving debris fencing, as well as willow planting and training banks, were progressively constructed up until about 1984 at locations as far upstream as Kowhai Creek, a short distance downstream of the Dart River bridge. These works not only reduced inundation damage in adjacent farmland but also gave a degree of protection to the Kinloch-Routeburn Road. **Photograph 1** shows the lower Dart River Valley which is subject to flooding.



Photograph 1
Lower Dart River Valley Downstream of Kowhai Creek (May 1999)

Severe flood conditions experienced in the 1970s and early 1980s meant that works were often damaged before they could become fully effective; these were invariably restored. Subsequently the works have mostly survived but maintenance is essential to ensure their continued effectiveness.

Tributary creeks such as the Glacier Burn, Turner, Kowhai and Scotts Creeks, that traverse the steep slopes of the Humboldt Mountains can deposit significant quantities of unwanted detritus when they outflank their banks. They also have frequently severed the road links to Kinloch and the Routeburn. In January 1994 the road was severely washed out at Kowhai and Scotts Creeks (see **Photograph 2**).

Photograph 2
Wreckage of Kowhai Creek Road Bridge Caused by January 1994 Flood

Generally the integrity of these roads has been progressively improved in recent years, with the waterway capacities of several of the bridges and culverts being increased and road levels being raised. However a section of road between Woodbine Station and Kinloch is still believed to flood during significant events. The Dart River bridge (constructed in 1971) was designed to pass a flow of 3,100m^3/s, estimated to be the 1% flow. At the peak of the October 1978 flood there was approximately 1.8 metres clearance between the water level and the bridge soffit.

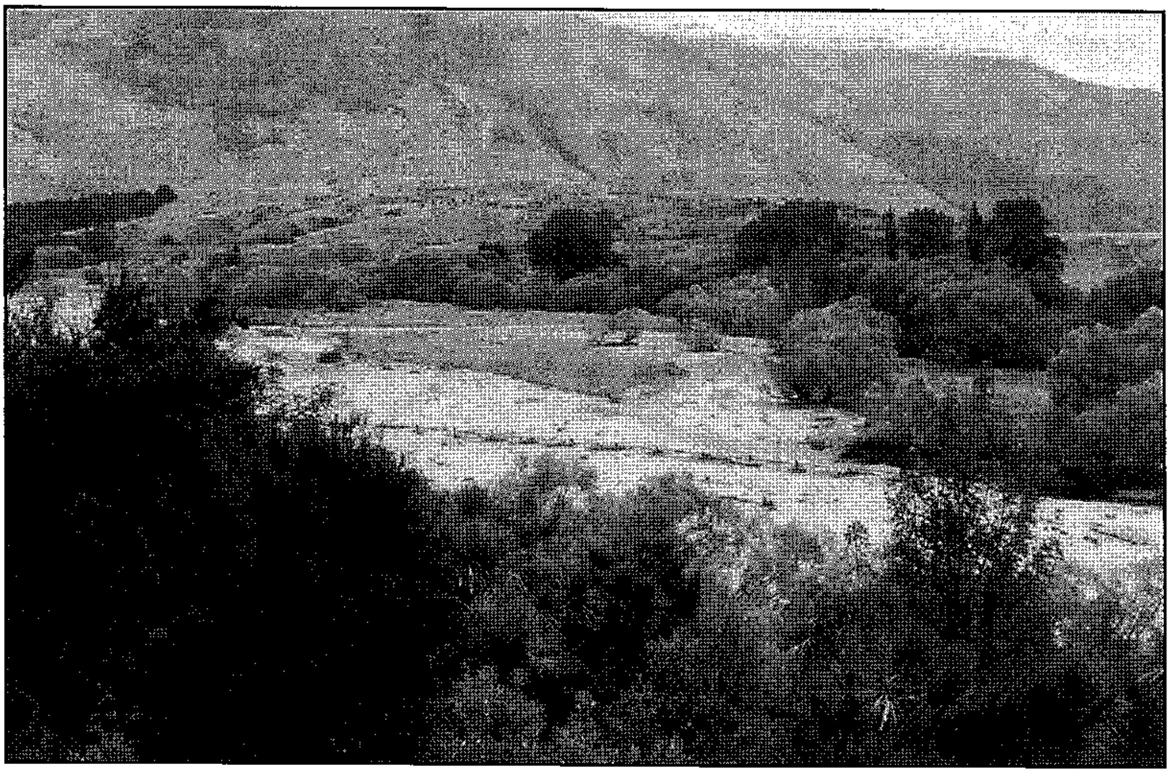
The flood plain hazard zone for the Dart River shown on **Figure 3** is based on on-site inspection, local comment and historical file notes. The absence of any water level recording sites in the catchment prior to 1996, the remoteness of the area and its inaccessibility, particularly during times of major floods, contribute to the uncertainty regarding the exact extent of the floodplain in many areas. Future flood events may highlight the need for amendments.

5.2 Rees River

The Rees River catchment lies between the Mount Earnslaw massif (elevation 2,800m) the Forbes Range to the north and the Richardson Range to the east. The topography is generally steep and has been extensively glaciated. Most of the catchment consists of finely foliated schist much of which is very erodible. Active slumping has been a feature in the Muddy Creek catchment which contributes substantial quantities of detritus to the lower Rees system.

The Rees catchment is subject to relatively frequent heavy rainfalls, and flash floods occur in the main river and its tributaries. Seasonal snowmelt can add significantly to flood flows. The bank full capacity of the river has been estimated at approximately 350m³/s, but peak flows far exceed this figure.

Approximately 400 hectares of river flats are potentially liable to inundation. **Photograph 3** shows part of the river flats that are subject to flooding. The main problems associated with flooding in the lower Rees catchment are the deposition of detritus on productive farmland, the formation of side channels whose development serves to isolate and devalue large areas of otherwise valuable land, and the threat of disruption of vital road links (The Glenorchy-Paradise Road has been frequently under threat of river attack, necessitating its realignment in the late 1960s). The old road bridge at Camp Hill regularly incurred damage as high velocity, debris-laden flood flows impacted on it. In the flood of February 1952 a substantial part of this bridge was carried away by the raging river and the decision was taken to construct its replacement some 3-4 km further downstream where the river valley was somewhat wider and less steep. The threat of direct damage to a bridge at this site was considerably reduced, but the marked tendency of the river bed to aggrade is continuing to reduce the waterway capacity of the bridge, and is likely to increase the likelihood of flooding of the lower flats generally.



Photograph 3
Rees River Floodplain Downstream of Old Bridge Site (March 1993)

From the mid-1950s considerable effort was expended in constructing pile and waling training works at various locations between the sites of the old and new road bridges. The works, the greater part of which were constructed in the period between 1968 and 1980, were intended to prevent erosion of riverbanks, the development of old river channels, excessive deposition of gravels over fertile farmland (especially on Earnslaw Station on the right bank of the river), damage to fencing, washouts of the Glenorchy to Paradise Road and outflanking of the Rees River bridge itself.

The works had limited success and in the 1980s, the focus changed to allowing the river greater freedom but still preventing overflows across farmland. In 1984, approximately 4km of floodbanking was constructed on the right bank upstream of the Rees Bridge together with willow plantings adjacent to the bank. The severe environment and unpredictable advent of flash floods has necessitated fairly regular repairs and maintenance, including the repair of a major break that threatened the Glenorchy-Paradise Road in January 1994 In 1996, a low floodbank was constructed on the left bank upstream of the road bridge to reduce overflow in this area.

The floodable areas shown on **Figure 3** are based on an assumption of floodbanks being overtopped or breached, and reflect a tendency of the floodplains to fall away to the west towards Diamond Creek. The Rees and Dart Rivers are known to have merged upstream of Lake Wakatipu in the manner shown in January 1924, February 1952 and January 1994 and possibly on other occasions as well.

The Rees River has also caused flooding of parts of the township of Glenorchy. In recent times, the main channel of the river shifted to the Glenorchy side of the fan, increasing the threat of flooding to the Glenorchy township. A floodbank is to be constructed between the river and the town which will substantially reduce this threat. In addition to the flood threat, bank erosion is also a concern. Rock protection has been required at one location adjoining the township.

There are additional flooding problems in the Rees catchment associated with the tributaries draining the western faces of the Richardson Mountains. The most significant of these is the Temple Burn (also known as Precipice Creek).

The Temple Burn (catchment area 8.74 sq km) has created flooding problems at the Glenorchy-Paradise Road approximately 7km north of Glenorchy township. In January 1983 the road was cut at this point. The bridge was replaced in 1988 and now has an estimated capacity of the order of $50m^3/s$. This is substantially greater than the waterway it replaced but it may still be incapable of passing more than about the 10% flood flow without overspill. The Temple Burn also has a tendency to overspill its banks, particularly on the Glenorchy side, some 300 metres upstream of the road.

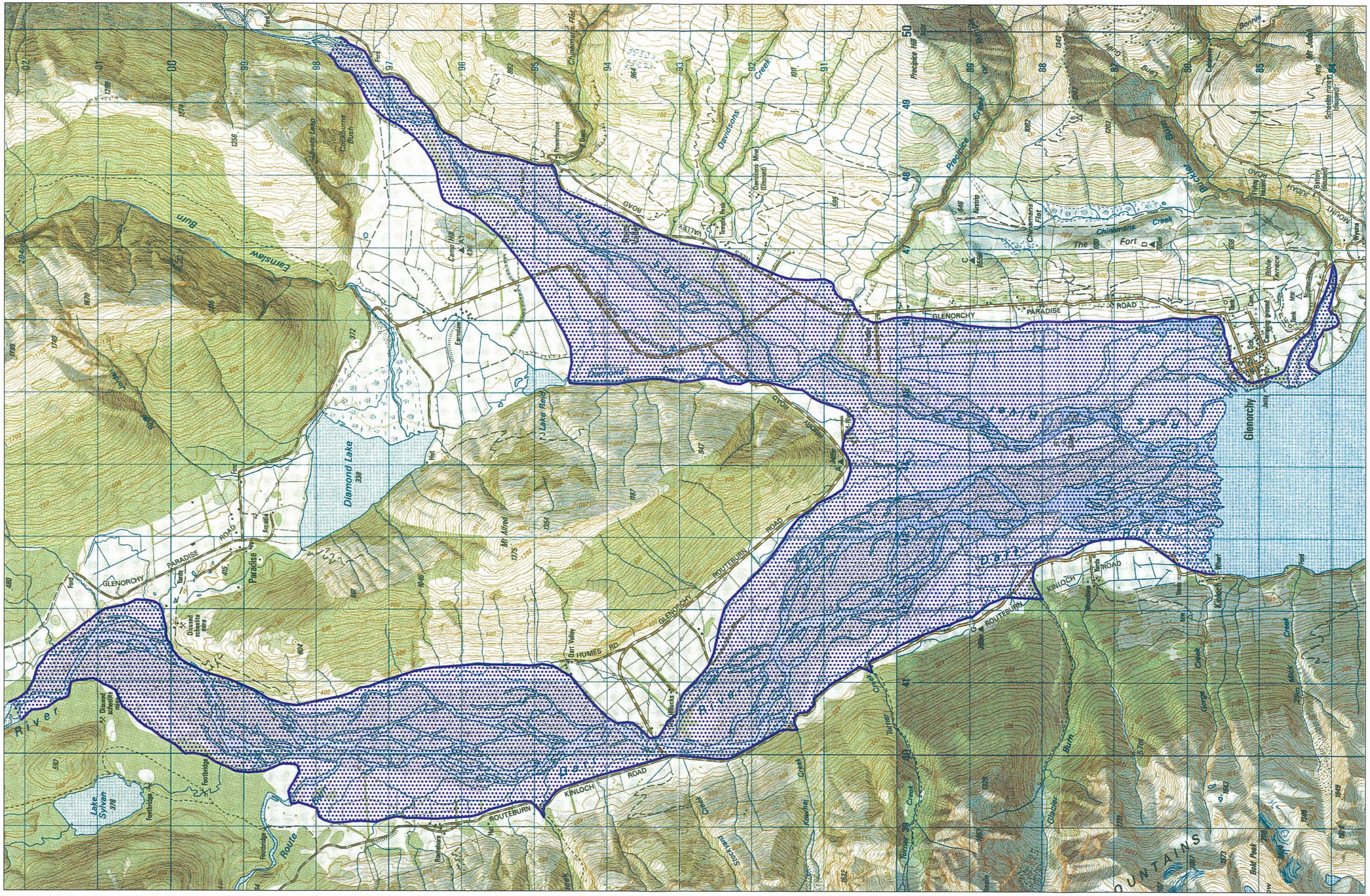


Figure 3
Dart and Rees River and Buckler Burn Floodplains

Scale 1:50 000

6 Buckler Burn

The Buckler Burn drains a 52 sq km catchment which rises steeply to an elevation of 2,060m. The Buckler Burn discharges directly to Lake Wakatipu immediately to the south (Queenstown side) of Glenorchy. Scheelite mining has been carried out at locations within the southern part of the catchment. The 10% probability flood has been estimated at around 100m³/s; the 2% flood about 140m³/s.

Runoff from the Buckler Burn catchment is rapid and flood flows have been responsible for the formation of a steep shingle fan between the Queenstown-Glenorchy Road Bridge and Lake Wakatipu. This gravel deposition over many years resulted in an increased incidence of flooding of parts of Glenorchy a short distance to the north.

In 1971 Alex Harvey Industries Limited (AHI) constructed a number of cottages at the southern side of Glenorchy a few hundred metres upstream of the lake. The cottages were intended as the first stage of accommodation to ultimately provide for up to 100 people associated with the proposed open cast mining of scheelite. The residential development was authorised by the local authority, presumably unaware of the propensity of high country gravel fans to migrate within their confines, and of the fact that the site was previously occupied by a school, built in 1912 but later moved because of the threat of flooding.

