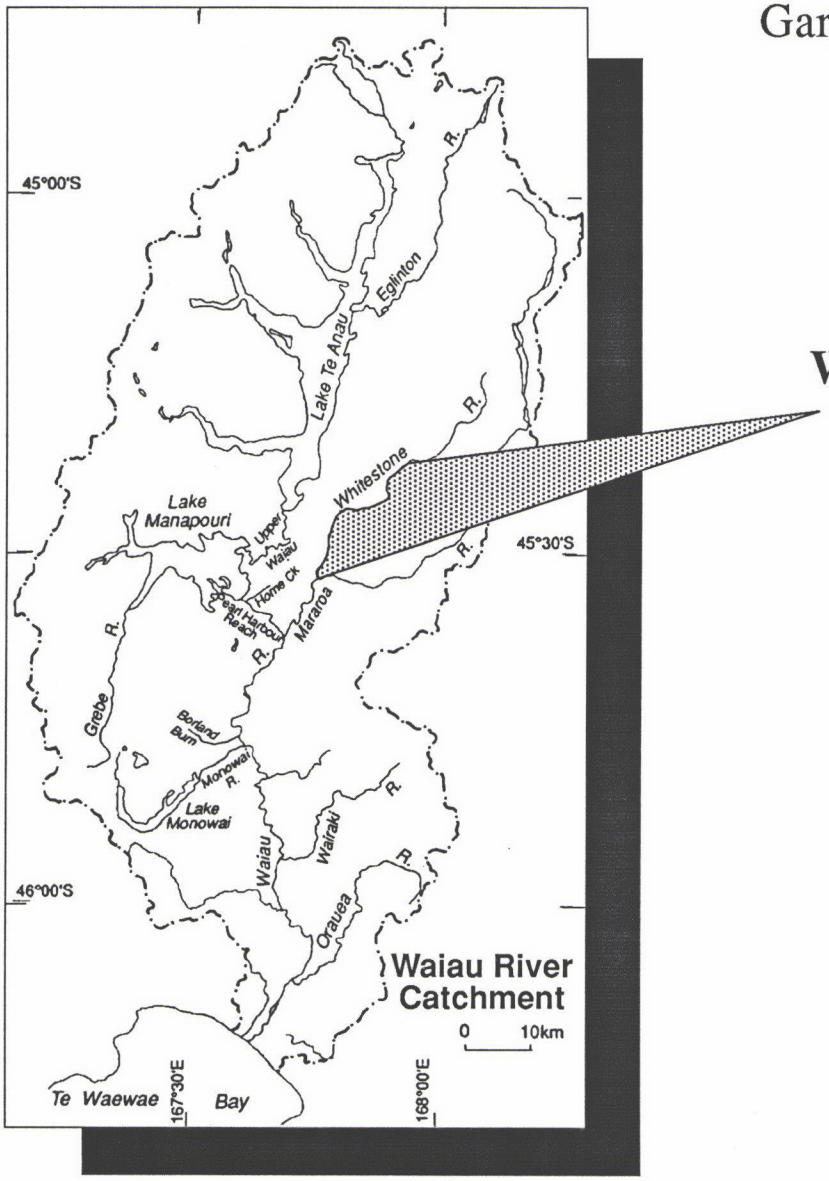
WHITESTONE RIVER
Reach Analysis

Gary J. BRIERLEY
April, 1993



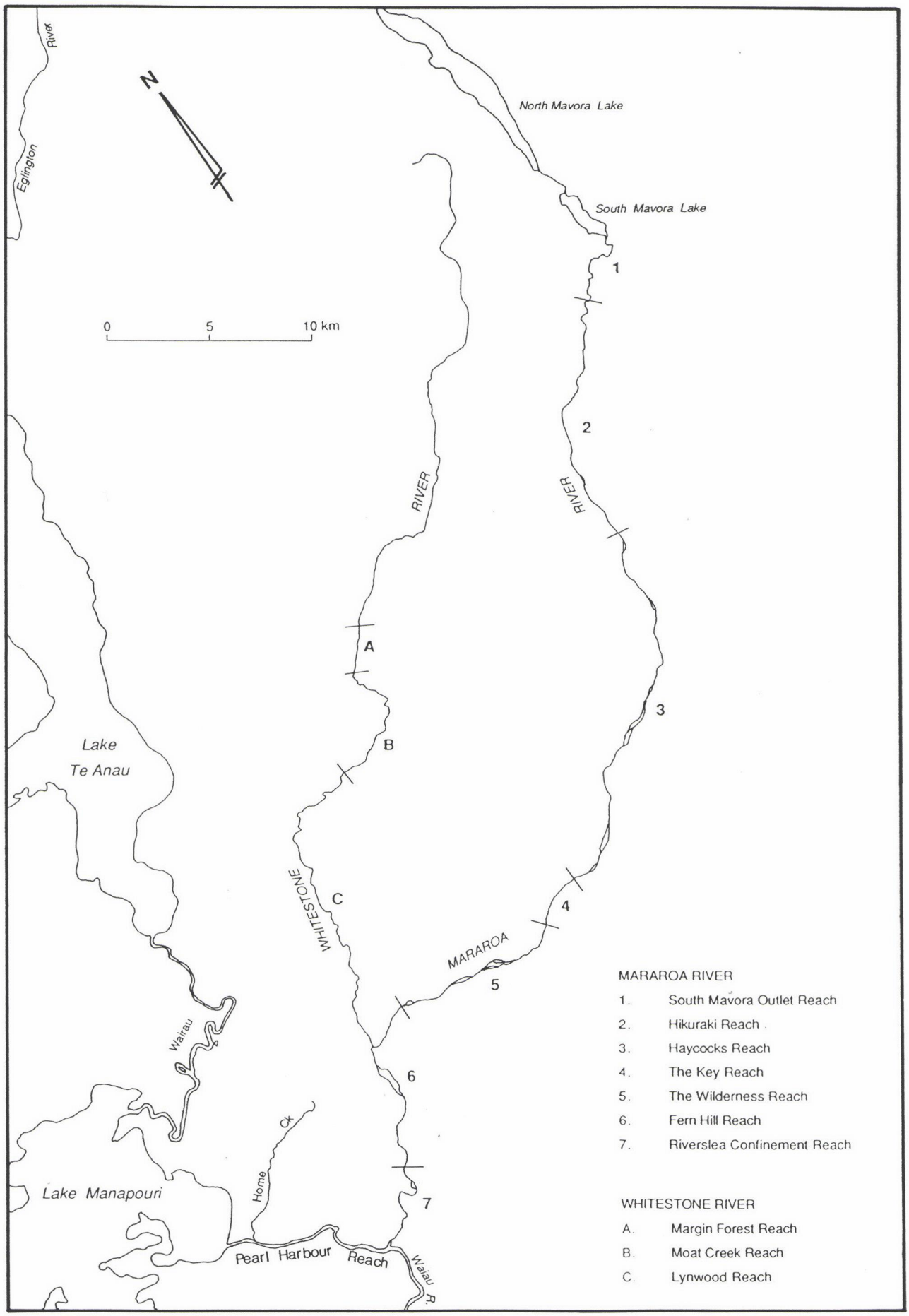
Whitestone River

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WHITESTONE RIVER
A. Margin Forest Reach
B. Moat Creek Reach
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REACH NAME : MARGIN FOREST REACH

Geographic description of reach : 2.5 km stretch of Whitestone River downstream of Kakapo road Bridge. Margin Forest reach is characterized by a single channel with extensive gravel surfaces. Whitestone River has been extensively modified in this reach, with stop banks along the entire length and major straight diversion channels at the upsteam and downstream ends of the reach. These artificial channels contrast starkly with the highly sinuous course of former channels evident on the alluvial flats.

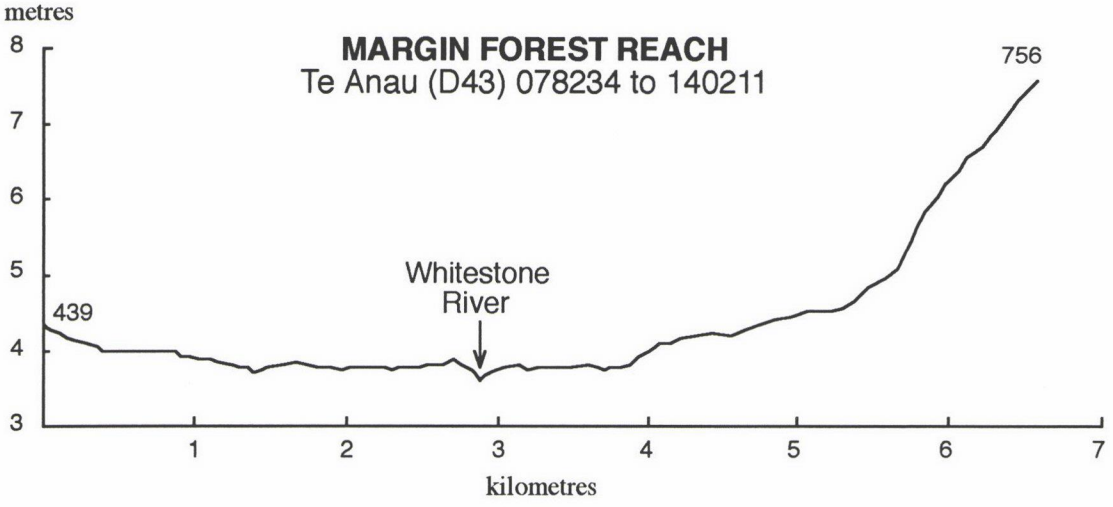
Analysts : GB, AH, BJ Date of Analysis : 20.01.93

Grid co-ordinates of reach : Te Anau (D43) 1:50,000, 112233 to 099210

Air Photos used : Southland Regional Council Survey # 0963, 18.12.91

VALLEY CHARACTERISTICS

Valley cross section



Valley setting
Broad valley with remnant upper terraces at its margins. Whitestone Valley is set between Te Anau Hill and Margin Forest on the right bank, and the foothills of Mount Prospect on the left bank.