Flooding from the Buckler Burn of the AHI site was experienced in 1978 and 1979. A training bank and floodbank were constructed in 1980 by the Otago Catchment Board to protect the cottages which are now in private ownership. No subsidy was available to fund these works that protected urban interests that had been built in a floodplain, so the full cost of $15,000 was met by the owner. In 1984 the floodbank was extended downstream to the lake to more fully protect additional low lying areas of the town in the vicinity of Benmore Place and Forbes Place. These works were funded by Lakes County Council and the Department of Lands and Survey.

The training works and floodbanks (built to 300mm above the October 1978 flood level) are currently in a very good state of repair and are heavily vegetated with lupin and the like to such extent that their existence may not be obvious to a casual observer. Future shifts of the Buckler Burn channel could, however, subject the floodbank to erosive attack.

In recent years considerable quantities of gravel have been taken from the Buckler Burn in conjunction with roading development in the Glenorchy area. The gravel removal operation has provided opportunities for channel training in the lower Buckler Burn that currently reduces the likelihood of gravel fan migration in the direction of Glenorchy township. Ongoing removal of gravel will be essential if the gains are to be sustained. Aggradation of the fan is likely to lower the standard of flood protection provided. The floodplain is shown in **Figure 3**.

7 Lake Wakatipu, Queenstown and Glenorchy

Lake Wakatipu is a glacially-formed lake having a surface area of 293 sq km and a catchment area of 3,067 sq km. It is New Zealand's third largest lake after Lakes Taupo and Te Anau. The major rivers flowing into the lake are the Rees and the Dart which flow into the northern arm near Glenorchy. Other significant contributors include the Von, Greenstone and Caples while the Shotover has been known on several occasions to head up the Kawarau River to levels sufficient to impede, and even reverse, outfall from the lake at Frankton.

The highest recorded level of Lake Wakatipu occurred in September 1878 when a level of RL312.6m was attained. Antecedent climatic conditions had been extreme. The winter had been severe with snow drifts up to 30 metres deep in some ravines. Heavy rain commenced on 21 September and continued until the 29th. On that day alone 94mm of rain fell in Queenstown. The lake at Queenstown rose to levels previously considered impossible. "There were some six feet (1.8m) of water in Eichardt's Hotel, and boats navigated Rees and Beach Streets rescuing people. Men waded in the streets and gardens up to their chests in water as they removed their furniture and goods. The timber from one of the yards floated away, and a strong breeze drove the logs against the houses like so many battering rams. The handsome Masonic Hall had holes rammed in its stone walls, Mr Hotop's chemist shop fell in pieces, and Mr Davis's stone brewery collapsed. Two old hotels, the Victoria and the Prince of Wales, were both utterly destroyed, and all that part of the town which stood on the lower level suffered severely." Gilkison (1930)

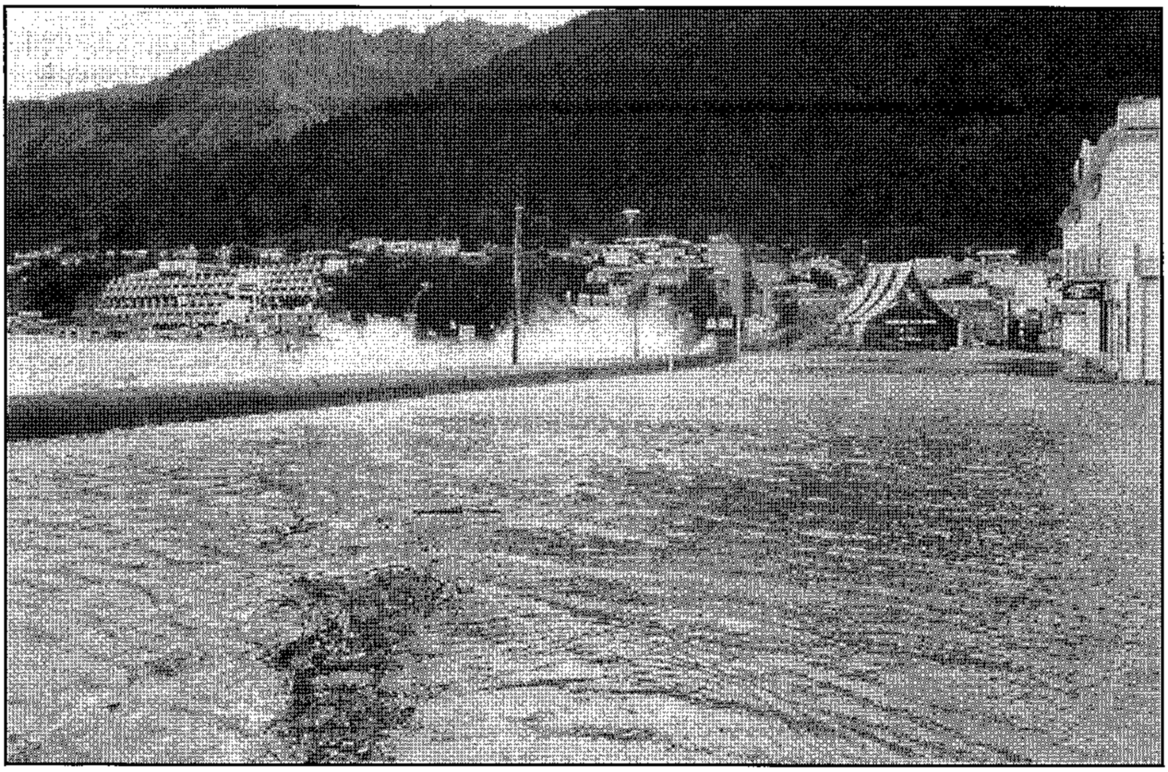
Jowett and Thompson (1977) estimate that total rainfall across the catchment in 1878 ranged from 350-670mm over six days. Warm NW winds melting vast volumes of snow aggravated the situation considerably.

The 1878 flooding of Queenstown is by far the worst experienced, but on several other occasions lake levels have been sufficiently high to inundate parts of the town. Strong winds have sometimes aggravated the risk presented by high lake levels. The Otago Witness of 22 January 1924 reported the events of 10 days earlier:

> "Rain commenced to fall, and the wind, which had been blowing from the north, veered round to the south-west. This drove the lake into the lower portion of the town, and in the space of a few minutes the Marine Parade and Rees Street and the lower end of Beach Street were a running sea. The buildings on the lower side were quickly invaded. Mount Cook Company's office at the corner of Rees and Ballarat Streets suffered most from the intruder..... The whole of Marine Parade from the soldiers' memorial to Horne Creek was submerged, as well as a street running parallel. The Coronation Bath House, situated on the normal waterfront, was partially wrecked as the result of the undermining action of the current and the battering it received from the waves."

In mid-October 1978 a stationary cold front across the South island caused heavy rain and widespread flooding. The rainfall intensities were of the order of the 100 year return period, but fortunately lake levels prior to the deluge were low. In one 24 hour period 292mm fell at Routeburn. As it had in 1878, 1919 and 1949, the Shotover flowed back up into Lake Wakatipu which peaked at RL 311.10m. Similar levels were attained in November 1982.

In mid-January 1983 a major storm of 3-4 days duration brought the level of Lake Wakatipu to its highest level since 1924. The lake peaked at RL 311.71m. Water entered some shops in the business area between Rees and Beach Streets. Two houses in Marine Parade were evacuated. Water was lapping at the doors of several holiday homes in Frankton. **Photographs 4** and **5** show the flooding that occurred during the January 1983 event.



Photograph 4
Queenstown Flooding Along Marine Parade (15 January 1983)

A further high lake level (RL 311.29m) was recorded on Christmas Eve 1984. This level - sufficient to just cover the Earnslaw steamer wharf - resulted in minor flooding of Beach Street. One shop at the bottom of the mall suffered inundation to a depth of about 150mm.

Two major events occurred in the mid 1990s. On 24 January 1994 the lake peaked at RL 311.68m (exceeding slightly the 1983 level), and in December 1995 at RL 311.62m. On both occasions parts of Rees and Beach Streets and Marine Parade were inundated.

The occurrence of these two floods in close succession prompted some suggestions that sedimentation within the Shotover delta or in the upper Kawarau Gorge was responsible. An Otago Regional Council report (Johnstone, 1996) and a joint Otago Regional Council / Queenstown Lakes District Council report (various, 1997) demonstrated that the causes of Queenstown's recent exposure to flooding were primarily related to rainfall events (Lakes Wakatipu and Wanaka were shown to have behaved similarly) and that dredging of downstream sediment would not provide a practical, economic or sustainable solution.

From the above descriptions it is clear that some degree of flooding of the lower areas of Queenstown from the lake is a not infrequent occurrence. Usually damage is comparatively minor (stormwater backflow occurs at about RL 311.3m) but the effects are likely to be more severe if wave action is generated by strong winds blowing across the long reaches of the lake.

A mitigating factor is that rates of rise of lake level rarely exceed 50mm/hour so there is usually an opportunity to sandbag threatened areas.

Photograph 5
Queenstown Flooding at Beach Street (15 January 1983)

An analysis of historical flood levels updated by the Otago Regional Council in 1997 produced the following probabilities of flat water lake levels of Lake Wakatipu being reached or exceeded in any given year:

Probability	**RL.** (MSL = 0.00m)
1%	312.00
2%	311.78
5%	311.51
10%	311.31

The beach along Saint Omer Park and Marine Parade has typically a crest level of RL. 311.5m while the discontinuous lakeside wall adjacent to Marine Parade is at a level in the order of a metre higher. A report written by Dr Jeremy Gibb in 1986 dealing with erosion problems and sediment transport in the Queenstown Bay area noted that, during period of high lake levels, wave action tended to build up the gravel berms by up to a further one metre in some areas.

The areas of Queenstown adjacent to the lake likely to be affected by flat water levels of RL 312.0m and RL 312.6m respectively are shown in **Figure 4.**

The 312.6m level has only been reached once (in 1878) since records have been kept, but the possibility of wind-generated waves approaching such levels should not be overlooked. Indeed the wall adjacent to Marine Parade (RL 312.6m) was frequently overtopped by wave action during the December 1995 flood despite the flat water level not exceeding RL 311.63m.

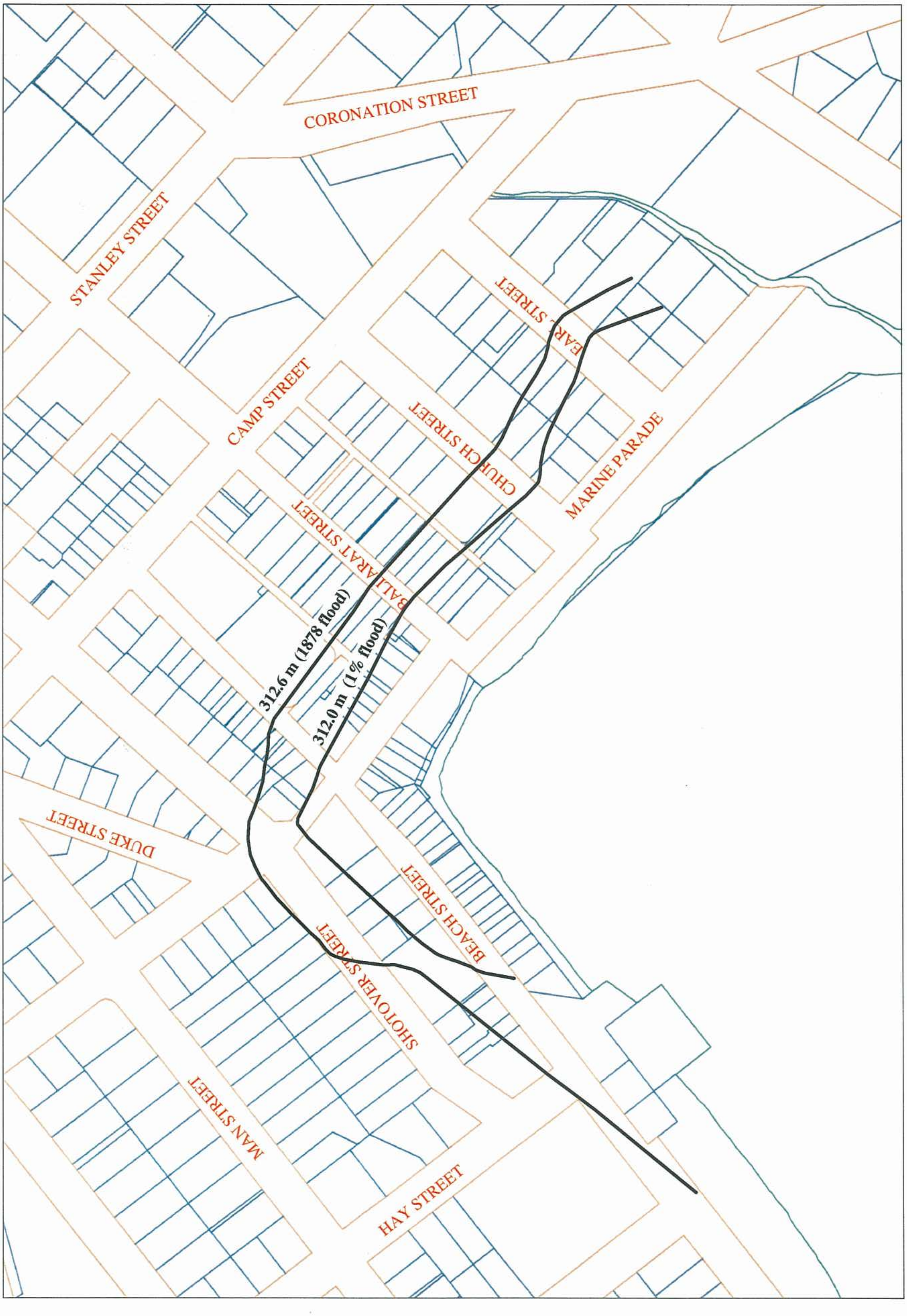


Figure 4
Lake Wakatipu Flood Levels at Queenstown

Figure 5
Likely Extent of 1878 Flood Level in Lake Wakatipu at Glenorchy

In recent years minimum floor levels for new buildings in Glenorchy have been set at RL 312.8m. This level is presumed to be the approximate peak water level experienced there in the 1878 flood, with some allowance for Rees River backwater effects. The current proposed District Scheme reduces the building level for Glenorchy to RL 312.0m (the same as Queenstown). The flood hazard zone encompassed by the 312.8m contour at Glenorchy is shown in **Figure 5**.

8 Horne Creek

Horne Creek flows through Queenstown in a generally southerly direction before discharging into Lake Wakatipu in the vicinity of the Botanic Gardens.

The creek flows down a U-shaped glacial valley behind Queenstown. The mountains in the headwaters of the catchment (area 11 sq km) rise steeply to elevations in the order of 1,600m. Soil layers in the catchment are generally thin and there are extensive areas of bare rock so absorption of rainfall tends to be minimal. The major tributary is Brewery Creek - also known as Bush Creek - which has a catchment area of some 3 sq km. This sub-catchment is a major source of flood debris (schist, soil and trees) that have the potential to cause serious channel obstruction in the lower catchment. The Horne Creek catchment is shown in **Figure 6.**

The earliest reference to flooding in Queenstown from Horne Creek concerns a midwinter flood in 1863. Considerable damage was also reported in 1878 when 95mm of rain was recorded in a 24 hour period. Damaging floods were also experienced in 1949, 1951 and 1957 (when rain fell on a frozen catchment.) The usual pattern of flood damage involved the escape of floodwaters down Shotover, Beach and Ballarat Streets through the business area of the town.

Queenstown has limited areas of flat land available for residential or industrial development, and the last thirty years have seen considerable development in areas of significant flood risk with little provision initially being made to provide an unobstructed flood channel for Horne Creek.

A flood protection scheme designed and constructed by the Otago Catchment Board/Otago Regional Council enables the Horne Creek system to pass the 1% flood from the upper catchment through Queenstown and into Lake Wakatipu, thus greatly alleviating the flood risk.

The main features of the design are i) a detention dam a short distance below the Brewery Creek-Horne Creek confluence that traps debris and provides some 360,000 cu.m of floodwater storage, thus enabling a reduction of some $9m^3/s$ (24 to $15m^3/s$) in the design peak discharge at that point; and ii) a spillway section on the right bank of the creek a short distance above the main commercial area of Queenstown that diverts flows above about $16m^3/s$ into storage in the sportsground. The detention area is linked to the lower Horne Creek channel via a 2.54m x 1.88m corrugated steel arch.

The ponding areas are shown in **Figure 8.**

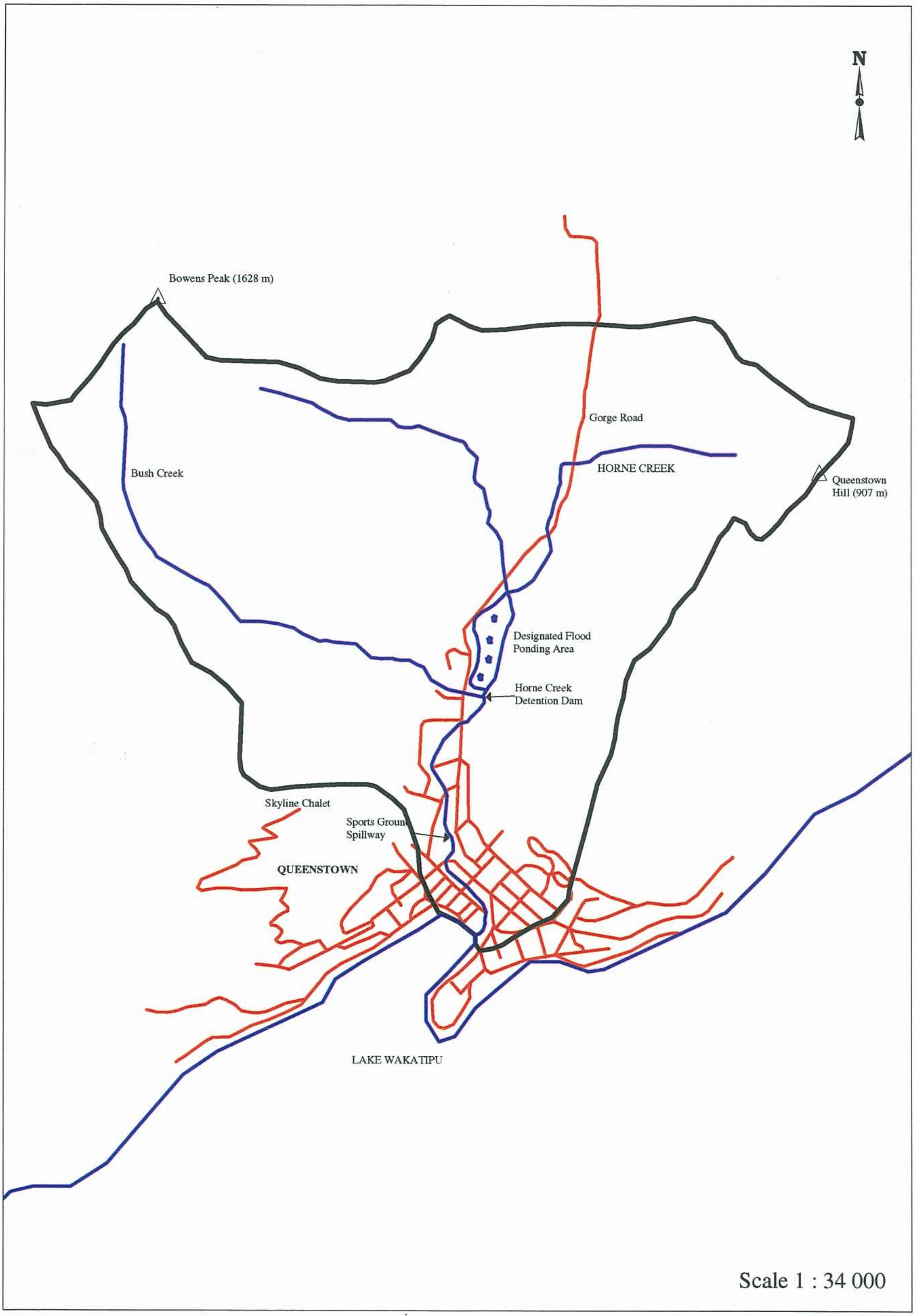


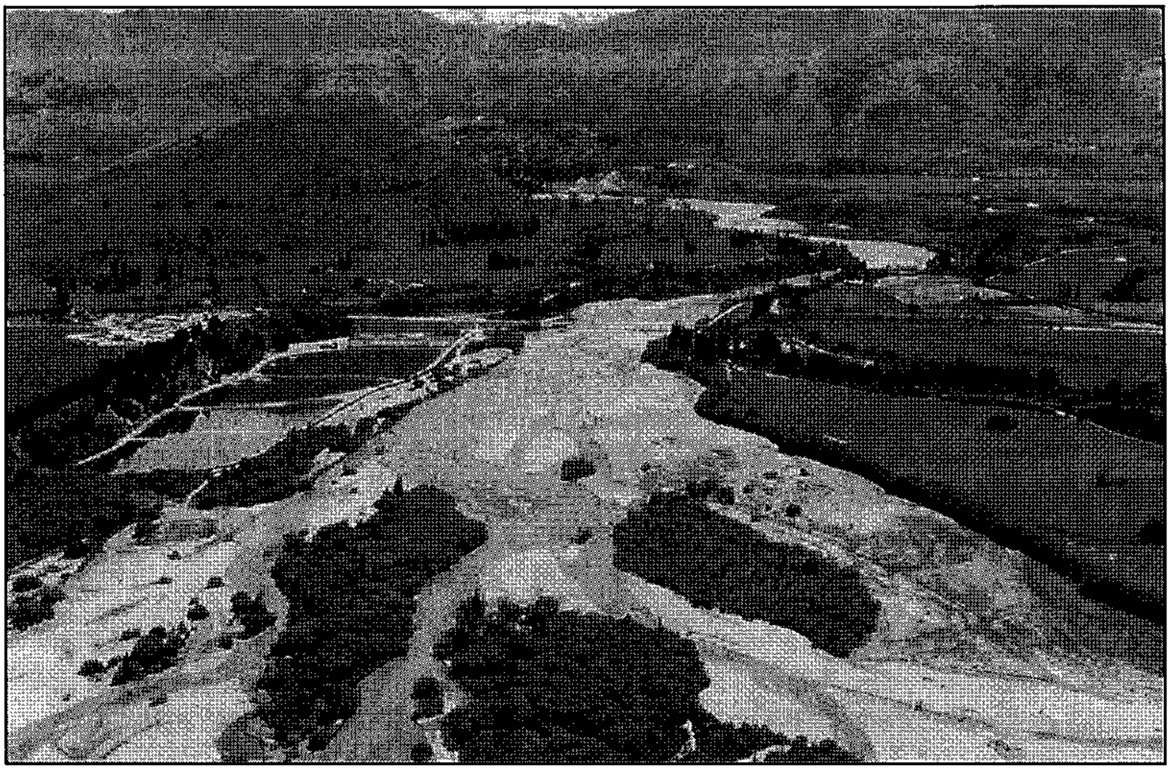
Figure 6
Horne Creek Catchment

9 Shotover River

The Shotover catchment (area 1,096 sq km) is particularly mountainous being bounded by the Richardson Mountains to the west and the Harris Mountains to the east. The highest point in the catchment is Centaur Peak (2,524m), but there are many others over 2,000m. Approximately two-thirds of the catchment lies above the 900m contour. The Shotover catchment is shown in **Figure 7.**

Rainfall tends to be heaviest in the north and north-west of the catchment but, in common with most remote catchments, there is little rainfall data available. Flash floods are common but the considerable storage areas in some of the upper catchment valleys can be expected to attenuate flood peaks to some extent.

Unlike the other major high country rivers, the Shotover discharges directly and undamped into the Clutha River system rather than into one of the major lakes. As a result it has a disproportionate effect on main stem peak discharges, and its considerable sediment load is carried more or less directly as far as the hydro dams (bed load), and beyond in the case of some of the suspended load. **Photograph 6** shows the Shotover River Delta.



Photograph 6
Shotover River Delta (November 1994)

In March 1949 the Shotover contributed an estimated 850m³/s of the 1970m³/s Clutha flood peak at Alexandra. The Shotover, at its peak, flowed up the Kawarau into Lake Wakatipu. Similar impediment to outflow from the lake resulting from high Shotover levels, sometimes aggravated by deposition of large quantities of bed load in the Kawarau channel, is known to have occurred in 1878, 1951, 1952, 1957, 1978 and 1994. This phenomenon occurs because

Shotover flood peaks invariably occur earlier than do peak Lake Wakatipu water levels. Under normal circumstances there is little natural drop between the lake and the Shotover delta. Consequently there are often situations when water levels at the delta are slightly higher than at the lake outlet, and backflow occurs. This backflow tends to be particularly visible because of the discoloration of the silt laden Shotover waters. The backflow rarely exceeds 50-100m^3/s and usually lasts for only a few hours. (By contrast combined Rees and Dart River inflows to the lake can approach 10,000m^3/s in major flood events). Outflow from Lake Wakatipu is only impeded when the water level differential across the weir at Kawarau Falls is less than approximately 250mm. Such conditions tend to occur early in flood events (as the Shotover peaks) and tend to exist for only a few hours. An Otago Regional Council report (Stevenson and Scarf, December 1997) concluded that aggradation and degradation of bed levels on the Shotover delta is a cyclical phenomenon which is closely related to the frequency and magnitude of floods in the Shotover River catchment. The report also notes that "significant variation of the Shotover River delta bed level can occur rapidly. In the 18 months from March 1996 to September 1997, the lower delta went from the highest (level) measurement since 1980 to the lowest".

The worst flood in the Shotover occurred in July 1863 when heavy warm rain fell on a snow-covered catchment. F W G Miller's Golden Days of Lake County gives an indication of the severity of this flood:

> "From Arthur's Point came the news of a fearful deluge in the Shotover and the indications were that such a flood had not passed through this gorge in a hundred years. More than fifteen hours of torrential rain brought the river up forty feet in the gorge and for miles of its length, rocks, sand and gravel slid away from the bedrock and fell into the rapids below with a roar like thunder. Many miners had their tents pitched on these beaches in the gorge, thinking that because the matagouri grew there profusely the river never rose to that level. The number who lost their lives through that false assumption will never be known, and dozens of miners who had neither friends nor relatives to miss them disappeared forever under those turbulent waters."

Access to most parts of the catchment is very difficult because of the steep unstable nature of much of the land and because of the disruption caused by the frequent occurrence of freshes in the many tributary streams of the Shotover. As a result there has been very little development pressure in the catchment upstream of Arthur's Point. Between Arthur's Point and the confluence with the Kawarau River the floodplain is clearly defined and structural development has been restricted to terraces well above the river.