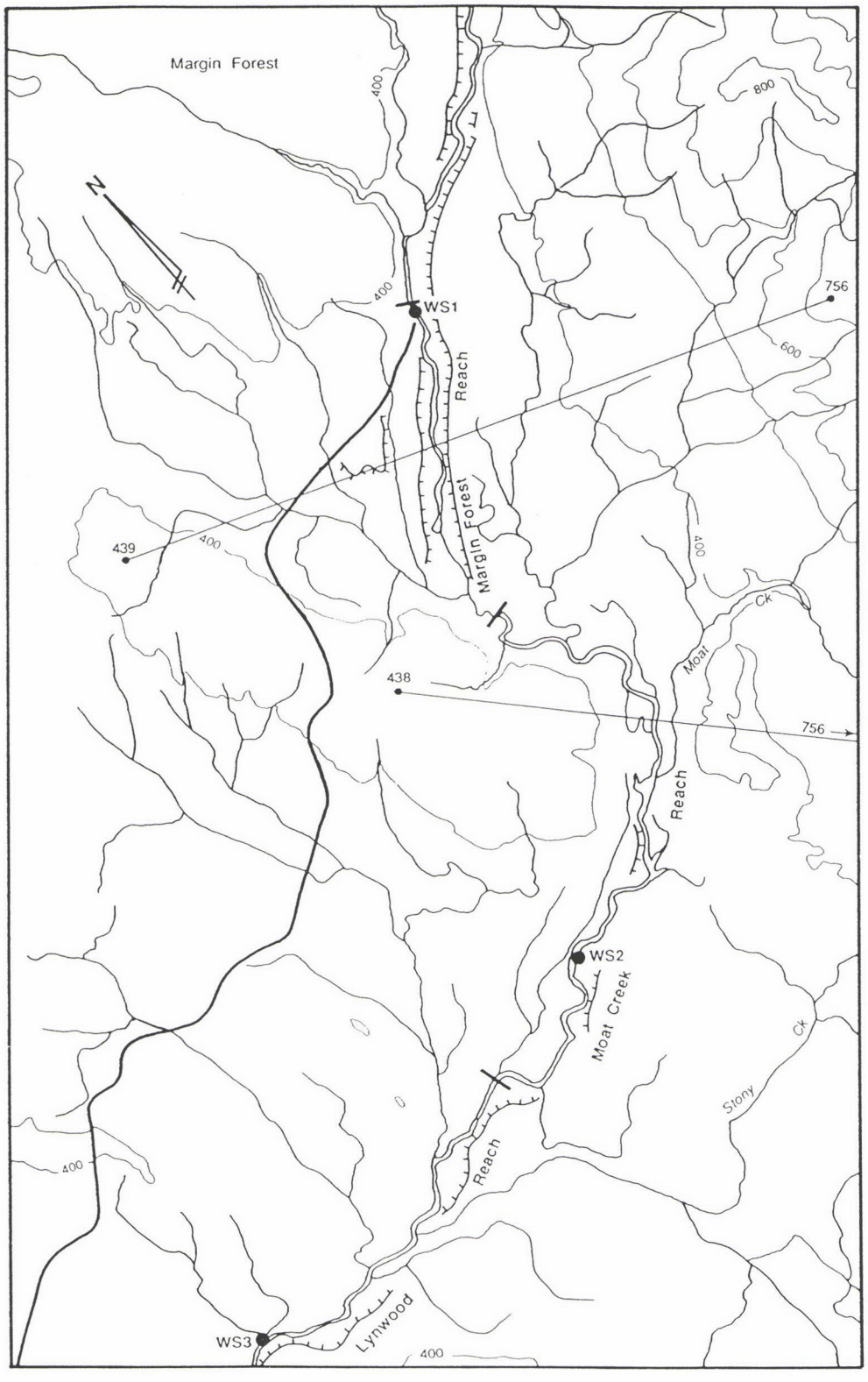
Extent of Valley flat
Fairly uniform at about 1.5 km wide.

Terrace character
The primary difference between this valley and Mararoa Valley appears to be the extent of removal of outwash gravels terraces. Whitestone Valley only has remnant perched upper terraces, resulting in a rectangular valley cross-sectional form with much less evidence of preserved terraces.

Left Bank
A very discontinuous upper terrace is noted upstream of Kakapo road bridge (from GR 132246 to 124233). This is a distinctly valley-marginal feature, about 80 m above the present channel. High remnant terraces are also observed downstream. No lower terraces are evident, indicating the relative ease with which the channel could shift over the valley flats - hence the need for stop banks.

MARGIN FOREST AND MOAT CREEK REACHES

Te Anau (D43) 1:50,000



0 1 2km

LEGEND

- Road
- 500 Contours (metres)
- Terrace riser
- Creeks / rivers
- Cross section
- WS Sample location
- Reach margin
- Catchment margin

Right Bank
Channel-marginal terrace upstream of Kakapo road bridge is about 10 m above the channel. This discontinuous surface is about 200 m wide adjacent to the bridge. This is a remnant form pinned against the valley side. No upper terraces are evident.

Extent and character of Alluvial flat
Between the stop banks the flats are about 200-300 m wide. The flats would extend well beyond this - to the valley-margin itself - if the stop bank wasn't there. The zone between the stop banks has an almost hummocky surface, with windy secondary channels. This indicates that alluvial flats are readily reworked at high discharge stages. Many abandoned bends of the formerly sinuous Whitestone River are evident.

Degree and character of channel constriction
Alluvial flats are confined by stop banks. Within this area the river has adopted a 'channelized zone' about 80-100 m wide. This gives a ratio of available alluvial flats to active channel zone of around 4:1.

Character and impact of tributary streams
Unnamed right bank tributary forms the downstream margin of Margin Forest reach (GR 099213). This stream, along with two other right bank tributaries upstream of Kakapo road bridge (Fred's Burn and another unnamed tributary with confluences at GR 118240 and 115239 respectively), drain relatively large catchments, but they flow for some distance over the valley flats prior to joining Whitestone River. The low slopes of these tributaries seemingly indicate that while they have transported substantial volumes of material in the past, they are not actively supplying large volumes of material to Whitestone River. The same can probably be said for Lady Burn (confluence at GR 163255) and a series of other small left bank tributaries immediately upstream of the studied reach. An avulsed former course of this sinuous tributary is evident on the left bank alluvial flats.

Surficial geology
Hummocky ridge-like topography in this area seemingly reflects regionally-tilted sedimentary strata and glacially-derived surficial materials. The ridged terrain is comprised primarily of Pliocene-Pleistocene sandstones, siltstones and conglomerates. Outwash deposits form discontinuous remnant terraces pinned several tens of metres above the left bank of Whitestone River.

Vegetation
Valley side/flats : Remants of beech forest; terrace risers have a cover of introduced grasses with scattered manuka (some recently burnt off) and ferns in sheltered locations.

Alluvial flats/Bank/Bars : Grasses, with coprosma, poplars, willows, sweet thorny briar (rosehip), lupins and other exotic weeds.

Land use
Pasture.

Direct human impacts
Primary impacts in this reach are diversion channels at the upstream and downstream ends of the reach. The channelized zone itself is defined by 2-3 m high stop banks. Groynes and willow plantings within stop banks deflect flow towards the channel, serving to protect the stop banks. Kakapo road bridge is protected by rip-rap consisting of angular boulders 1-2 m in width. Various other local, irregular management structures have been emplaced, including mounded gravel banks.

Other comments
The steep upland relief, removal of most terrace materials, and the lack of a regulating lake at its headwaters, have resulted in quite different river responses to those described for the Mararoa. Beyond this, the manner and extent of human modification of the river has resulted in a disequilibrium river style - the Mararoa and Whitestone are quite different systems. Occasional logs are observed in the channelized zone. Local scale variability in bar style, channel definition and accumulations of fine gravel lobes on bars surfaces attest to indirect consequences of the various management strategies carried out in this river reach.

CHANNEL CHARACTERISTICS

Number of channels : Predominantly single-channelled, with occasional channel division of bar surfaces and riffles by chute channels. Very few side channels are evident.

Channel geometry : Relatively high width:depth, with shallow expansive flow spread across the channel. The pool-riffle sequence is disturbed by rip-rap immediately upstream the bridge site, while the bar sequence within the diversion channel has yet to stabilize resulting in an irregular channel geometry.

Sinuosity : Channelized zone is relatively straight, but the channel itself alternates from side to side within this zone with low to moderate sinuosity. No tight bends are observed, as flow is aligned down-valley with only a limited cross-valley component. This channel alignment differs significantly with the pattern of meander loops abandoned following construction of the straighter diversion channels, as evidenced at the upper and lower ends of this reach.

Lateral stability of channel(s) : The channel shifts with relative ease within the channelized zone, with significant exposed active gravel surfaces. However, the flats themselves within the stop banks appear relatively stable with little or no evidence of aggradation. The flat margins are being locally eroded opposite lateral and point bar margins.

Bar type and scale
Alternating lateral bars are dominant at the reach head. These frequently form as extensions of riffles which extend across-channel. Bars are typically up to a few hundred metres long, but are only a few tens of metres wide. These bars appear to be translating downstream rather than migrating laterally, as gravels are funnelled down the channelized zone rather than being dispersed onto the channel-marginal flats. This pattern is not maintained throughout the reach, however, as a series of unit point bars have formed at the head of the diversion channel. These bars are less laterally stable than upstream lateral bars. One of the bends has breached the former right bank, and is now dissected by chute channels at various topographic levels. In this area the active gravel area is significantly wider than upstream (locally up to 100 m). This has mid-channel bar features downstream. The chaotic transition in bar styles over very short distances attests to the disequilibrium nature of this reach. These bars have sheets/lobes of fine gravels over their surface, and appear to represent local sediment accumulation zones.

Bed/Bank character (extent and materials)
Bar surfaces are moderately imbricated at the head of the reach, with discrete lobes of finer grained materials draped across bar surfaces. Banks are typically about 1 m high and grassed. Willows have been planted locally, especially at the margins of channel bends in the diversion channel. Within the lower section of the diversion channel, the banks of the active channel zone are very poorly defined. In some sections the bed of the river is sandy and very loose.

Flow character
Uniform flow with occasional white water over riffles. Flow is too shallow for development of boils and other turbulent structures.

SAMPLE SITE CHARACTERISTICS

Sample number : **WS1** Analysts : AB, BA

Grid reference : Te Anau Sheet (D43), 112233

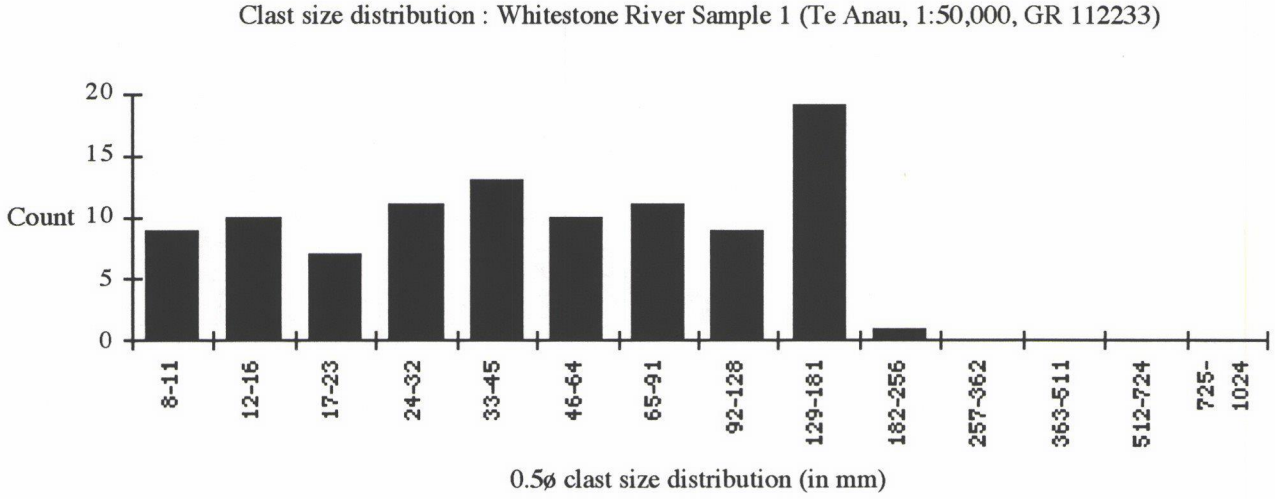
Sample type : 2 x 25 m @ 0.5 m interval

Bar type : Bank-attached bar with a dissected riffle and small mid-channel bar at its head. The bar is esentially composed of a single unit of relatively coarse material. Influxes of finer gravel sheets are evident down-bar. The bar surface has been modified at its tail, associated with the bridge.

Sample position on bar : Extends from the riffle at the bar head, about 5 m from the water's edge.

'Particle characteristics'

0.5ø Clast size frequency Histogram



D95 175 mm;D84 135 mm; D50 45 mm; D16 15 mm; D5 10 mm

Mean 68.76 mm; Sorting 59.52 mm

Sorting : Very poorly sorted, as indicated by the uniform distribution of clasts in the 0.5ø histogram above. A mud drape has recently been washed over much of the bar surface.