Many hectares of once fertile land on the left bank of the river immediately upstream of the Kawarau confluence have been lost to river erosion and the effects of an aggrading gravel fan over the past 2-3 decades. River training works that would have protected these areas were deferred in the mid-1970s as there were concerns that the piers of the new highway bridge might be undermined by the scouring of the river bed, resulting from the works. Other flat areas in the Lower Shotover such as Tucker's and Big Beaches remain liable to inundation. Flood prone areas of the Lower Shotover are shown in **Figure 8.**

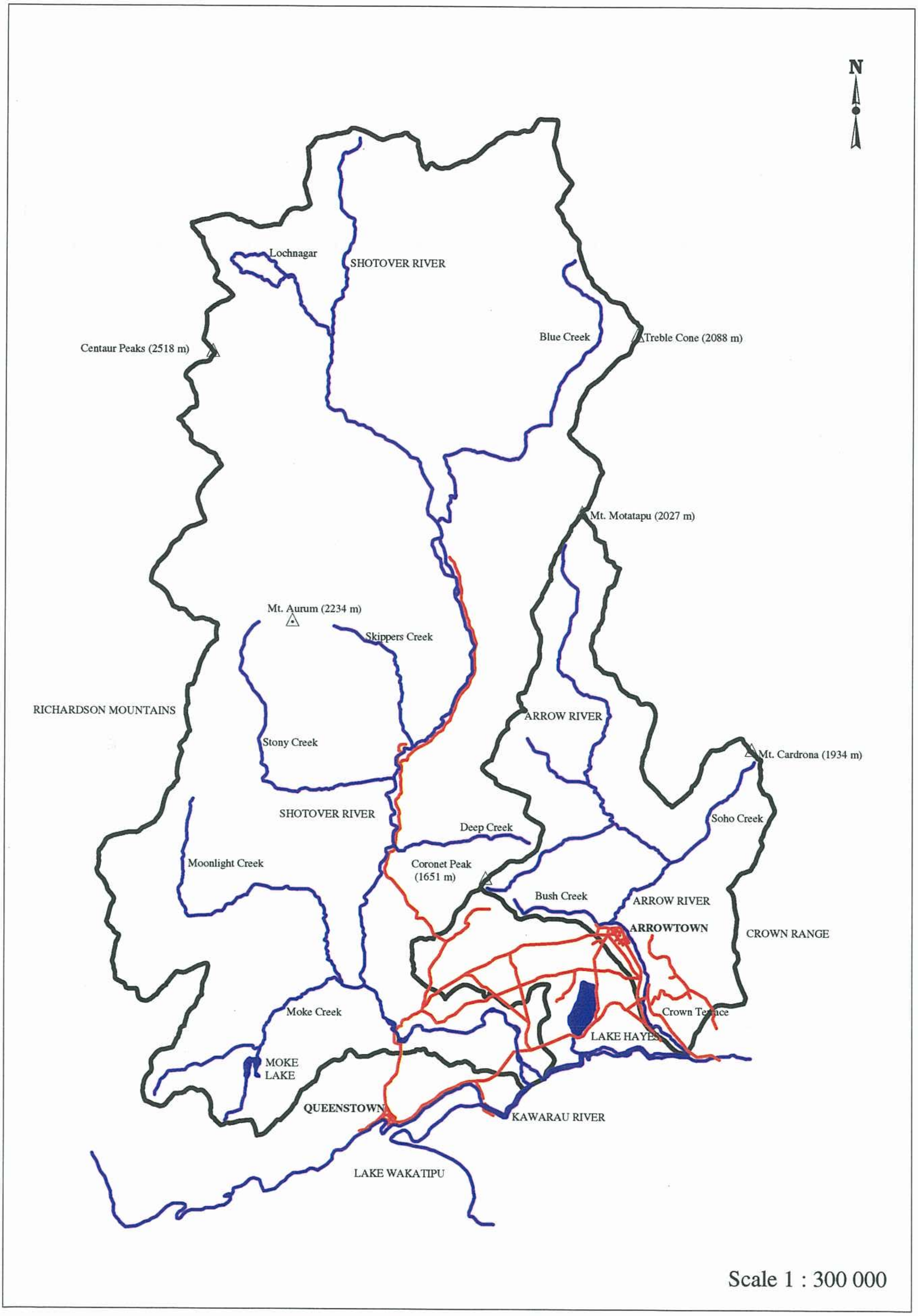


Figure 7
Shotover River and Arrow River Catchment

Figure 8
Shotover River and Horne Creek Floodplain

Scale 1:50 000

10 Arrow River

The Arrow River catchment (area 136 sq km) is nestled between the Harris Mountains and the Crown Range (see **Figure 7**). The river feeds directly into the Kawarau River some 10-12 km downstream of the Shotover River confluence. Rainfalls in the catchment tend to be similar to those experienced in the adjacent, and larger, Shotover catchment.

The river channel is entrenched along most of its length although there is a fairly small confined flood plain downstream of the Bush Creek confluence in the vicinity of Arrow Town itself.

In common with the Shotover River, the most severe inundation recorded in the Arrow catchment occurred in the winter of 1863. "On 27 July, there was another destructive and fatal flood in the Arrow, with the loss of at least twenty lives. The rain resumed on the 24^{th} and came down in a solid sheet, washing a huge body of snow off the mountains into the rivers. The Arrow rose 16 feet above its ordinary banks, sweeping all before it in promiscuous destruction. The lower Arrow township narrowly escaped demolition and the Shamrock Hotel and several stores were destroyed." Many miners camped on the flats opposite the town were lucky to escape." (Miller, 1949)

As a result of the havoc caused by the 1863 flood, the main street of Arrowtown was reconstructed at a higher, safer level. Largely as a result of this, the developed areas of the town today remain clear of the likely floodable area although it is necessary for the spread of willows and other vegetation in the floodplain to be monitored and controlled to avoid the risk of the river channel becoming seriously congested.

11 Mill Creek

Mill Creek flows into the northern end of Lake Hayes. It has a catchment area of about 36 sq km and provides about 75% of the inflow to the lake. Little flood data is available for the stream but a peak flow of 9.5m^3/s recorded in June 1985 is believed to be representative of a major flood.

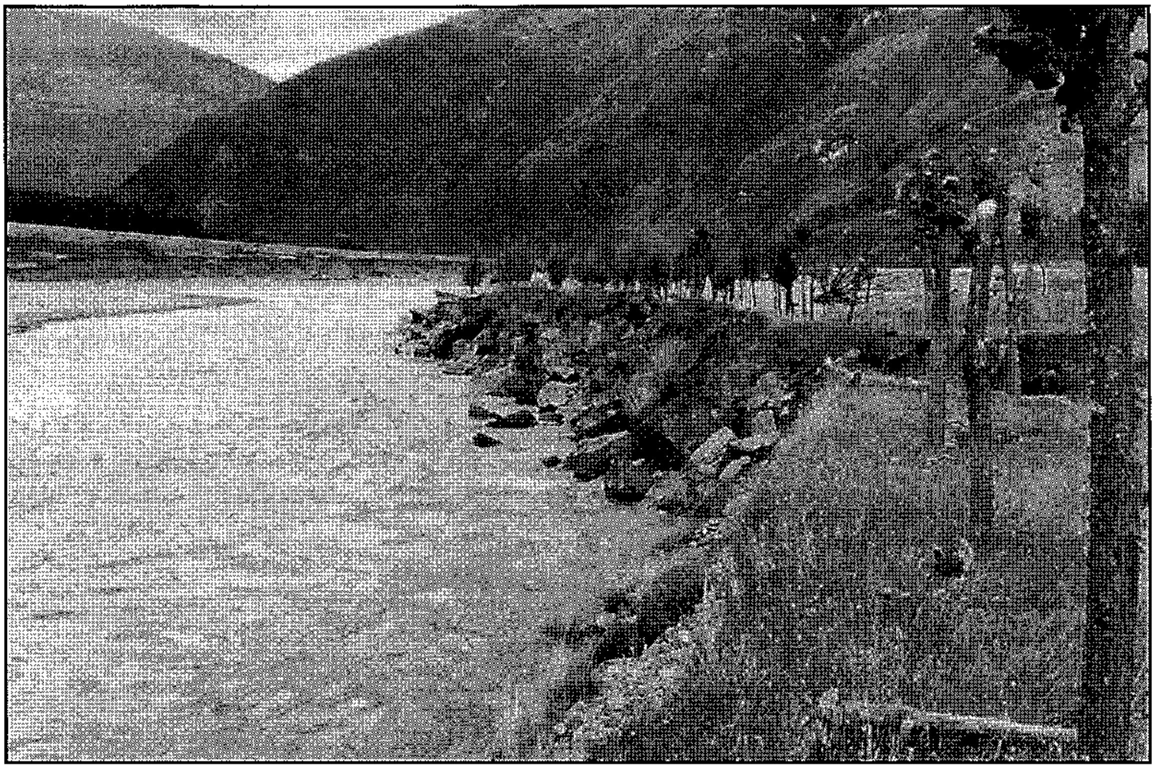
No major flooding difficulties are believed to be experienced in the catchment, but increasing demand for small residential blocks upstream of the lake may bring pressure to utilise land within the floodplain. This development needs to be carefully managed to ensure that the flood risk is appropriately accounted for.

12 Matukituki River

The Matukituki River drains an area of approximately 867 sq km into the western side of Lake Wanaka. The catchment lies between the Harris Mountains to the south (Black Peak 2,306m), the main divide in the vicinity of Mt Aspiring (3,035m) to the west, with the range to the north east reaching 2,389m at Mt Alta. The Matukituki catchment is shown in **Figure 9**.

The Matukituki valley floor lies at an elevation ranging from 280m to 350m. The Matukituki is subject to frequent and sometimes very intense rainfall, often with very little warning. Annual precipitation ranges from approximately 875mm at Lake Wanaka to some 5,000mm at Mt Aspiring. Historically the river has behaved as a typical high country braided channel, frequently changing its alignment and inundating and eroding highly productive river flats or rendering large areas useless by depositing huge quantities of gravel detritus. Loss of such land has threatened the viability of such high country stations as Mr Aspiring Station, Cattle Flat (right bank) and West Wanaka (left bank). Road access to these stations and to Mt Aspiring National Park and Treble Cone Ski Field has also been at risk.

The bankfull capacity of the Matukituki is estimated to be in the order of 2,000m³/s but flooding and significant roading disruption have also occurred at lower river discharges when tributaries such as the Leaping Burn, Phoebe Creek, Carmel Burn (Speargrass Creek) and Twin Falls Creek have outflanked their normal channels.



Photograph 7
Matukituki River – Rock Revetment Works

Since 1955, and probably earlier, considerable effort has gone into works intended to prevent the Matukituki River and its tributaries disrupting farming operations and access links in the area. In that time floodbanking has been carried out on the Carmel Burn, Leaping Burn, Boggy Burn and Phoebe Creek tributaries amongst others, and at many locations along the main river channel itself. Log lines, rock revetment work and live willow plantings have been extensively utilised as means of flood mitigation and debris control. **Photographs 7 and 8** shows works undertaken in the catchment.

The enormity of the task can perhaps be appreciated by considering an extract from an OCB Engineer's report on developments within the main channel in the mid 1970s:

> "An enormous amount of bank erosion also occurred in the last few floods in the lower reaches of the west branch of the Matukituki where the river has carved something in the order of a million (cubic) yards of material from the toe of a large fan, and this has possibly aided the dramatic swing in channel alignment at the downstream end of Cameron Flat where the river has cut back to an earlier channel line and created another severe erosion problem...."

In an attempt to overcome such problems a training line of railway iron and walings was constructed downstream of Glenfinnan. These have been successful in reducing erosive attack on the right bank of the river by flow redirection and by building up a river terrace of silt and gravel, deposited during floods, on the landward side of the works.

Isolated areas of erosive attack are still evident on the right bank above Glenfinnan and between Niger Point and the confluence of the Motatapu. Flood-induced erosion can occur along much of the left bank, most of which is unprotected.