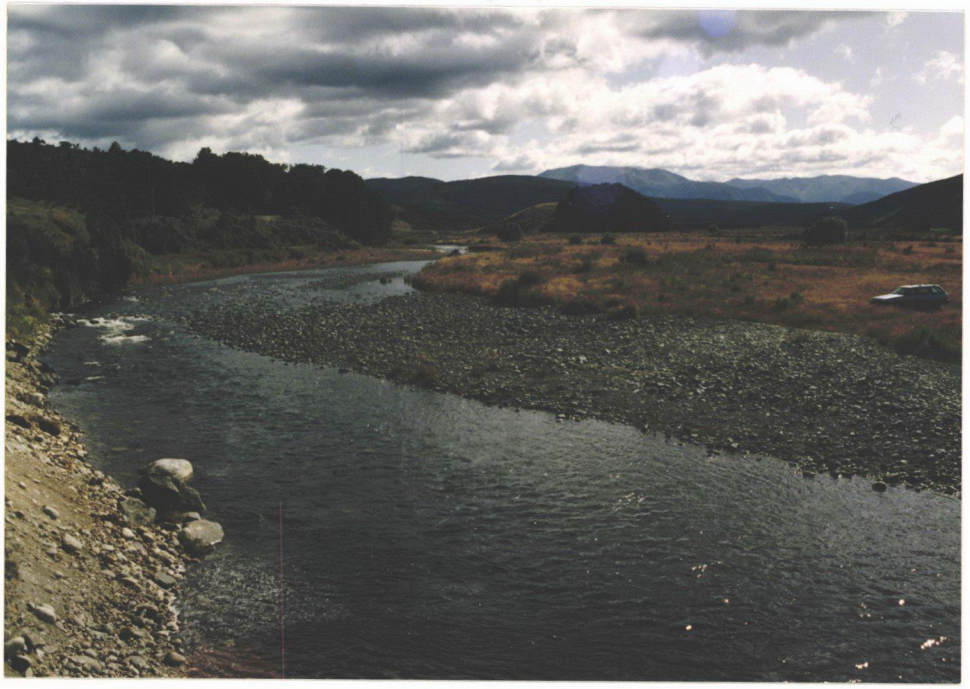
Packing arrangement : Moderately imbricated, well-packed gravels with many partially-buried clasts. A high percentage of fines are trapped beneath these one or two-layer thick, larger clasts. Surface is winnowed down to 10 mm.

Shape : Subrounded to rounded; blocky

Lithology : Mixed.

Other characteristics : No down-sample variation noted. Bar is only sparsely vegetated by grasses and exotic weeds.

Whitestone River Photo 1, Margin Forest Reach
View upstream of Whitestone River, taken from the right bank terrace immediately upstream of Kakapo road bridge. Note the sequence of alternating bars, with flow division around the bar head riffle in mid-photo. Sample site WS1 was located downstream of this riffle. Large boulders have been placed within the channel to inhibit bank erosion and protect the bridge. The fringes of Margin Forest are evident on the left hand side of the photograph.
20.01.93 WH 2/7 Te Anau (D43) 1:50,000, GR 113234



Whitestone River Photo 2, Margin Forest Reach
Sample site WS1, located downstream of a riffle on a lateral bar. Note the eroding terrace on the outside of this broad bend.
20.01.93 WH 1/10 Te Anau (D43) 1:50,000, GR 112238



Whitestone River Photo 3, Margin Forest Reach
View of Margin Forest reach looking downstream from Kakapo road bridge. Note the shallow banks, and the stop bank in front of the buildings on the left hand side of the photo.
20.01.93 WH 1/2 Te Anau (D43) 1:50,000, GR 112234



Whitestone River Photo 4, Margin Forest Reach
Tiered and pole planted willows and boulder rip-rap at the outside of a bend at GR 112232.
20.01.93 WH 2-8 Te Anau (D43) 1:50,000, GR 112232



Whitestone River Photo 5, Margin Forest Reach
Straight diversion channel of Whitestone River a few hundred metres downstream of Kakapo road bridge.
20.01.93 Wh 2-9 Te Anau (D43) 1:50,000, GR 108228



Whitestone River Photo 6, Margin Forest Reach
Less constrained channel conditions beyond the straight diversion channel described above. Active gravel surfaces are locally extensive.
20.01.93 WH 2-10 Te Anau (D43) 1:50,000, GR 105225



Whitestone River Photo 7, Margin Forest Reach
The downstream end of Margin Forest reach. Note the abrupt change in channel character downstream, where the channel adopts a more sinuous course with less active gravel surfaces. This transition is a direct, human-imposed condition associated with river management works. Note also the smaller sinuous thread of a tributary channel on the left bank alluvial flats. Flow direction is from left to right.
16.01.93 GBF1/15



REACH NAME : MOAT CREEK REACH

Geographic description of reach : Moat Creek reach extends from the downstream end of a diversion channel through a reach with cliffs of well-bedded grey-coloured tilted outwash materials to its downstream limit at a laterally constrained river section. The reach is characterized by a well-defined primary channel which has a moderately sinuous thread. Alluvial flats are more extensive than upstream, but active gravel surfaces are proportionally less extensive. Stop bank constraints are less imposing than upstream. Occasional side channels and abandoned channel courses are evident on the alluvial flats.

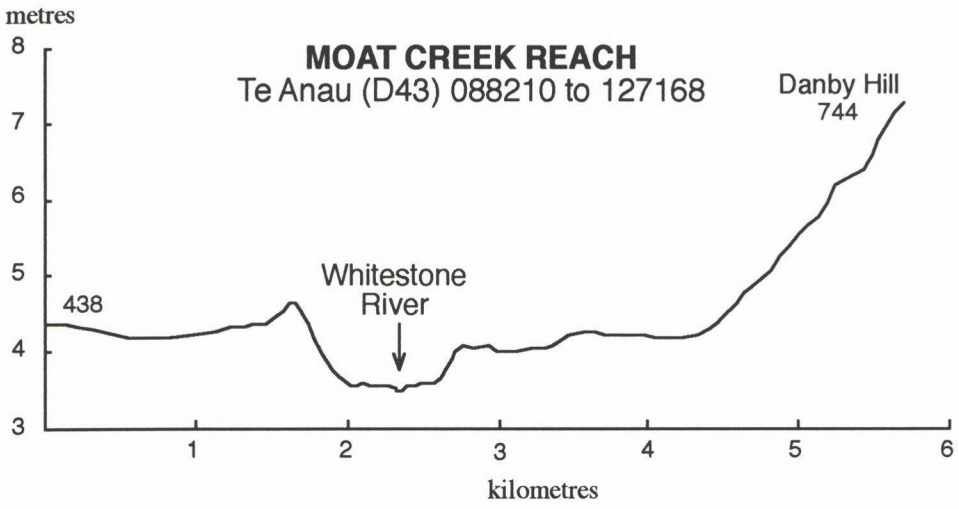
Analysts : GB, AH, BJ Date of Analysis : 20.01.93

Grid co-ordinates of reach : Te Anau (D43) 1:50,000, 099210 to 073178

Air Photos used : Southland Regional Council Survey # 0963, 18.12.91.

VALLEY CHARACTERISTICS

Valley cross section



Valley setting

Broad valley with discontinuous eroding grey outwash(?) cliffs up to 100 m high. These gravels are tilted in some exposures, but appear roughly horizontal in others. This bedrock forms a ridged terrain on the right bank of Whitestone River. Several shallow angle fans are evident on the left bank (e.g. Moat Creek fan at the base of Mount Prospect).

Extent of Valley flat

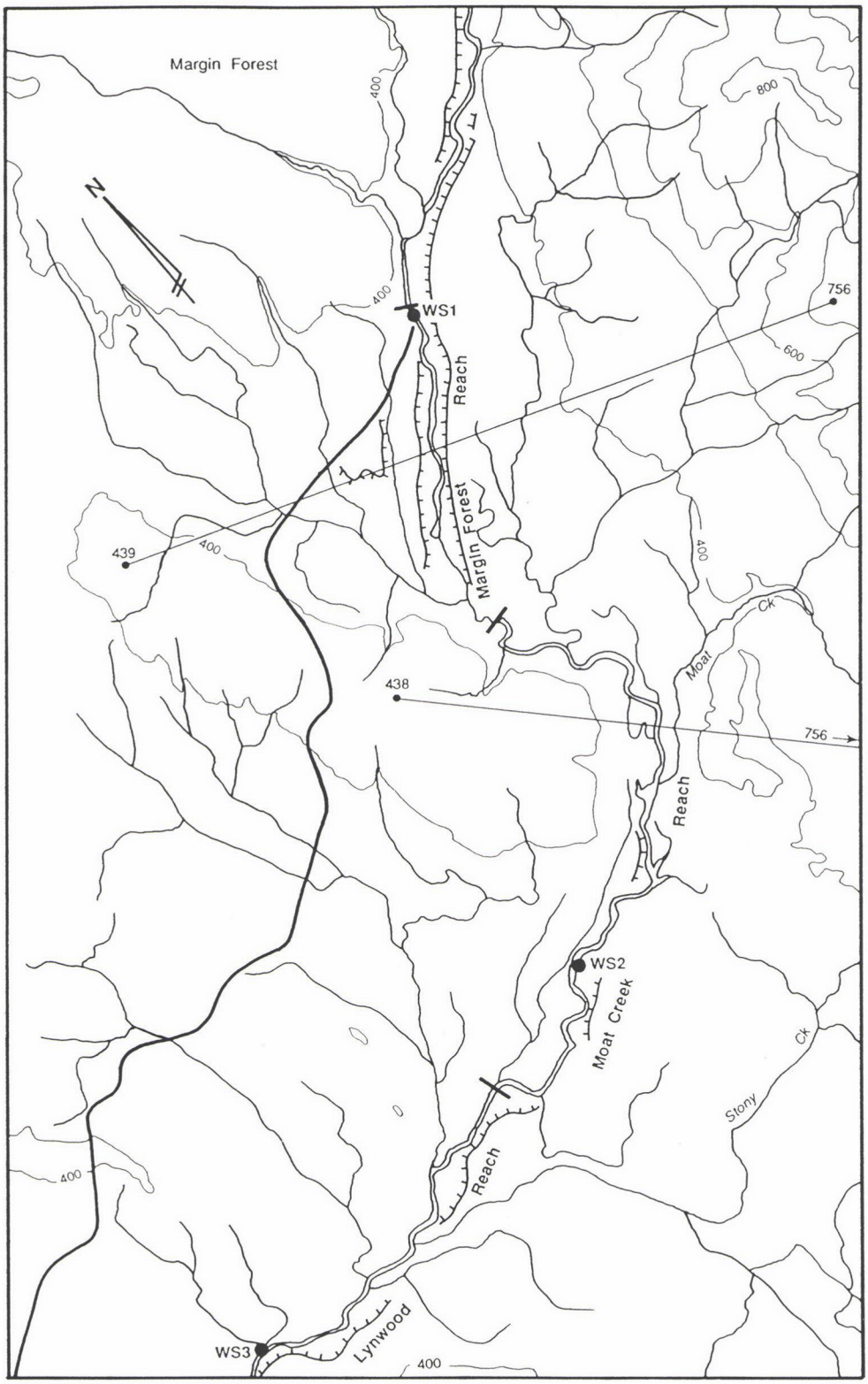
Valley flats narrow from about 1.5 km at the reach head to about 500-800 m adjacent to Moat Creek confluence. Valley flats are constrained by bedrock for about 2 km downstream, but at the downstream end of the reach, adjacent to Talbot Road, the valley broadens once more.

Terrace character

Discontinuous upper terraces are evident on both banks, but these are perched, remnant features. Lower terraces are barely evident. Deposits that made up left bank terraces must have been removed prior to emplacement of the fans.

MARGIN FOREST AND MOAT CREEK REACHES

Te Anau (D43) 1:50,000



0 1 2km

LEGEND

- Road
- 500 — Contours (metres)
- Terrace riser
- Creeks / rivers
- Cross section
- WS — Sample location
- Reach margin
- Catchment margin

Extent and character of Alluvial flat
Alluvial flats are much less constrained than upstream given the general lack of stop banks. Other than a couple of subreaches with stop banks, the channel is able to shift over virtually the entire valley bottom. However, there is no evidence of erosion surfaces at the toes of the left-bank fans. Numerous side channels and abandoned former courses of Whitestone River are evident on the surface of the alluvial flats. At the downstream end of the reach there are abandoned channels on the right bank which still hold water and form duck-shooting ponds.