Photograph 8
Matukituki River Right Bank – Reclaimed Land Downstream of Training Works (January 1994)

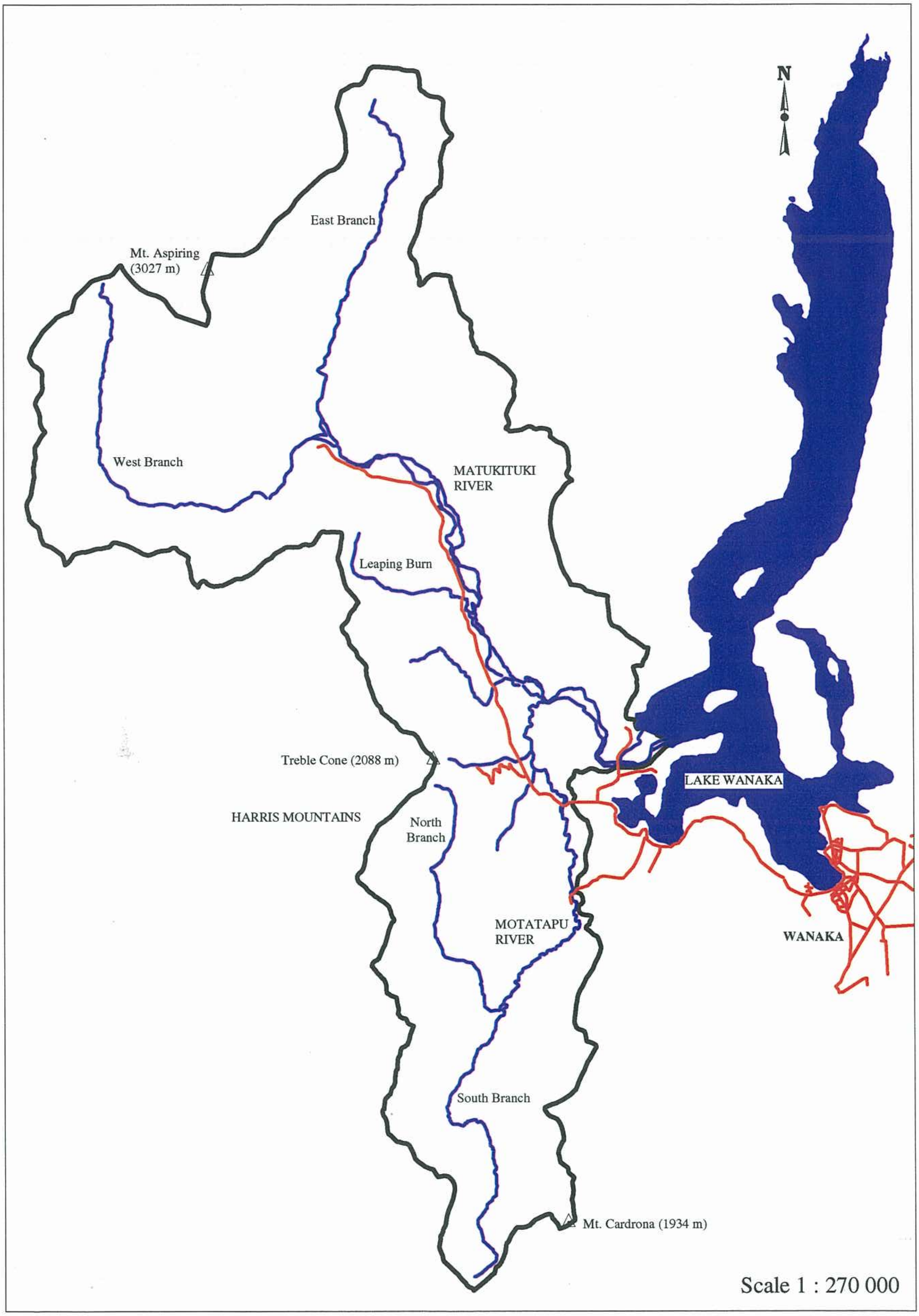


Figure 9
Matukituki River Catchment

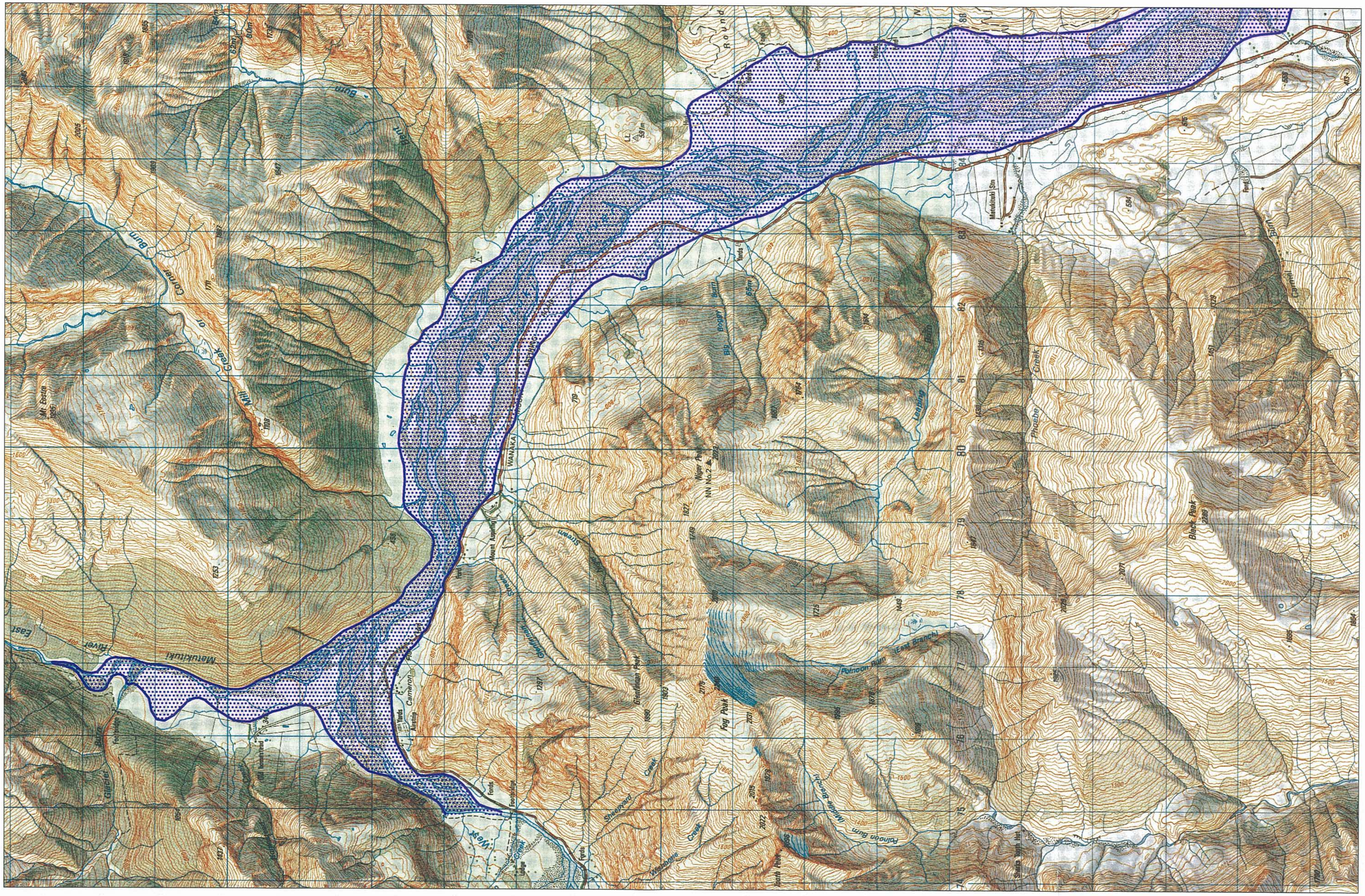


Figure 10
Upper Matukituki River
Floodplain

Scale 1:50 000

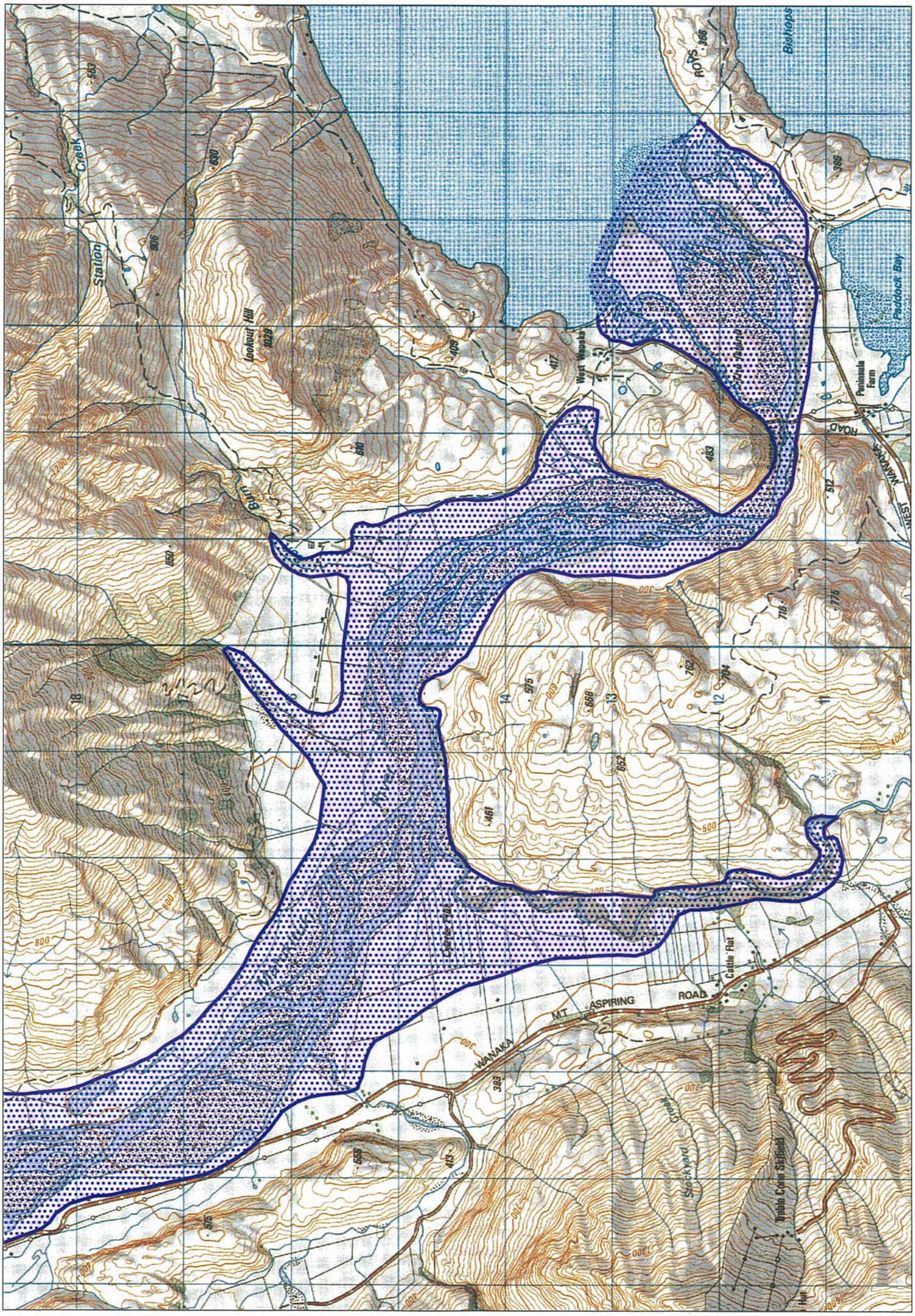


Figure 11 **Scale 1:50 000**

Lower Matukituki River Floodplain

In the lower reaches of the river the most dramatic event in recent years was the loss of the bridge across the Matukituki to West Wanaka Station in March 1974 when floodwaters associated with Cyclone Zoe rose to within 900mm of the bridge decking. Immediately downstream of the bridge site a flood channel has developed, thereby accelerating bank attack on an area of West Wanaka Station known as "The Island".

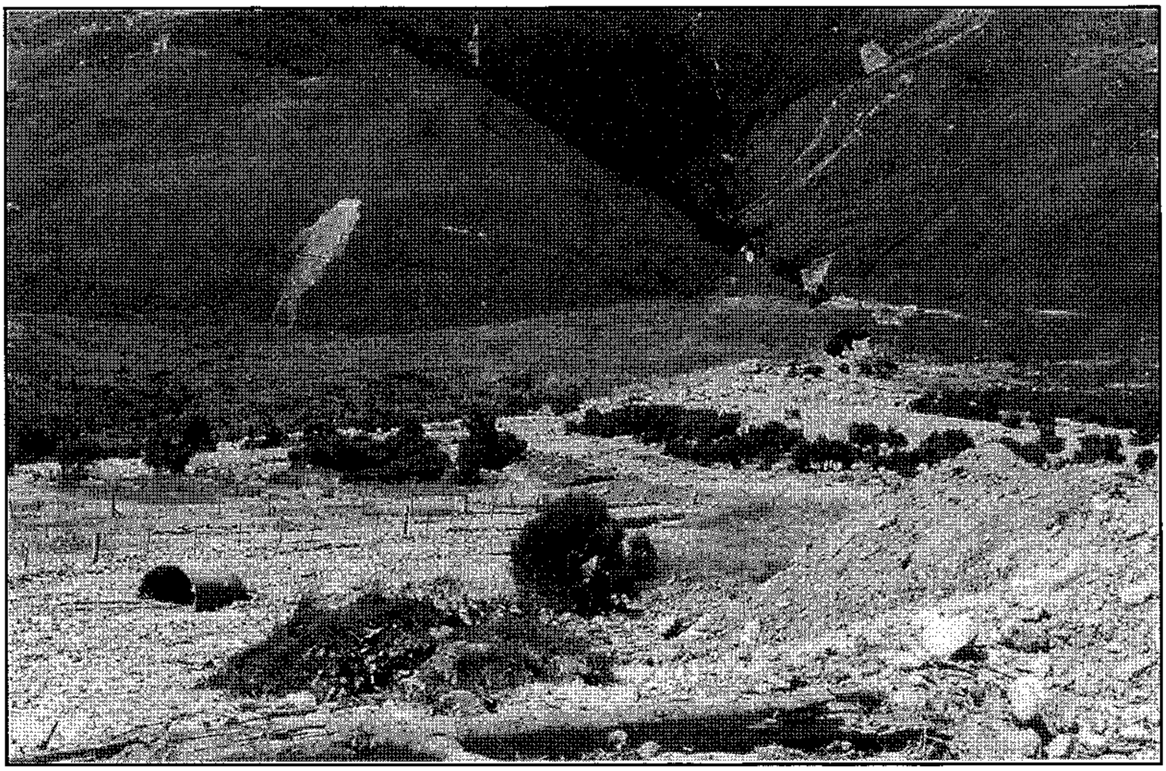
The Motatapu River flows into the Matukituki from the east, some 7-8km upstream of Lake Wanaka. In common with all such high country rivers, its flood durations tend to be short. Some overland flow is experienced on Cattle Flat just upstream of the Matukituki. Flooding problems in the lower Motatapu have tended to be aggravated by in-channel willow growth. This was particularly evident during flood events of 1978 and 1979.

The floodplain zones have been determined by on-site inspection, aerial photography and contour surveys. They are shown on **Figures 10 and 11.**

13 Makarora River

The Makarora River catchment (710 sq km) exists as a series of glaciated valleys between the Divide and the Young and McKerrow ranges. Several peaks in the catchment exceed 2,500m in elevation. The Makarora River's major tributaries are the Wilkin and the Young. The catchment is shown in **Figure 12**.