Degree and character of channel constriction
Although the valley is narrower than upstream, Whitestone River is scarcely confined in Moat Creek reach. However, the channel locally abuts and erodes grey bedrock cliffs. Banks are typically just 1-2 m high. In the narrowest section of the reach, between eroding bedrock cliffs and Moat Creek fan, active gravel surfaces are quite extensive, and there is plenty of evidence for lateral erosion.

Character and impact of tributary streams
Shallow angle fans have formed at the valley margin as the unnamed stream from Mount Prospect and Moat Creek overflow into Whitestone Valley. On the recent air photographs there are few active surfaces evident on these fans. The complete morphology of these fans indicate that they have not been reworked since their most recent fan-shape was derived. The unnamed right-bank tributary at the head of the reach does not appear to have induced any adjustments in channel configuration; rather, this reach transition is associated with widening of the channel-zone associated with the termination of the upstream diversion channel and stop banks. Other than these tributaries, the Whitestone is also joined by a series of drainage ditches, which have only localized impact, if they have any impact at all.

Surficial geology
Regionally-tilted sedimentary strata and glacially-derived surficial materials. The massive cliff face at GR 103199 is a moderately well-bedded grey-coloured outwash(?) unit, up to 100 m high. This has a hummocky upper surface and forms a generally ridged terrain. The exposure is made up of compacted grey-coloured clast-supported gravels, typically ranging in size up to 100 mm, with occasional sandy lenses. This thick sequence of greywacke gravel set in a lightly cemented sandy matrix, with discontinuous sand lenses and some sand and silt beds, is the type section for the Prospect Formation (McKellar, 1973). This Miocene to basal Quaternary formation always occurs beneath the oldest Quaternary till units, and extends along the entire lower course of Whitestone River.

Discontinuous drapes of glacial till and reworked glacially-derived deposits mantle the landscape, with a series of glacial advances evident. A large proportion of these deposits were reworked to form large outwash plains (sandurs) at the downstream margin of ice lobes. Subsequent river incision has effectively flushed these gravels downstream, and only remnant terrace sequences are evident in Moat Creek reach.

Vegetation
Valley side/flats : Dense coprosma (with creepers) and matagary covers the extensive, discontinuous terrace riser. The large size of the matagary indicates that this surface has been stable for some time. The scree slope at the downstream end of the first right bank exposure of grey bedrock cliffs in this reach are covered by large matagary. Compared to upstream, less beech forest is evident.

Alluvial flats/Bank/Bars : Grasses, with coprosma, willows, sweet thorny briar (rosehip), monkey mush (mimulus), hebe (korokimo), wild spaniard, lupins and other exotic weeds cover the channelized zone of this reach.

Land use
Pasture. Pine plantation on the left valley side at the lower end of the reach. Anglers access. The downstream end of this reach is characterized by low-lying ponds along a former abandoned course of the river. These ponds are used for water fowl-hunting with mai mais (e.g. Hacienda Hut).

Direct human impacts
Stop banks are discontinuous along Moat Creek reach and channel modifications are significantly less than upstream. Exceptions include an excavated channel cut-off on a large bend at the head of the reach (GR 104200) and a channel cut-off bend at the downstream end of the reach. Willow plantings have been emplaced to prevent bank erosion in the latter bend and at other locations within-reach. Most drainage ditches on flats have been artificially straightened.

CHANNEL CHARACTERISTICS

Number of channels : Primarily single-channelled, with occasional chute cut-offs.

Channel geometry : Although channels have a moderately high width:depth, the thalweg is much better-defined than upstream. Channel width is variable within-reach, reflecting local human modification and the manner of reworking of active gravel surfaces. In subreaches of dissected point and compound bars channel geometry is much more irregular. At the downstream end of the reach the channel is distinctly narrower.

Sinuosity : Moderate to high, with well-developed bends. Smaller tributaries on the flats also have sinuous outlines. These contrast starkly with straight diversion channels in the upstream and downstream reaches. A dry cut (runner) has been dug to redirect flow in an upper bend (GR 104200) and at the downstream end of the reach. Several abandoned (avulsed) courses of the river are evident on the alluvial flats. The sinuosity of the bends in these abandoned channels is roughly consistent with that of the present channel in this reach.

Lateral stability of channel(s) : The channel is laterally eroding throughout most of the reach. Banks are relatively shallow, and the channel locally abuts aginst bedrock cliffs. Despite this activity, the channel has not reworked Moat Creek and other left bank fans. While this may reflect the presence of a channelized zone on the alluvial flats, it is equally possible that the flats are fairly extensive and it is merely a matter of time before this reworking commences.

Bar type and scale
Active gravel surfaces are primarily restricted to the inside of bends. Moving down-reach, point bars become more dissected, reflecting a more complex history of channel shifting. On down-reach bends the lateral component of channel migration is less pronounced, and there is a greater downstream component to channel movement. The dissected bar at GR 089183 has thick sheets of loose fine gravels at its tail, and a distinct mud drape. The point bar immediately downstream of GR 089193 has a considerably wider active gravel surface. In some instances dissection of riffles at the bar head results in small-scale mid-channel bars. Broader bends are characterized by complex point bar assemblages. Adjacent to some of the abandoned loop sections the bar pattern has yet to stabilize, and the active gravel surfaces and alluvial flats are dissected by channels of various scale, producing compound bar features. Diversion channels at the downstream end of the reach have greatly altered the 'natural' bar type, with development of lateral bars and some sedimentation at the outside of meander bends (possibly reflecting infill following cut-off development).

The extent of active gravel surfaces is quite variable down-reach. Local-scale diversity of bar styles presents a range of difficulties in development of a suitable river management strategy, and also presents a number of implications for the pattern of within-channel aggradation.

Bed/Bank character (extent and materials)
Banks are poorly defined and relatively shallow (< 1 m high). Bank undercutting is common throughout the reach. A riffle at the head of the small diversion channel that cuts off the bend at GR 104200 is aligned towards the inner bank, and is actively eroding the inside of the bend.

Bar surfaces are not especially packed, although occasional imbrication attests to the relatively high flow energy at high discharge stages. Bar surfaces are not winnowed, with mud drapes evident. Sand sheets have accumulated on flats adjacent to the channel, reflecting waning stage deposits from floods.

The bed shows no indication of incision and may actually be aggrading. Conglomeratic gravels from the cemented outwash exposure at the head of the reach are clearly mobile and are actually accumulating on the point bar downstream. Extensive sheets of moderately well sorted gravels (up to 100 mm wide) are noted on compound point bar surfaces within-reach, implying recent aggradation. Local within-channel sedimentation may be inducing reduced channel capacity.

Flow character
Uniform flow with riffles that extend across the entire channel. Occasional deeper pools are noted at the outside of eroding bends. Riffles become less pronounced down-reach. Flow character is more irregular in modified channel subreaches.

SAMPLE SITE CHARACTERISTICS

Sample number : **WS2** Analysts : AB, BA

Grid reference : Te Anau Sheet (D43), 085182

Sample type : 2 x 25 m @ 0.5 m interval

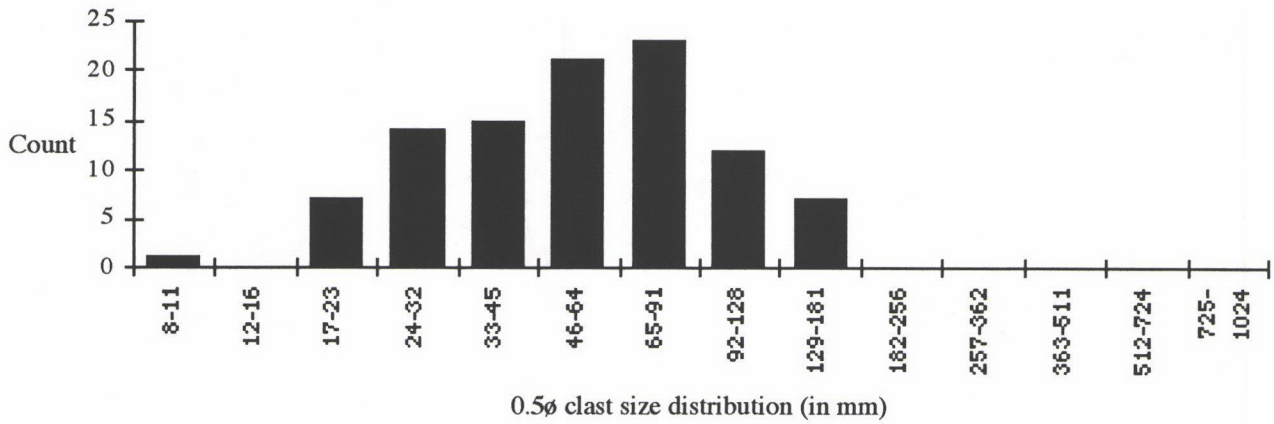
Bar type : Mid-channel bar, with riffles in both channels at the bar head. This bar seems to represent a single depositional unit with a finer grained unit at it's tail.

Sample position on bar : Down-bar from the left-side riffle, 1 and 2 m from the water's edge.

'Particle characteristics'

0.5ø Clast size frequency Histogram

Clast size distribution : Whitestone River Sample 2 (Te Anau, 1:50,000, GR 085182)



D95 135 mm; D84 100 mm; D50 55 mm; D16 25 mm; D5 20 mm

Mean 63.15 mm; Sorting 34.54 mm

Sorting : Moderately poor, with smaller clast-size variation than at sample site WS1.

Packing arrangement : Moderately paved surface, which is generally well packed with few loose clasts. Clasts are moderately imbricated, and winnowed down to 20-25 mm. The surface layer of clasts 1-2 grains thick protects a subsurface of fine muddy-sand matrix.

Shape : Subrounded to rounded; predominantly blocky.

Lithology : Less mixed than sample WS1, with sedimentary rocks more prevalent.

Other characteristics : Sparsely vegetated surface. The smaller clast sizes at this site compared to sample WS1 may simply reflect the greater availability of finer gravels from eroding outwash cliffs.

Whitestone River Photo 8, Moat Creek Reach
Aerial view looking downstream at the transition zone from Margin Forest to Moat Creek reach. The reach limit is at the end of the straightened channel section on the right hand side in mid-photo. Upstream of this point the channel has a well defined channelized zone with a large proportion of active gravel surfaces. Alluvial flats are constrained by stop banks. Moat Creek reach is characterized by a well defined, sinuous channel which locally divides at cut-offs in bends. Moat Creek itself has built a shallow fan of deposits on the left bank of Whitestone River.
16.01.93 GBF 1/14



Whitestone River Photo 9, Moat Creek Reach
View upstream of the upper end of Moat Creek reach. Note the extensive alluvial flats, with minimal terrace preservation, and the well defined meandering single channel.
20.01.93 WH 2-15 Te Anau (D43) 1:50,000, GR 103200



Whitestone River Photo 10, Moat Creek Reach
Eroding cliffs of greywacke gravel set in a lightly cemented matrix, with discontinuous sand lenses and some beds of sand and silt. This is the type section for the Pliocene-Pleistocene Prospect Formation, located near the head of Moat Creek reach.
20.01.93 WH 2-14 Te Anau (D43) 1:50,000, GR 105200



Whitestone River Photo 11, Moat Creek Reach
View downstream from eroding cliffs shown above. The 'chute' channel in the foreground is an artificial cut off, the right bank of which is eroding upstream of the lateral bar in mid photo. Note the different vegetation pattern on the shallow surface of Moat Creek on the extreme right hand of the photo.
20.01.93 WH 2-11 Te Anau (D43) 1:50,000, GR 103200



Whitestone River Photo 12, Moat Creek Reach
Although banks remain relatively shallow in Moat Creek reach, channels are well defined and active gravel surfaces are not abundant. Alluvial flats, however, are extensive. This view shows Whitestone River, looking upstream, 1 km downstream of Moat Creek fan.
20.01.93 WH 2-19 Te Anau (D43) 1:50,000, GR 089183



Whitestone River Photo 13, Moat Creek Reach
View upstream at sample site WS2. Note the local channel division at this site and the shallow, vegetated banks.
20.01.93 WH 1/4 Te Anau (D43) 1:50,000, GR 085182



Whitestone River Photo 14, Moat Creek Reach
Tilted sequences of grey-coloured greywacke gravels in a lightly cemented sandy matrix (Pliocene-Pleistocene Prospect Formation), exposed along the left bank of Whitestone River in Moat Creek reach, immediately downstream of sample site WS2.
20.01.93 WH 2-18 Te Anau (D43) 1:50,000, GR 089183



Whitestone River Photo 15, Moat Creek Reach
Active gravel surfaces become more abundant at the downstream end of Moat Creek reach. Note the tiered willows on the right bank (left hand side of photo), and the diversionary cut-off channel on the right hand side of the photo.
20.01.93 WH 2-20 Te Anau (D43) 1:50,000, GR 078177



Whitestone River Photo 16, Moat Creek Reach
Grey cliffs of the Prospect Formation on the left bank of Whitestone River at the downstream end of Moat Creek reach. Sample site WS2 was located on a small mid-channel bar in the bend on the left hand side of the photograph. Note also the lack of physiographic relief between Whitestone and Mararoa Rivers, and the Takitimu Ranges in the background.
16.01.93 GBF 1/13



Whitestone River Photo 17, Moat Creek Reach
The downstream end of Moat Creek reach. The reach divide to Lynwood reach is located at the head of the artificially straightened channel on the right hand side in mid-photo.
16.01.93 AHF 1/2



REACH NAME : LYNWOOD REACH

Geographic description of reach : Lynwood reach extends from the upstream end of a diversion channel a few kilometres beyond Talbot Road down to Mararoa confluence. Immediately downstream of the diversion channel at the head of the reach, Whitestone River locally abuts against cliffs of well-bedded grey-coloured tilted outwash materials on the right bank. Beyond this point the river flow through a less laterally constrained section down to Mararoa confluence.

The primary feature of Lynwood reach is the degree of human modification of the channel. A series of river engineering works have been implemented at various sites along the reach. In essence these measures have reduced the width of the active channelized zone and imposed a straighter single-channelled configuration. The pattern of bars is highly irregular, and is seemingly in a state of adjustment to the altered channel condition. There is pronounced within-reach local variability in channel character and the nature of the adjacent alluvial flats.

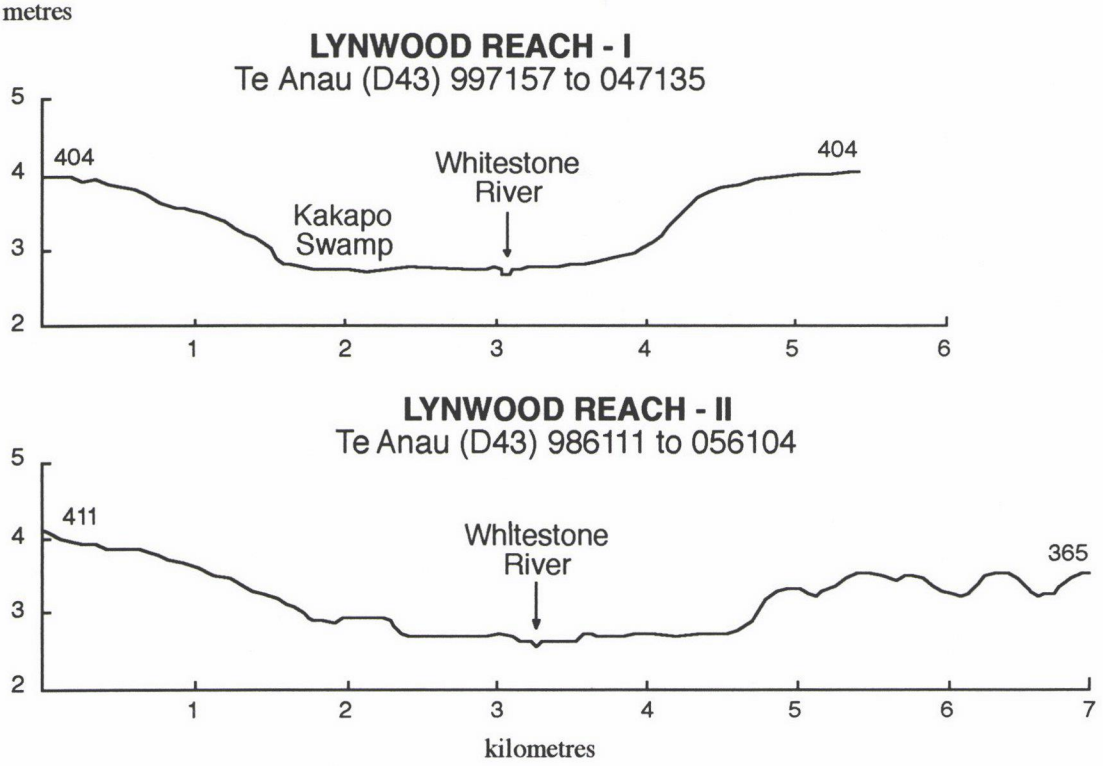
Analysts : GB, AH, BJ Date of Analysis : 20.01.93 and 21.01.93

Grid co-ordinates of reach : Te Anau (D43) 1:50,000, 073178 to 003061 (Mararoa confluence)

Air Photos used : Southland Regional Council Survey # 0963, 18.12.91.

VALLEY CHARACTERISTICS

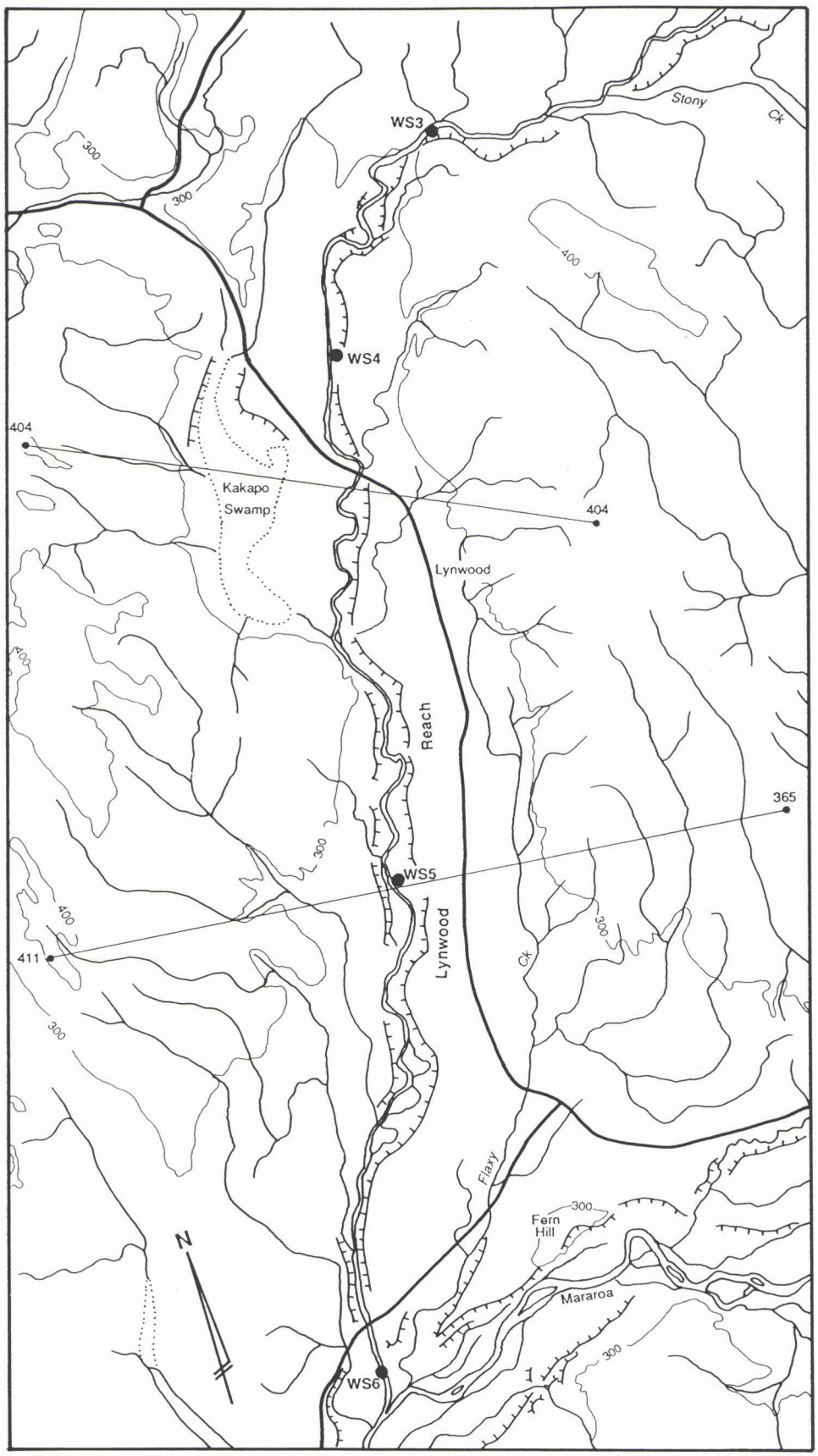
Valley cross section



Valley setting

Broad valley with perched remnant high terraces. Surrounding relief is dominated by hummocky ridges composed of tilted sedimentary strata. Ridges are generally aligned north-south. Weaker, more erodible bedrock layers have been selectively reworked, and form the course of several meltwater channels. Kakapo Swamp infills one of these channels.

LYNWOOD REACH Te Anau (043) 1:50,000



LEGEND

- Road
- 500 — Contours (metres)
- Terrace riser
- Creeks / rivers
- Cross section
- WS — Sample location
- Reach margin
- Catchment margin

Extent of Valley flat
Valley flats are 600-800 m wide at the head of the reach. They widen considerably downstream of the bedrock constraint at GR 046176, and the valley maintains a fairly uniform width of 2-3 km adjacent to the head of Kakapo Swamp. Downstream of this point the valley narrows associated with bedrock constraint on the right bank (The Ramparts). Beyond this point the valley maintains a relatively uniform width of about 1.8 km, down to Mararoa River confluence. Adjacent to the confluence, which is also coincidental with Flaxy Creek, the valley widens to 2.5 km. Shallow angle fans are evident at valley margins.

Terrace character
High perched terraces, about 60-80 m above the present channel position, are generally paired along large sections of the reach. These terraces become much more discontinuous down-reach. Most lower terraces have seemingly been removed. At the head of the reach there is a remnant 4 m terrace. This discontinuous feature is located in a wider section of the valley. Beyond GR 046076 this 4 m high terrace surface has a second right bank terrace about 3 m above it. Both terrace surfaces are distinctly hummocked reflecting the former channel complex of a braidplain. Distinct flights of terraces are notable by their absence, and it is only in the section just upstream of Mararoa confluence that a series of right bank terraces have been preserved at approximately 2, 5, 10 and 18 m above the channel.

Extent of Alluvial flat
Other than the area adjacent to Kakapo Swamp the flats extend to the valley margin. Due to stop bank construction, however, flats are generally no longer active surfaces. A large number of former channel surfaces are evident on these older alluvial flats. At GR 043176, immediately downstream of the confined bedrock area at the head of the reach, the alluvial flats are about 500 m wide, with a stop bank defining a 150 m wide channelized zone. In this channelized zone, the channel is about 20 m wide, whereas in less constrained sub-reaches channel width extends to 40-50 m wide over active gravel surfaces.