Early reports suggest that the river in its lower reaches was confined within banks of matagouri, tussock, scrub and timber. Most of the valley's exploitable timber had been taken by the turn of the century, and the loss of a great deal of tussock cover from uncontrolled burning created large areas of instability on the steep slopes, freeing huge quantities of detritus that could enter the river system during periods of intense rainfall. As a result the Makarora evolved into a typical braided river system characterised by an expansive gravel bed, unpredictable development of major channels across the valley floor, erosive attack and flooding. This has proved a major concern for the runholders farming the fertile flats and for those with the responsibility of maintaining the state highway through to the Haast which was opened prior to World War II. Disruption of this increasingly important road link has been more often caused by flooding of the tributary creeks (Flaxmill, Cemetery, Township, Camerons, Boggy etc.) that flow from the eastern slopes across the flats to the river. In many instances the waterway capacity of the highway bridges prove inadequate to handle the massive quantities of material carried by these streams. Roading communications are disrupted and farmland is flooded (short term) and covered with detritus (a longer term problem). **Photograph 9** shows deposition of detritus that can occur following a storm event in the catchment.



Photograph 9
Makarora River Catchment – Boggy Burn Gravel Fan (January 1994)

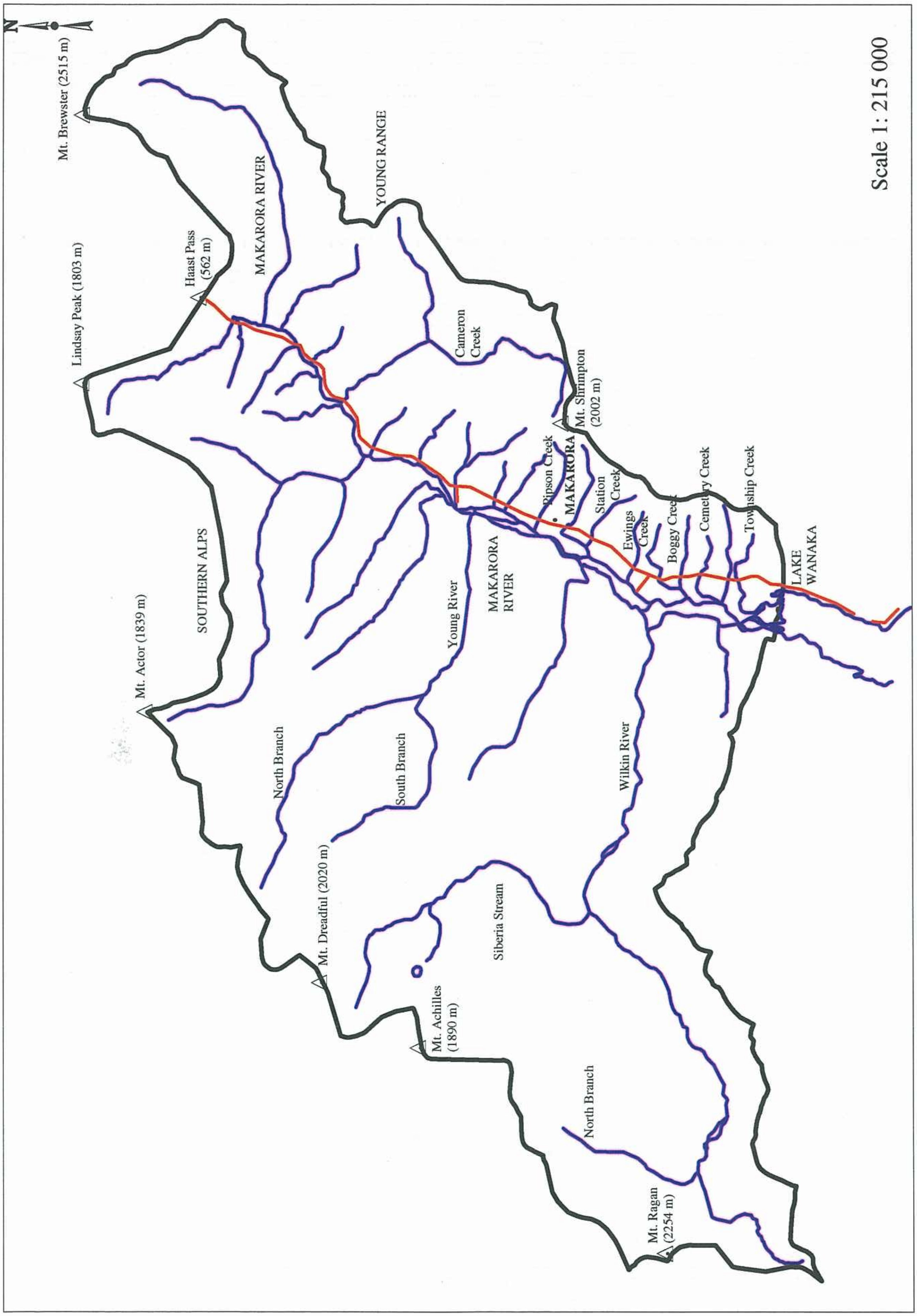


Figure 12
Makarora River Catchment

The Makarora River catchment is frequently subjected to heavy rainfall. Typical annual precipitation ranges from 1,500mm at Lake Wanaka to 7,500mm in the headwaters. During the storm of 13 October 1978 some 240mm fell in a 24 hours period at Makarora Station. In 1994 more than 180mm fell on 8 January and more than 300mm between 7-9 January. The 50% (2 year return period) flood in the main channel has been estimated at about 1,200m^3/s; the 5% flood, 2,100m^3/s.

Flood damage has been a constant threat in the catchment throughout this century, but most damage has understandably occurred in periods when major storms have occurred in quick succession (e.g. 1950-52 and 1978-80 and 1994-95). Under these circumstances the inability of damaged areas to revegetate before the next onslaught has resulted in accelerated movement of flood detritus downstream. **Photographs 10 and 11** show debris and detritus entering the Makarora River following the flood of January 1994.

The following abbreviated list of flood occurrences is not claimed to be exhaustive, but it should convey an impression of the types of problems experienced relatively frequently in the area since 1950.

1950 (May): Makarora River flood, 2,000 sheep lost at Makarora Station.

1952 (February): Makarora River flood. Extensive erosion. Major damage sustained by tributary creeks.

1967 (March): Makarora River flood. 350mm of rain within one week at Makarora. 35 hectares of farmland isolated by the development of a side channel of the river a short distance upstream of the lake.

1967 (December): Township, Flaxmill, Station and Brady's Creeks filled with gravel during high tributary flows.

1976: Gravel and trees again block Flaxmill Creek.

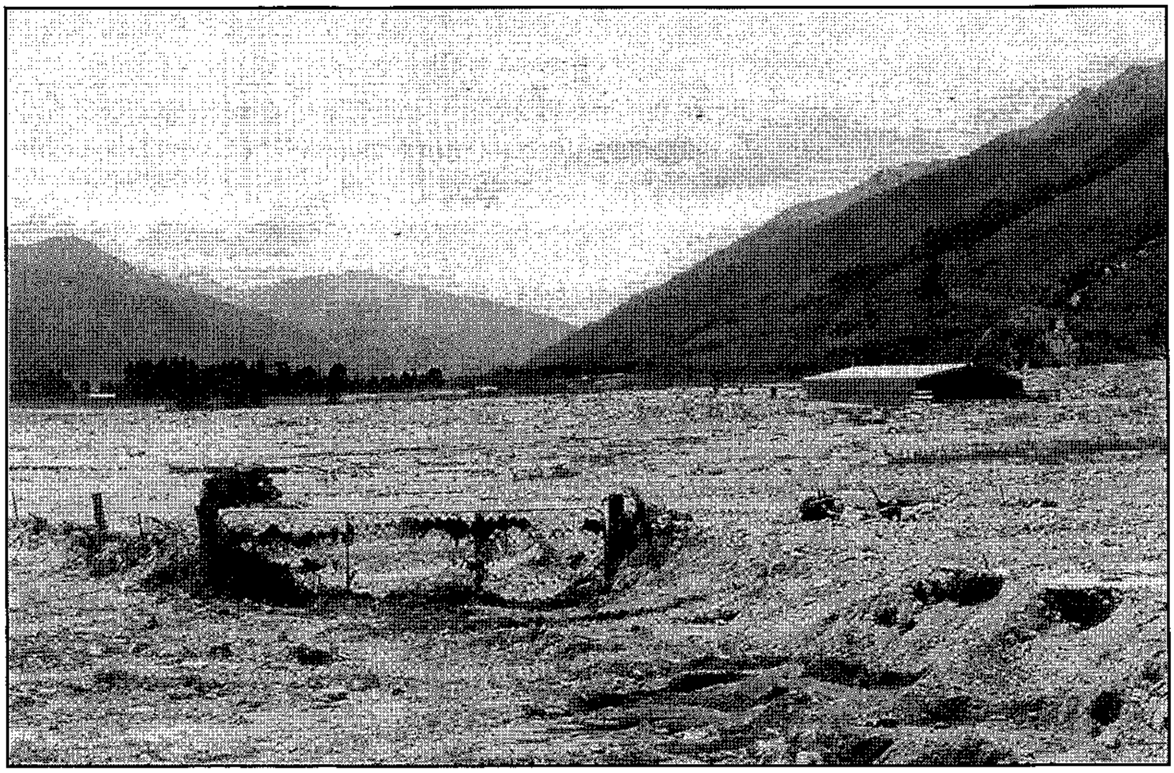
1978 (October): Major river flood. 200 ewes and 1,100 lambs lost from Makarora Station; also 5 km of fencing destroyed and 100 hectares covered by silt.

1979 (December): Makarora flood levels higher than recorded in 1978. Floodwaters reach doorstep of Mr K Blanc's house at Makarora.

1980: Township Creek capacity severely limited by gravel buildup during the winter.

1986 (April): 112 mm of rain falls at Makarora within a 24 hour period. Flaxmill Creek is badly affected. Large quantities of boulders, gravel and silt are deposited in the stream bed from its confluence with the Makarora to a distance some 300 metres upstream of the State Highway, effectively blocking the stream. The stream banks are overtopped at several locations.

1994 (January): 300mm of rain falls at Makarora Station between 7-9 January and a further 180mm between 21-23 January. Six bridges between the Neck and Makarora were washed out. Major depositions of gravel occurred in several tributaries.



Photograph 10
Makarora River Catchment – Debris Left in the Wake of a Major Flood in the Boggy Burn (January 1994)

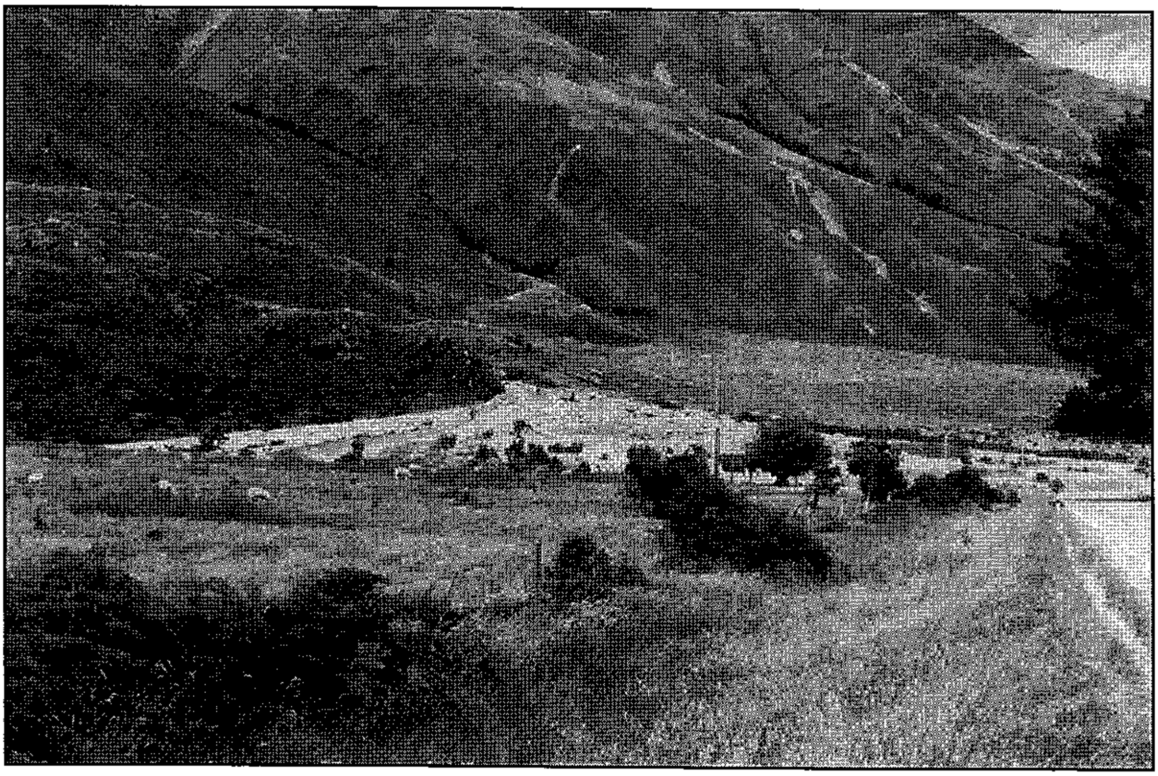
13.1 Flood Mitigation Measures in the Makarora Catchment

Over the past 30-40 years considerable effort has been devoted to work designed to prevent the encroachment of the Makarora River and its tributaries into the river flats and to minimise the effects of flooding. The works undertaken have included:

- Training works to arrest the development of undesirable side channels (Makarora River).
- Floodbanks to prevent the catastrophic effects of high velocity, debris-laden flows devastating farmland (Makarora River). This included the construction of a 7.1km floodbank along the left bank of the Makarora River between Station Creek and Lake Wanaka. The crest of the bank, built about 1982, was designed at a level some 200mm higher than that attained by the major flood of October 1978.
- Catchment control works to reduce the amount of debris being sluiced into the tributary streams of the eastern slopes. The main works involved the Makarora Faces Catchment Control Scheme which was undertaken during the mid 1980s. Work was concentrated on Flaxmill, Cemetery, Camerons, Township and Boggy Creeks and involved oversowing, topdressing of the upper slopes, dewatering of saturated slips, willow planting to stabilise debris and fencing to exclude stock from vulnerable areas. The stream channels were rock raked and the material removed was incorporated in adjacent floodbanks. Most of these streams now have a multiple series of parallel floodbanks to reduce the likelihood and severity of outflanking.
- Channel improvement and floodbanking of those tributary streams in their lower reaches.
- Upgrading of bridges and culverts under the State Highway.