Immediately upstream of Te Anau-Mossburn road bridge (GR 026146) the bed is incised 2 m beneath an alluvial flat surface which may now act more as a terrace. Adjacent to Te Anau-Mossburn road bridge the active zone of the alluvial flats is less pronounced. Mid-way between the bridge and the Mararoa confluence (at GR 017109) numerous channel surfaces are evident, most of which are smaller, more sinuous features than the present channel.

Degree and character of channel constriction
Lynwood reach is characterized by a series of channelized sections in which flow is artificially constrained within stop banks. For example, two stop banks at the head of the reach were breached in quick succession in 1991. This prompted extensive channelization works, with a straightened section 800 m long at the head of the reach. The ability of former channels to shift more readily is evident at GR 037174 where old meander scars are apparent on the alluvial flats. Other than in channelized areas, the active channel is able to shift laterally within 150 m wide stop banks. This gives a ratio of alluvial flat width to channel width of approximately 4:1, which is much lower than elsewhere. The channel abuts against bedrock at both the upstream end of the reach and 1.5 km downstream of Te Anau-Mossburn road bridge, adjacent to Kakapo Swamp (GR 019132).

Character and impact of tributary streams
Tributary streams that join Whitestone River in Lynwood reach drain small catchments with limited relief, and exert negligible impact on the character of Whitestone channel. These tributaries are extensively ditched on the alluvial flats, while their headwaters may be incised (e.g. Stony Creek). A small right bank tributary at the head of the reach has a sinuous lower course. Kakapo Swamp drains the largest subcatchment in this reach, but this serves as a sediment/water trap, as the swamp acts as a buffer zone to sediment movement. A series of short right bank tributaries join Whitestone River downstream of Te Anau-Mossburn road bridge. These tributaries, which drain The Ramparts, flow for extensive distances down the alluvial flats prior to joining the Whitestone. The best example of this downstream deflection of flow is represented by Flaxy Creek, a left bank tributary which flow along the valley flats of Whitestone River from Lynwood and actually joins the Mararoa River 250 metres upstream of Whitestone-Mararoa confluence.

Surficial geology
Regionally-tilted sedimentary strata comprise thick sequences of greywacke gravel set in a lightly cemented sandy matrix, with discontinuous sand lenses and some sand and silt beds. These are part of the Miocene to basal Quaternary Prospect Formation (McKellar, 1973), which always occurs beneath the oldest Quaternary till units, and extends along the entire lower course of Whitestone River.

Discontinuous drapes of glacial till and reworked glacially-derived deposits mantle the landscape, with a series of glacial advances evident. A large proportion of these deposits were reworked to form large outwash plains (sandurs) at the downstream margin of ice lobes. Subsequent river incision has effectively flushed these gravels downstream, and only remnant terrace sequences are evident in Lynwood reach. At least four meltwater streams draining the Te Anau ice lobe combined along the lower course of Whitestone River. A series of moraines marking glacial advances, and their subsequent reworking by meltwater streams, has resulted in a landscape with a hummocky surface in which ridges are generally north-south (e.g. The Ramparts).

Vegetation

Valley side/flats : Pine trees on terrace surfaces at the reach head only act as windbreaks or shelter belts on ridge tops down-reach. No beech are evident. Coprosma, matagary, remnant tussock, and grasses are dominant.

Alluvial flats/Bank/Bars : Well established willows, with localized recent pole-plantings (e.g. at head of reach). Grasses, exotic weeds and lupins are dominant, with occasional ferns on banks.

Land use

Pasture and deer farms. Pine plantations. Gravel extraction. Rural water supply pump (GR 043174).

Direct human impacts

Stop banks have been constructed along the channel throughout the reach. Moving down-reach, the following management practices were observed :

The head of the reach is characterized by various channelization practices. Between stop banks there are series of dry cuts and diversion channels. Groynes have been constructed at the head of diversion channels and perpendicular to the main channel at the outside of bends (e.g. GR 028167) amongst 10 year old willows. Drainage ditches in tributaries and on flats have been artificially straightened, while layered willow plantings, in conjunction with pole planting of willows, have been implemented to prevent bank erosion in various bends.

Heaps of willow pole-planting has taken place downstream of the straightened channel at the head of the reach. Both bends downstream of this point have dry cuts on them. Beyond these bends the channel outline has been artificially straightened almost as far as the Te Anau-Mossburn road bridge.

Immediately downstream of a rip-rapped bend at GR 028167 the channel outline is adjusting to its imposed straightening. Localized pole plantings of willows and bulldozed gravel mounds are evident.

Upstream of the Te Anau-Mossburn road bridge (GR 025153) gravels have been extracted from bar/flat surfaces. Extraction equipment has locally compacted gravel surfaces.

At the Te Anau-Mossburn road bridge itself (GR 026146) the channel has been constricted by rip rap.

Beyond the bridge, at GR 024144, extensive volumes of gravel have been removed from a bank-attached compound bar for use in the cement works. Immediately downstream of the gravel extraction works there is a major diversion channel of rectangular cross-sectional geometry (between GR 025143 and 024140). Incipient lateral bars are evident within this channel. Extensive willow plantings are evident down to GR 019132. An older diversion channel is evident upstream of this point.

At GR 024124 there is an abandoned meander loop, with extensive willows planted on its concave bank. The present channel short circuits this old loop. Similarly, at GR 023118 the channel has been diverted away from its old course, and the old course itself is now planted with willows.

At GR 022117 substantial willows at the outside of a bend have been cut and tied-in to stabilize the bank. 'Webb's' Diversion channel at GR 019116 has artificially realigned the channel towards the left bank stop-bank (i.e. away from the meander loop on the right bank). At GR 017109 'Stephenson's' Diversion channel has cut-off a broad right-bank meander. Layered willows have been emplaced at the downstream end.

Just upstream of Hillside-Manapouri road bridge (GR 005073) gravel extraction has taken place on a large bank-attached compound bar to take pressure off the outside of the bend by increasing channel capacity. Willows have been cut and tied-in along the outside of the bend to inhibit erosion.

Other comments

It appears that channel works in this reach are driven by a range of motives that are locally emplaced with little regard for the overall picture of channel movement in Lynwood reach. Emplacement of a series of piecemeal river management measures has resulted in a channel condition which is out-of-phase with flow and sediment characteristics. The river is now in a semi-permanent state of adjustment. For example, beyond the end of the channelized zone at the head of the reach (GR 044174) there is a large gravel accumulation on a dissected point bar surface, with a couple of small diagonal channels. These straightened subreaches are in a state of adjustment in which an equilibrium cross-sectional geometry has yet to be attained. Their rectangular form acts to convey finer gravels through them relatively efficiently. This throughput of gravels associated with increased competency results in deposition downstream. The outer (willowed) bank was dry cut in 1992. Tiered willows now line the banks. Willows on the left bank at GR 043175 were actually planted pre-channelization - the plan was to protect the rural pumping station behind them, as the willows serve to stabilize banks. Many tiered willow plantings are evident. In some instances the pole planting itself may lead to bank destabilization (e.g. on right bank downstream of the dry cut at the head of the reach).

CHANNEL CHARACTERISTICS

Number of channels : Whitestone River is generally single-channelled in Lynwood reach, though a number of secondary channels may be evident as the channel divides over dissected active gravel surfaces (especially in bends). A few kilometres above Hillside-Manapouri Road bridge, between GR 016096 and 008083, there are a number of distinct secondary channels of low W:D and irregular sinuosity. These side channels act as distributary channels.

Channel geometry : In recently constrained (artificial) channels the channel typically has a rectangular cross-section, with uniform w/d. These locally efficient, deeper-channelled subreaches alternate with sections of irregular cross-sectional channel geometry and occasional complex, unstable (partially reworked) active gravel zones. Riffle spacing is non-uniform. In many instances the channel is presently adjusting its geometry to its modified configuration.

Sinuosity : In general the active channel zone is a series of straight sections. Within this zone, the main channel is generally of low sinuosity. Broad bends alternate with straight diversion channels. Channel works have clearly served to reduce the 'natural' sinuosity of the river. Within straightened reaches the channel alternates from side to side. Many meander scars on the alluvial flats beyond the stop banks attest to the much greater sinuosity of Whitestone River in the past. There is effectively only one subreach that is equivalent to this former channel alignment, namely the sequence of bends 2 km upstream of Te Anau-Mossburn road bridge (between GR 038174 and 028167). Lateral adjustment of this sequence of bends is now controlled by rip-rap and planted willows.

Lateral stability of channel(s) : The degree of lateral stability is locally variable, contingent on the nature of channel modification and channel position relative to the stop banks. Moving down-reach the following characteristics were observed :

At the head of the reach local instabilities are evidenced by reworking of flats, and some willows are now in mid-channel. Active, dissected gravel surfaces are several tens of metres wide.

Downstream of GR 043175 the channel abuts against the older 4 m terrace which has a highly dissected surface. Substantial willows on the left bank (along the fenceline) suggest relative stability through this reach.

At GR 028167 the channel is laterally unstable within stop banks and is highly irregular down-reach.

At GR 022117, roughly mid-way between road bridges, the channel condition is clearly imposed, although there is plenty of evidence to show significant channel adjustments in the past, with abandoned channels and irregular topography of the alluvial flats.

The pronounced local instability of the channel is demonstrated at GR 019106, where a meander loop has been abandoned and the channel has realigned down a former course. At the this point the active gravel surface is about 80 m wide, as the loop infills with finer gravels and sand lenses.

At GR 016096 the outside of a bend has either been abandoned or the channel has been forcibly shifted.

Bar type and scale

Bar types in Lynwood reach do not conform to text-book notions of bar development and downstream pattern, as human modification in a series of channel works has greatly altered channel alignment and geometry. The local availability of materials and the extent of active gravel surfaces, set in the context of upstream channel alignment and position of stop banks, determine on-going channel adjustments in bar configuration.

In the straight channelized subreach at the head of Lynwood reach there is early stage development of alternate bars. Immediately downstream of this short channel (at GR 043175) there is a complex gravel assemblage with no characteristic morphology. This dissected bar complex has loose lobes of fine gravel sheets atop. These well-sorted sheets form a new bar platform. A sand dune-field was observed immediately downstream.

At GR 043176 there is a chaotic assemblage of bars which have not had sufficient time to stabilize into a predictable downstream pattern. Incipient lateral bars in a diversion channel are transitional downstream to dissected active gravel surfaces. The latter comprise reworked lateral bars, small mid-channel features, and extensive bar platforms on point bars. Individual depositional units that make up the complex bar surfaces are of uniform character, but the assemblage of units is itself irregular, such that the overall grain size distribution is distorted. Abundant fine gravels have exceeded channel capacity, with consequent aggradation of chaotic misplaced bars. These disrupt low-stage flow direction, inducing localized erosion in places that would not be expected.

At the entrance to a bend at GR 037173, a mid-channel bar is coincident with a riffle, reflecting local oversteepening of the bed. This bar has a cluster of coarser gravels at its downstream end (i.e. local-scale redistribution of gravels is irregular). Dry-cut channels adjacent to the highly-dissected point bar immediately downstream (GR 034168) are no longer dry. This bar has a thick sheet of fine gravels at its tail.

In the bend at GR 032167, a fine gravel sheet forms a mid-channel unit adjacent to the point bar head. This has redirected the thalweg towards the outside of the bend, upstream of the apex. Opposite the bar head (in the misplaced erosion zone) are golden willows. Rip-rap boulders have been positioned opposite the bend apex, with more layered golden willows downstream.

Alternating point and lateral bars at GR 028167 are transitional downstream to chaotic bar assemblages with bank-attached and mid-channel compound features. Adjacent alluvial flats are largely reworked.

Upstream of Te Anau-Mossburn road bridge at GR 026146 is a large bank-attached compound bar that is being used as a source for gravel extraction.