Maintenance of such high country river works is essential to ensure their continuing effectiveness.

The determination of the flood hazard zone as shown on **Figure 13** is based on personal observation, historical accounts and catchment inspection. The State Highway is in many areas above flood level but may be subject to damage at many of the locations where bridges or culverts accommodate waterways. The hazard zone around some of the tributary creeks has been expanded to allow for the effects of blockage of the waterways on sites upstream of the highway. On the gravel fans the source of the flood hazard is not the Makarora River but the creeks which have the potential to break out from their channel, disgorging sediment-laden water over the gravel fan. It is indeed by such processes that the gravel fans have developed over time. Maintenance works within some tributaries have reduced, but not eliminated, the possibility of stream breakout. Because of the varying nature of the terrain within such areas, suitability for development should be assessed on an individual case basis.



Photograph 11
Makarora River Catchment - Gravel Fan Cemetery Creek (January 1994)

14 Lake Wanaka

Lake Wanaka has a surface area of approximately 180 sq km making it New Zealand's fourth largest after Lakes Taupo, Te Anau and Wakatipu. Its main sources of inflow are the Makarora River from the north and the Matukituki River from the south west, although a large number of small streams also feed the lake. Lake Wanaka is the source of the Clutha River.

Lake Wanaka is a glacial lake, formed during the last period of glaciation some 18,000 years ago. Such lakes are characteristically very deep, Lake Wanaka exceeding 200 metres in most places and 300 metres in the extensive Minaret Basin. Rainfalls in the catchment area of the lake are estimated to be typically in the order of about 3,000mm annually which produces a mean lake level of approximately RL 277.3m and a mean outflow of some $190m^3/s$.

Rainfall tends to be heaviest in the regions immediately to the east of the main divide where as much as 8,000mm annually are not uncommon. The heaviest rainfall occurs in the catchment when an active frontal zone or depression moves slowly over the South Island. The moist warm air which precedes such a front provides a semi-infinite source of moisture for as long as the front persists. In the major storm of October 1978 some 240mm fell in 12 hours at Mt Aspiring Station (Matukituki catchment) and nearly 320mm in total at Makarora. Jowett (1980) estimates that inflow into Lake Wanaka peaked at a massive $6,290m^3/s$ but the storage characteristics of the lake saw the peak outflow from the lake to the Clutha River reduced by almost 90% to $693m^3/s$. The lake level rose by approximately 2 metres to RL 279.46m.

The natural recorded range of Lake Wanaka levels extends from a low of RL 276.1m (September 1959) to a high of RL 281.8m recorded in October 1878. The 279.76m level recorded in January 1983 was the highest recorded for some 60 years, but this level was surpassed in December of the following year when the lake reached RL 280.39m. In January 1994 the lake reached RL 280.20m and RL 280.33m in December 1995. On both the latter occasions sandbags were placed to limit flooding in the vicinity of Ardmore Street in Wanaka township. Despite this up to 100mm of water entered some shops near Helwick Street in the 1995 event. **Photograph 12** shows the lake level during the January 1994 event.

An analysis of historical flood levels updated by the Otago Regional Council in 1997 produced the following probabilities of flat water lake levels of Lake Wanaka being reached or exceeded in any given year:

Probability	**RL.** (MSL = 0.00m)
1%	280.65
2%	280.36
5%	280.00
10%	279.70

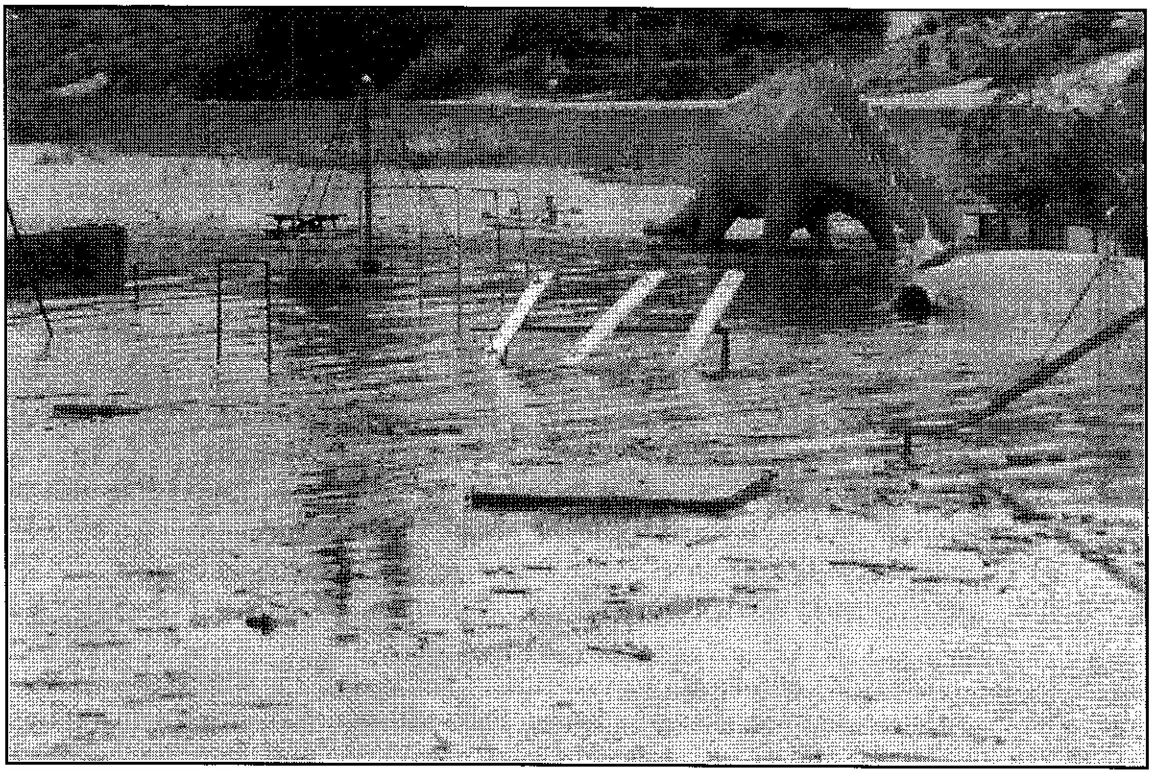
Clearly a repeat of the level attained in 1878 (RL 281.8m) would cause severe inundation of the commercial areas. The flood hazard zone shown on **Figure 14** is based on the 281.8m contour as surveyed in 1999. The assessed 1% probability level contour (RL 280.65m) is also shown. The area between the two contour lines could be expected to be subject to wave run up in a major flood should strong winds in Roys Bay coincide with the flood peak.

Figure 14
Lake Wanaka Flood Levels at Wanaka

In March 1990 Electricity Corporation of New Zealand commissioned Works Consultancy Services to investigate the effects of a major failure of the Lake Hawea control structure on downstream flooding. The failure scenario was assumed to be an earthquake induced piping or internal erosion type failure. (It should be stressed that this study was only one in a series that cover all such major hydro structures; it did not imply any specific concern with respect to the structural integrity of the Hawea structure).

The study showed that a catastrophic failure could produce a major reversal of the direction of flow into, rather than out of, Lake Wanaka. Peak spillage into Lake Wanaka was estimated to be in the order of 4,900-6,500m^3/s which is comparable with the largest natural floods entering the lake from the rivers and streams. Lake level was predicted to rise as high as RL 281.3m (cf 1878 level RL 281.8m) in such a scenario,

The study suggested, however, that it would take up to 36 hours for Lake Wanaka to reach RL 280m (the point at which minor flooding in the township could be anticipated) and a further 1½- 2 days to attain its peak level. This would obviously give time for an orderly evacuation of affected areas, if necessary, and for some damage mitigation measures to be carried out. It is estimated that the lake would take some 3-4 days to return to normal levels.



Photograph 12
Lake Wanaka – Flooding at Wanaka Playground WL 280.39m (22 December 1984)

15 Cardrona River

The Cardrona catchment has an area of 334 sq km and is shown in **Figure 15**. It is bounded to the west by the Crown Range and to the east by the Criffel Range. The river flows generally northwards from the Crown Range and flows into the Clutha River at Albert Town a few kilometres downstream of Lake Wanaka. The river's main tributaries are Spott's Creek, the Branch Burn and Timber Creek, all of which enter from the west and are crossed by State Highway 89, the Crown Range route between Wanaka and Queenstown. This is also the access route to the Cardrona ski field.

Occupation of the Cardrona dates from the 1860s when gold was discovered in the valley. The Cardrona provided a steady yield. There were up to 1,000 miners in the valley in the late 1860s, but fewer than 200 by the late 1880s.

The decline of mining operations in the Cardrona valley was hastened by the advent of the 1878 flood. The river destroyed much of the lower part of Cardrona Town. Mine shafts, houses, water races and access roads suffered great damage. For several weeks no wheeled traffic could reach the town. Today only the old school building and the old hotel building still exist, most of the buildings that survived the flood having been relocated to Wanaka or Luggate by the turn of the century.

Farming, which commenced in the Cardrona valley in the 1860s to service the miners, has continued. The high nutrient loamy soils have proved suitable for both stock and cropping. However, in recent times much of the lower river area has been broken up into "ten acre" blocks.

No flood since has had an impact in the valley as did that of 1878. No integrated flood protection scheme has ever been mooted although isolated works, usually intended to prevent erosive damage, have been undertaken. The majority of these works since the 1800s have been on the right bank of the river downstream of Mount Barker, although works have also been undertaken at locations on the left bank downstream of Spott's Creek and Timber Creek, and on the right bank downstream of Deep Creek. Usually the works have involved channel alignment correction and protective measures such as log line establishment.

Floods in the Cardrona River and its tributaries tend to be "peaky"; ie. they rise and subside quickly. The major effect of such floods in recent years has tended to involve disruption to State Highway 89. Bridge and culvert washouts have closed the road for up to 2-3 days on occasions and parts of the road itself lies within the floodplain between Hillend and a short distance upstream of the Spotburn.

The floodplain between the site of the old town of Cardrona and the Clutha River is quite clearly defined between elevated terraces, and there has been little ill-advised development undertaken within it. Stopbanks protect comparatively low-lying farmhouses and associated buildings at Waiorau a short distance downstream - and on the opposite bank - from Cardrona. The Cardrona floodplain zone is shown on **Figure 16.**