Incipient lateral bars are forming in the diversion channel downstream of the gravel extraction site at GR 025143, downstream of Te Anau-Mossburn road bridge. The pattern of lateral bars is moderately well-established in some diversion channels downstream.

The bend at GR 022117 has a recent gravel sheet (b max 150 mm) with discrete finer gravel/sand lenses at the outside of the bend, but no point bar on the convex slope. This local instability has resulted in incipient lateral bar development downstream (i.e. immediately upstream of Webb's diversion channel).

Downstream of Stevenson's divrsion channel (GR 017109) is a complex, highly dissected mid-channel compound bar. This has formed in association with the reduction in energy as flow diverges downstream of a straightened channel.

At GR 016096 a compound point bar on the inside of a bend is transitional downstream to a mid-channel bar on a dissected riffle, with a lateral bar beyond.

By GR 008083 a distinct transition in bar type is noted, as bars now demonstrate a tendency to migrate downstream more than the lateral migration pattern demonstrated upstream. Mid-channel and longitudinal bars are especially evident, and extend beyond Hillside-Manapouri road bridge, possibly indicating that this reach is a more efficient through-put subreach.

Bed/Bank character (extent and materials)

Other than when the channel abuts locally against stop banks, the banks are shallow (< 1 m) and locally undercut grassed surfaces. Channel bed conditions have been greatly altered by channel works, and the subsequent redistribution of gravels.

Upstream of the cliff-face near the head of the reach (GR 066177), the right bank of the channel is locally undercutting, with a 1 m high cut.

Downstream of the channelized section at GR 043175, early-stage lateral bars have developed. Immediately downstream of this actively reworked zone there is an extensive, highly dissected complex of fine gravels within a series of broad bends (GR 034169). This unstable area has a series of willow plantings of different ages.

The broad bend at GR 043176 is highly active, with abundant mobile gravel sheets composed of small gravels. These are relatively well-sorted, with finer gravel/sand drapes. Larger clasts are notably absent, probably in response to material availability associated with terrace removal and the aggradational regime of the channel.

The bank-attached compound bar at GR 027165 has a poorly sorted surface with moderately packed gravels and occasional clasts up to 250 mm wide. This unit is distinctly coarser than active gravel sheets which are presently moving through the system (and comprise present riffles). This coarser unit may represent the reworked pavement of a former channel bed.

At GR 025153 the bank is actively eroding around planted willows.

Just upstream of Te Anau-Mossburn road bridge there is 0.7 m sands atop shallow banks. At GR 026147 a break is evident in the left bank stop bank, although a larger stop bank is noted behind the channel-marginal bank.

At GR 022117 localized erosion on the inside of a bend indicates that within-channel sedimentation is destabilizing the bed configuration.

Bed materials at GR 016096 are deficient of the finer gravel sheets observed upstream. However, this is only a localized phenomenon, as sheets of finer gravels are evident once more at GR 008083.

Adjacent to the bridge of Hillside-Manapouri Road (GR 004069), occasional large white boulders and large clasts of other lithologies form a basal pavement on the channel. Large sheets of finer clasts (up to 100 mm wide) are clearly highly active atop this pavement.

Flow character

Flow is uniform at the head of the reach. The riffle and pool spacing is irregular, associated with the history of gravel reworking and the chaotic sequence of gravel bar assemblages. Gravel sheets attest to planar flow conditions during higher discharge stages. Dune surfaces are evident downstream of the bend apex of a point bar at GR 043175.

SAMPLE SITE CHARACTERISTICS

Sample number : **WS3** Analysts : AB, BA

Grid reference : Te Anau Sheet (D43), 042175

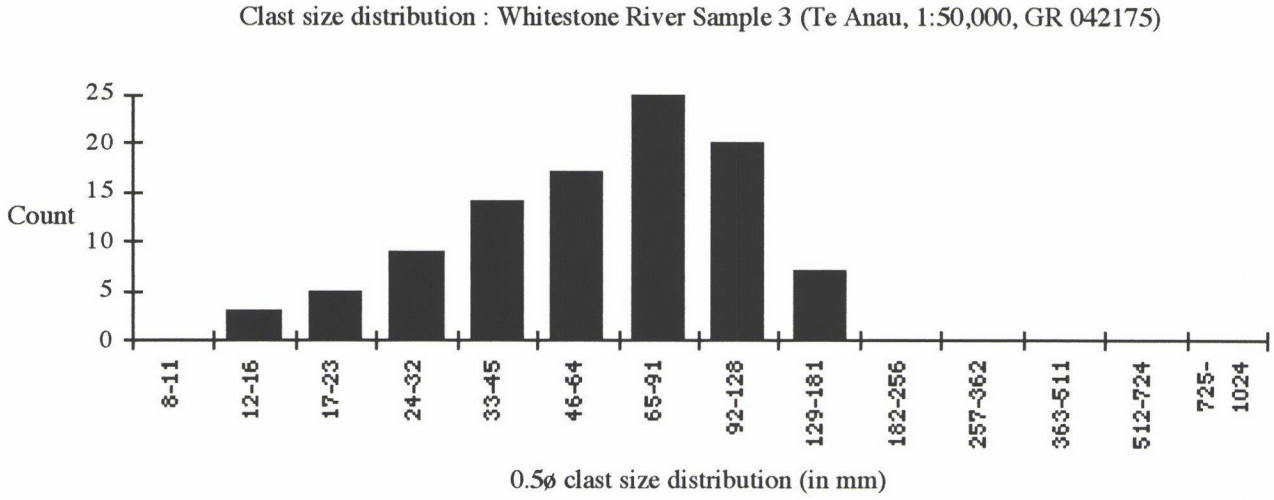
Sample type : 2 x 25 m @ 0.5 m interval

Bar type : Point bar. A riffle at the bar head is dissected at high flow stages. Fine gravel/sand units have accumulated at the bar margin and tail.

Sample position on bar : Downstream from the riffle, along the middle of the bar. Transects positioned about seven and 5 m from the water's edge.

'Particle characteristics'

0.5ø Clast size frequency Histogram



D95 135 mm; D84 110 mm; D50 65 mm; D16 30 mm; D5 20 mm

Mean 70.65 mm; Sorting 36.21 mm

Sorting : Moderately poorly sorted.

Packing arrangement : Paved, with a well-packed, regular surface. Few loose clasts. Moderate to high degree of imbrication. Winnowed down to 20 mm.

Shape : Subrounded to rounded; blocky with an increasig proportion of blades.

Lithology : More mixed population than upstream.

Other characteristics : No internal gradation noted. Bar surface is unvegetated. Some micortopography is noted, as depressions have formed around organic debris. Two distinct banks noted, the first is 0.5 m high and delimits the bar from the floodplain, the second 1 m high bank segregates coarse and fine gravel segments adjacent to the water's edge

Sample number : **WS4** Analysts : AB, BA

Grid reference : Te Anau Sheet (D43), 026157

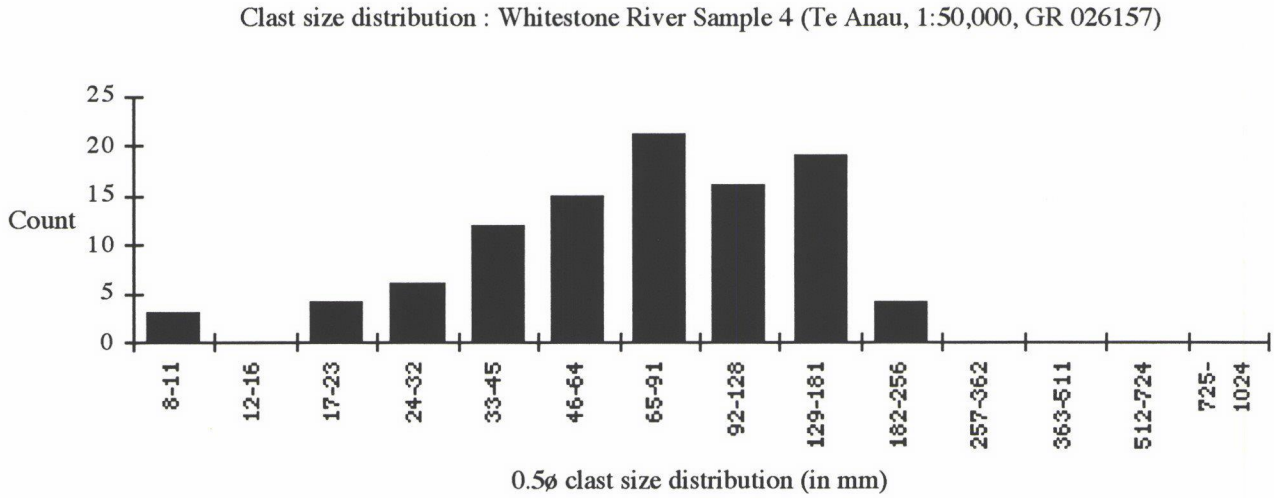
Sample type : 2 x 25 m @ 0.5 m interval

Bar type : Point bar. Continuous with a riffle at its upstream end. The bar surface has an assemblage of down-bar aligned depositional units, with a well-defined chute channel. Many lenses of coarse/fine gravels are evident.

Sample position on bar : In riffle at upstream end of bar. Transects were taken 7 and 5 m from the water's edge.

'Particle characteristics'

0.5ø Clast size frequency Histogram



D95 170 mm; D84 140 mm; D50 75 mm; D16 35 mm; D5 20 mm

Mean 85.7 mm; Sorting 48.97 mm

Sorting : Poorly sorted.

Packing arrangement : No paving or imbrication in sampled area, but finer unit further downstream on the bar is quite well paved and imbricated. Surface is quite well packed, with a rough microtopography. The percentage of loose gravels is greater than other samples taken along Whitestone River, but is still not very high.

Shape : Very blocky; subangular to subrounded.

Lithology : Mixed

Other characteristics : Vegetation is sparse, and restricted to a few primary colonizers. Bar surface appears to be a unit which has been recently reworked. Margins of depositional units are gradational rather than sharply defined.

Sample number : **WS5** Analysts : AB, BA

Grid reference : Te Anau Sheet (D43), 018107

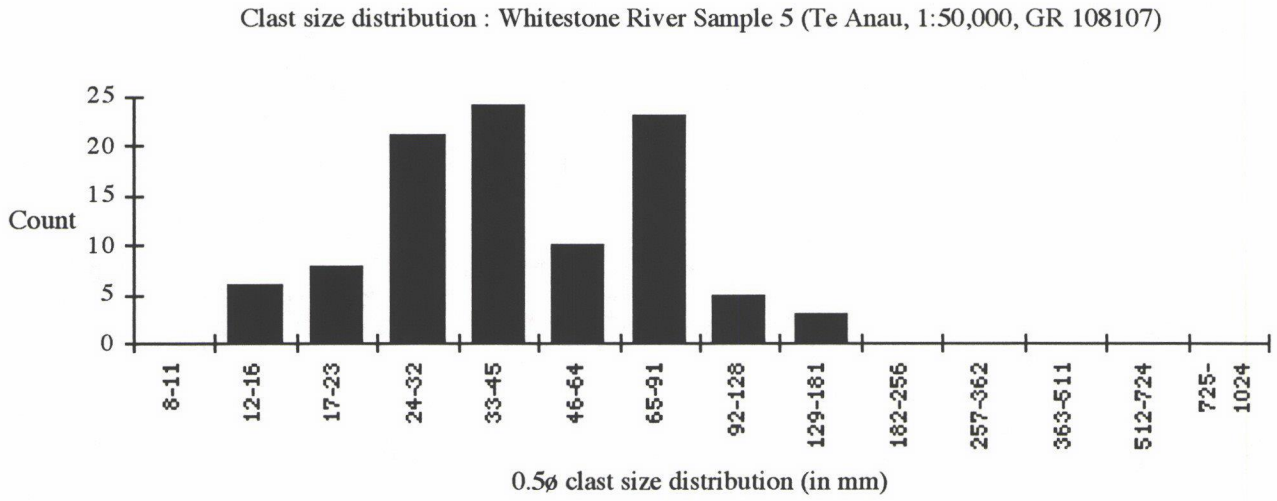
Sample type : 2 x 25 m @ 0.5 m interval

Bar type : Point bar formed in an old avulsed channel (or flood chute). The bar surface has a fairly complex assemblage of depositional units, with an 'alternating' sequence of coarse and fine units aligned down-bar. Some microtopography is evident, associated with organic debris.