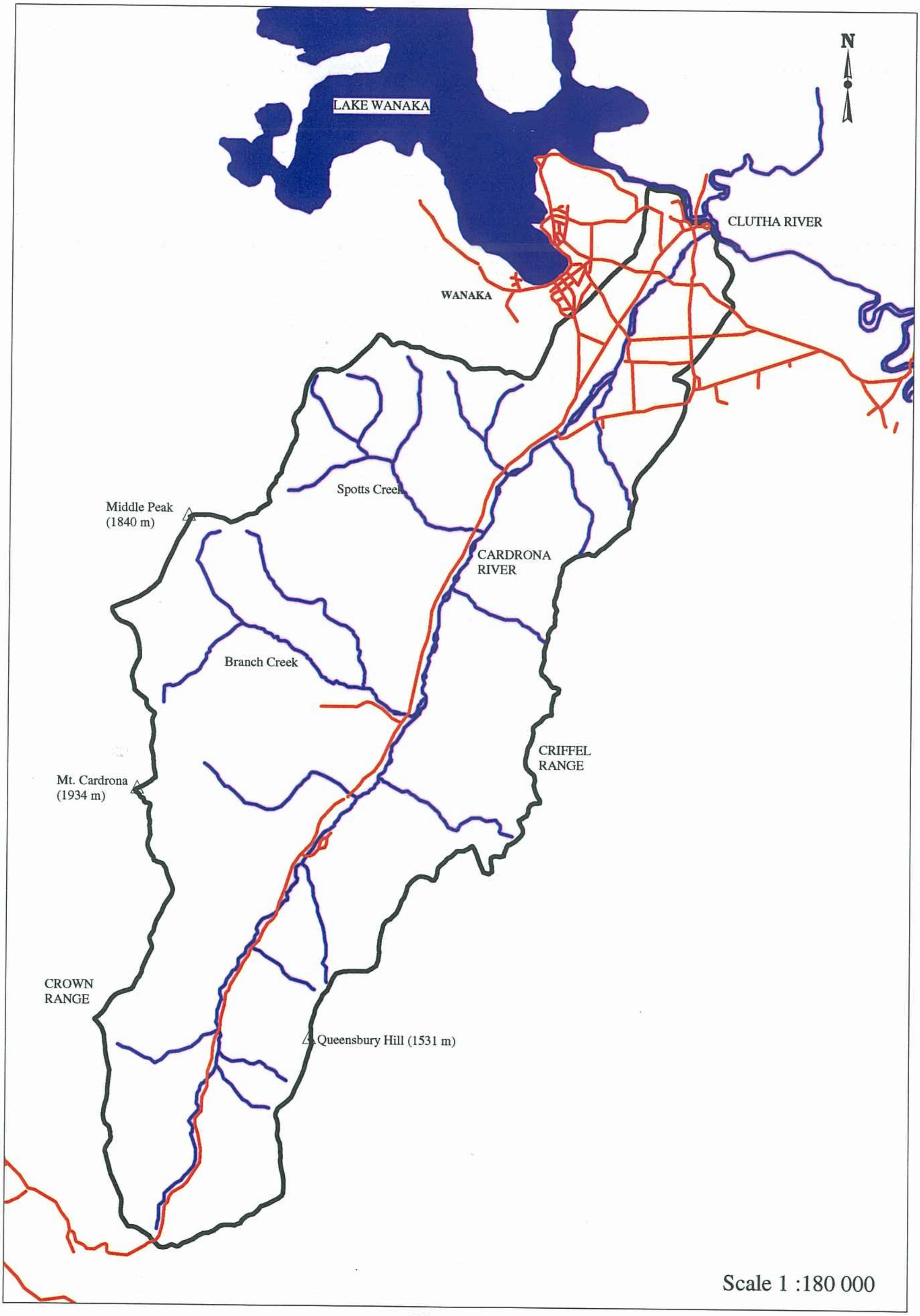


Figure 15
Cardrona River Catchment

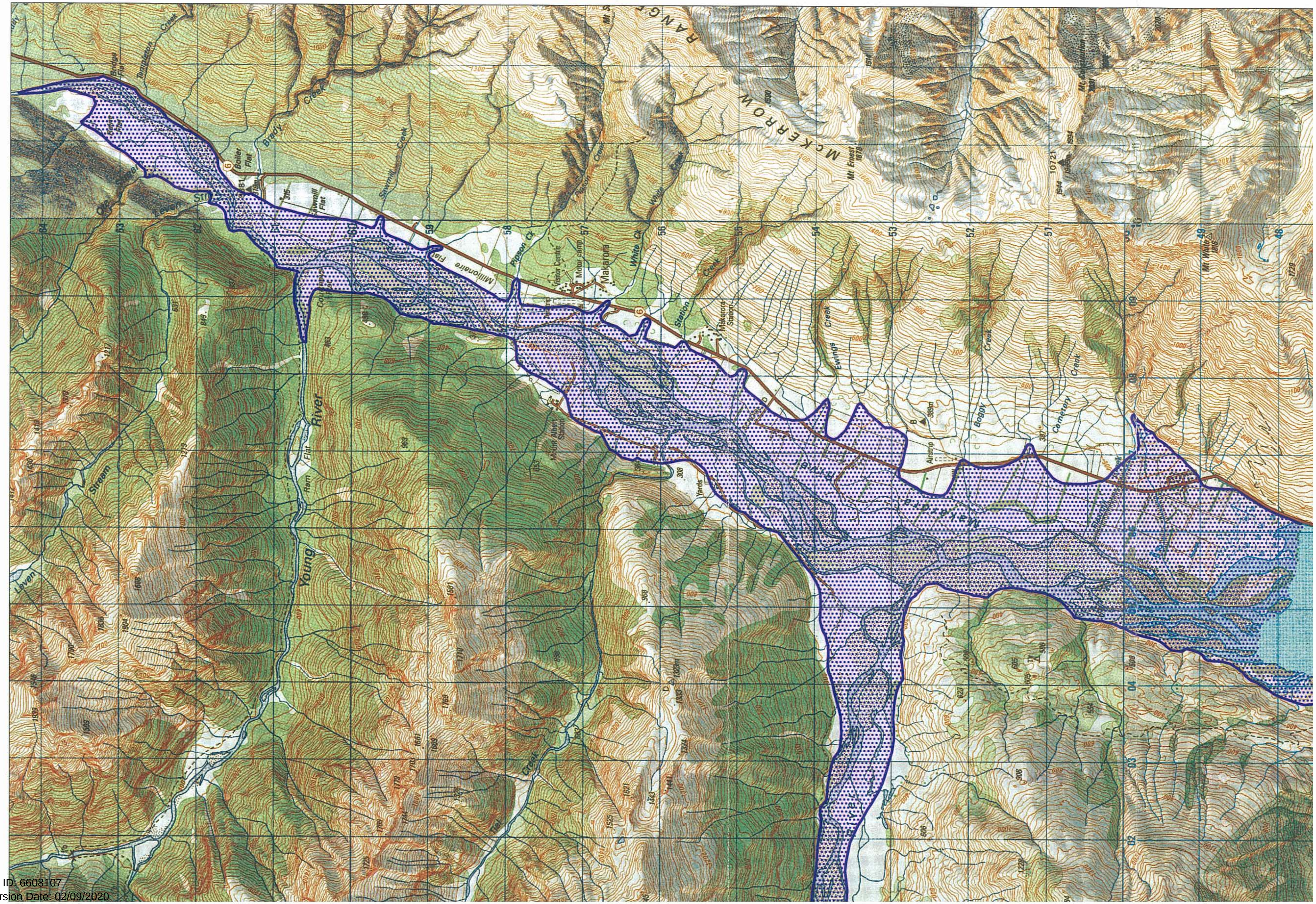

MCKERROW
RANGE
Makarora
Millionaire Flat
White Cr
Young
River
Stream

Figure 16 **Scale 1:60 000**

Cardrona River Floodplain

16 Luggate Creek

Luggate Creek enters the Clutha River downstream of Luggate township. For most of its length the channel is entrenched and presents no flood threat, but in the vicinity of the SH6 bridge infestation of poplars and willow trees and a buildup of sediment in channel has created situations where flood flows have overtopped the stream banks causing flooding of, most frequently, the domain upstream of the highway and, on occasions, of a number of nearby properties.

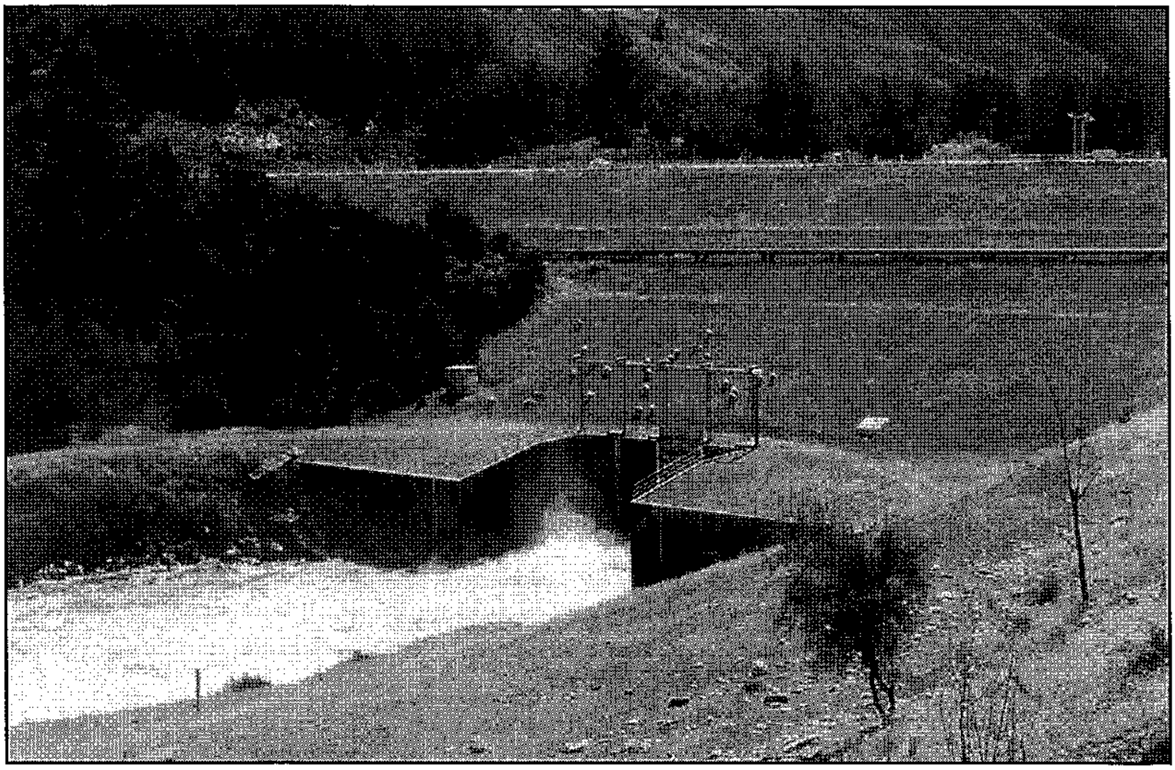
Since the mid 1950s intermittent channel clearing works and a channel diversion downstream of the highway have minimised flooding problems in the area, but ongoing channel maintenance is necessary from time to time.

17 Lake Hawea

Lake Hawea (151 sq km) is the smallest of the three high country lakes feeding the Clutha River system. The lake is bordered on both sides by high mountains including Dingle Peak (1,833m), Mount Arnold (1,973m) to the east and Sentinel Peak (1,811m) and Terrace Peak (2,027m) to the west. It has one major tributary, the Hunter River to the north and numerous smaller tributaries to the east and west.

In 1958 a 27.4m thick earth dam was constructed at the outlet to the Hawea River to raise (by some 18 metres) and control the level of the lake for electricity generation purposes. The dam (see **Photograph 13**) has a crest level of 351.4m and a low-level sluice capacity greater than the probable maximum outflow of 316m³/s (Jowett and Thompson, 1977; Webby, 1990).

The structure was originally intended to control lake levels over a range of approximately 20 metres from RL 327.4m to RL 346.75m). Such storage capacity was considered sufficient to contain the total inflow into the lake in a wetter than average year without discharge into the Hawea River. The control gates remained closed throughout the major Clutha floods of October 1978 and January 1994.



Photograph 13
Lake Hawea Control Structure

The raising of Lake Hawea caused little threat in terms of flood damage although lake levels above RL 346.0m tended to initiate instances of lakeshore erosion and comparatively minor damage to stock fencing adjacent to the lakeshore. Properties in the township of Hawea and the settlement of Gladstone are all sufficiently elevated to be unaffected by lake level rises (the lowest house in Gladstone has a floor level in the order of RL 350m for example), but considerable erosive activity - aggravated by wind generated wave lap - was generated along the cliffs at the southern end of the lake and along the eastern margins where sections of the road to the Timaru River had to be reconstructed. Rock protection was placed to protect the cliffs adjacent to Flora Dora Parade and Skinner Crescent in Hawea township. The maximum level attained by the lake have been RL 347.1m in March 1979 and RL 347.25m in December 1995. At these levels water was lapping at the foot of the southern cliffs.

Ironically, given that the lake had been substantially raised, most concerns aired involved situations that resulted from the lake being drawn down to low levels, especially below RL 336m. On such occasions extensive areas (up to 3,000ha) of drying mudflats were exposed. These were not only unsightly but a major contributor to dust storms.

In 1979 the National Water and Soil Conservation Authority fixed maximum and minimum permitted levels for Lake Hawea and these were reviewed in 1985. The maximum and minimum levels set in 1985 were RL 346.0m and RL 336.0m respectively, although there were provisions for this range to be extended in rare circumstances. During 1992, the year of generally low South Island hydro storage, the lowest level of the lake recorded was RL 340.31m although there have been other occasions when the lake has been drawn down to lower levels.

Given the height of the control structure (RL 351.4m) the storage capacity of the lake and the discharge capacity of the low level sluice it is almost inconceivable that the most disastrous scenario of the structure being overtopped could ever occur. Such an occurrence would seem to require very high antecedent lake levels, subsequent further massive rainfall across the catchment and an irreparable failure of the sluice gates in a closed or near-closed position.

A fuse plug (a stopbank that can be induced to fail if conditions such as the imminent overtopping of the dam, warrant) exists some 3km east of the control structure near the Hawea cemetery. It is believed that the lowering of this bank (crest RL 350.0m approximately) is intended to restore lake levels to about RL 349m by allowing overland flow from the lake to a point downstream in the Hawea River. The overland flow path that would occur in such an event described in ECNZ's 1994 publication. The Gladstone Gap Emergency Spillway – Dam Break Assessment. It must be stressed that the spillway would only operate in the event of a flood far in excess of anything recorded to date. Lake Hawea, for example, would have to rise a further 2.75m above its December 1995 record level.

References

Freestone, H J et al: Clutha Flood Report for Flood of 14 December 1995 (Works Consultancy Services, 1996)

Gilkison, Robert: Early Days in Central Otago (Otago Daily Times and Witness, 1930)

Griffiths, George: The Great Flood of '78 (John McIndoe, 1978)

Johnstone, N P: Floodplain Management Report of Queenstown-Lakes District (Otago Regional Council, 1993)

Johnstone, N P: Lake Wakatipu, Kawarau and Shotover Rivers Mathematical Model Report (Otago Regional Council, 1994)

Jowett, I G and Thompson, S M: Clutha Development, Flows and Design Floods (Ministry of Works and Development, 1977)

Miller, F W G: Golden Day of Lake County (Whitcombe and Tombs Ltd, 1949)

Stevenson, M K and Scarf, I M: Shotover River Delta Sedimentation Investigation (Otago Regional Council, 1997)

Various: An Assessment of Possibilities to Reduce Flooding by Lake Wakatipu (Otago Regional Council and Queenstown Lakes District Council, 1996)

Webby, M G: Hawea Lake Control Dam Report on Dam Break Analysis (Works Consultancy Services, 1990).

MS P:\Floodplain\QLDC\Queenstown-Lakes Floodplain Report.doc