Sample position on bar : Bar head samples, 3 and 7 m from the water's edge.

'Particle characteristics'

0.5ø Clast size frequency Histogram



D95 100 mm; D84 80 mm; D50 45 mm; D16 25 mm; D5 15 mm

Mean 51.25 mm; Sorting 30.44 mm

Sorting : Moderately sorted, with some well-sorted fine gravel lenses.

Packing arrangement : Packed, regular surface, with finer gravels especially well-paved. A distinct finer-grained unit is evident beneath a 2-3 clast thick veneer..The bar surface is moderately imbricated, with few loose gravels. Winnowed down to 15 mm.

Shape : Blocky; subangular to subrounded.

Lithology : Mixed, with relatively high proportion of sedimentary-derived clasts.

Other characteristics : Very sparse vegetation, with occasional lupins, thistles. Gravels at sample site are very similar in character to those evident in the eroding right bank. Bulldozers have recently been through this area of the river bed.

Sample number : **WS6** Analysts : AB, BA

Grid reference : Te Anau Sheet (D43), 1:50,000, 005064

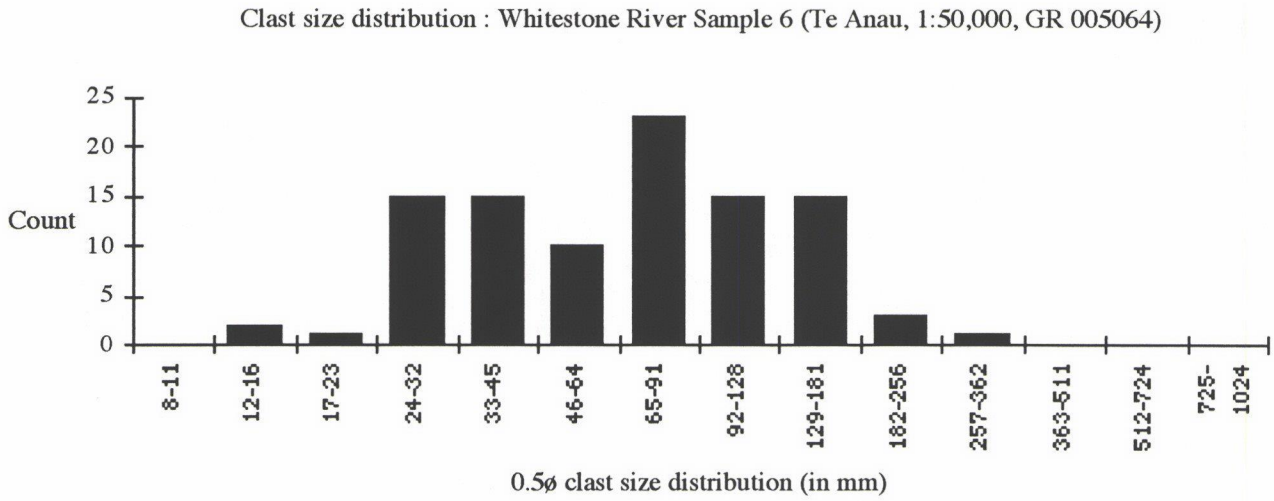
Sample type : 2 x 25 m @ 0.5 m interval

Bar type : Point bar immediately downstream of junction of two braid channels. Distinct riffle at the bar head. This bar has a relatively uniform surface other than a raised finer-grained vegetated surface at the bar margin.

Sample position on bar : Downstream of the riffle adjacent to the left bank at the head of the bar. Transects located 9 and 7 m from the water's edge.

'Particle characteristics'

0.5ø Clast size frequency Histogram



D95 175 mm; D84 130 mm; D50 70 mm; D16 30 mm; D5 25 mm

Mean 80.15 mm; Sorting 50.21 mm

Sorting : Poor. Note the spread in the histogram above.

Packing arrangement : No paving in the sampled area, but paving evident elsewhere on the bar (especially in the finer gravels fraction). Moderately packed, regular surface, with few loose clasts. High proportion of finer gravels beneath 1-2 clast-thick layer. Low to moderate imbrication. Winnowed down to 10 mm.

Shape : Blocky; subrounded to rounded.

Lithology : Mixed, with increased proportion of white crystalline rock and conglomerates.

Other characteristics : No vegetation. Upstream of the sample site the channel bed has been considerably disturbed by gravel extraction. The large proportion of fines on the channel bed adjacent to the sample site may reflect this disturbance. Alternatively, these fine-grained deposits may reflect backing-up of suspended load sediments upstream of Mararoa confluence.

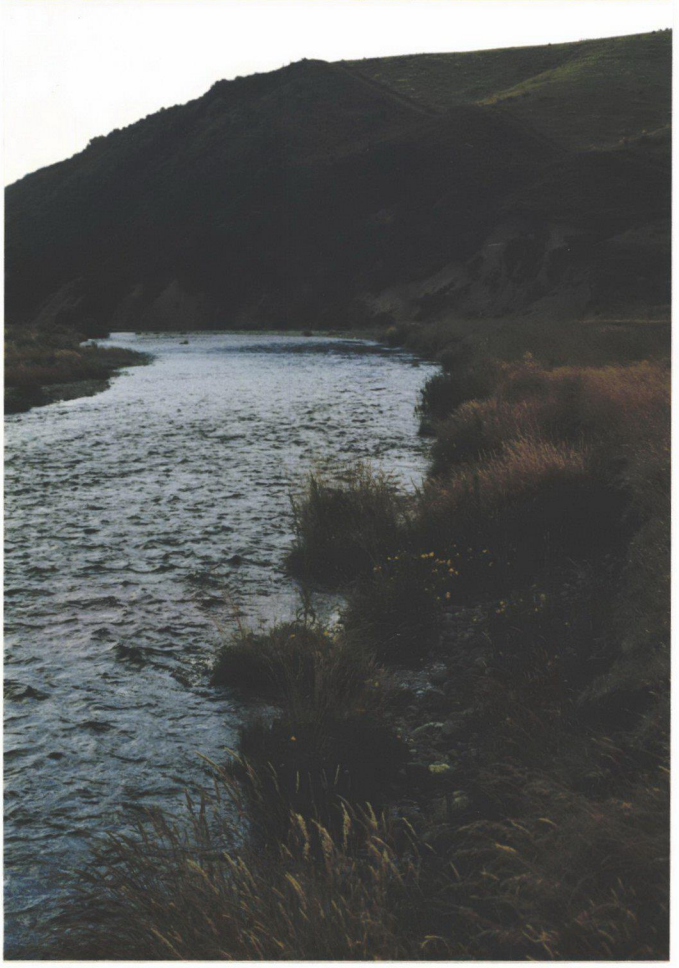
Whitestone River Photo 18, Lynwood Reach
View upstream at the head of the artificially straightened channel that marks the upstream limit of Lynwood reach.
20.01.93 WH 2-22 Te Anau (D43) 1:50,000, GR 073178



Whitestone River Photo 19, Lynwood Reach
View downstream showing the artificially straightened channel at the head of Lynwood reach.
20.01.93 WH 2-23 Te Anau (D43) 1:50,000, GR 073178



Whitestone River Photo 20, Lynwood Reach
Eroding cliffs at the downstream end of the artificially straightened channel at the head of Lynwood reach.
20.01.93 WH 2-24 Te Anau (D43) 1:50,000, GR 068177



Whitestone River Photo 21, Lynwood Reach
Within-channel sedimentation at the downstream end of the artificially straightened channel at the head of Lynwood reach. Note channel division over the shallow riffle and the willow in the deepest part of the channel.
20.01.93 WH 2-25 Te Anau (D43) 1:50,000, GR 068177



Whitestone River Photo 22, Lynwood Reach
The upstream end of Lynwood reach. Note the highly irregular and modified channel pattern, with artificially straightened segments, sections with alternating bars, areas of within-channel sedimenation, and different styles of side channel incision of alluvial flats. These various sections do not form a well defined or characteristic downstream sequence. Flow is from left to right.
16.01.93 GBF 1/12



Whitestone River Photo 23, Lynwood Reach
Shallow, poorly defined channel of Whitestone River, viewed upstream from sample site WS3. Photograph is taken from the bend 1.5 cm above the white building on the upper photo.
20.01.93 WH 1-9 Te Anau (D43) 1:50,000, GR 042175



Whitestone River Photo 24, Lynwood Reach
Sample site WS3, looking upstream. This is a bank-attached bar in a sequence of alternating features. Note the irregular distribution of clasts and jumbled surface on the bar.
20.01.93 WH 1/16 Te Anau (D43) 1:50,000, GR 042175



Whitestone River Photo 25, Lynwood Reach
View downstream from sample site WS3. Note the sand drape and pioneer vegetation on the bar surface, and the willows planted at the outside of the bend.
20.01.93 WH 1/7 Te Anau (D43) 1:50,000, GR 042175



Whitestone River Photo 26, Lynwood Reach
Sequence of well-developed, dissected bends 2 km upstream of Te Anau-Mossburn road bridge in Lynwood reach.
16.01.93 GBF 1/10



Whitestone River Photo 27, Lynwood Reach
Bank erosion protection works on the bend in the middle of the upper photo. Note the planted willows and rip-rap at the outside of the bend in mid-photo.
21.01.93 WH 1-21 Te Anau (D43) 1:50,000, GR 032167



Whitestone River Photo 28, Lynwood Reach
Sample site WS4, looking upstream. Note the poor channel definition in this highly modified reach.
20.01.93 WH 1-10 Te Anau (D43) 1:50,000, GR 026157



Whitestone River Photo 29, Lynwood Reach
Lynwood reach of Whitestone River, immediately upstream of Te Anau-Mossburn road bridge. The channel is greatly modified in this subreach, and presently demonstrates a sequence of alternating lateral bars. Gravel extraction takes place on the bar in mid-photo.
16.01.93 GBF 1/9



Whitestone River Photo 30, Lynwood Reach
Highly dissected compound point bar immediately downstream of Te Anau-Mossburn road bridge. This is a major source of gravels for the adjacent cement works.
16.01.93 GBF 1/7



Whitestone River Photo 31, Lynwood Reach
The greatly modified channel of Whitestone River immediately downstream of Te Anau-Mossburn road bridge.
21.01.93 WH 1-28 Te Anau (D43) 1:50,000, GR 026146



Whitestone River Photo 32, Lynwood Reach
Whitestone River downstream of Te Anau-Mossburn road bridge. Note the broad sweeping sequence of bends. This configuration has been greatly modified by a series of straightened reaches.
16.01.93 GBR 1/8



Whitestone River Photo 33, Lynwood Reach
View upstream of one of the broad sweeping bends of Whitestone River downstream of Te Anau-Mossburn road bridge. The channel appears to have adopted a more sinuous course inset within the broad sweeping bend, accounting for the gravel bar in the foreground which has accumulated at the outside of the broad bend.
21.01.93 WH 1-30 Te Anau (D43) 1:50,000, GR 022117



Whitestone River Photo 34, Lynwood Reach
The modified, straightened course of Whitestone River between Te Anau-Mossburn road bridge and Hillside-Manapouri road bridge. Flow is from left to right.
16.01.93 GBF 1/6



Whitestone River Photo 35, Lynwood Reach
The chaotic gravel surface in the disturbed channel section of Whitestone River. This photograph records the view downstream of the bar complex (4 cm from the right margin of the upper photograph).
21.01.93 WH 1-33 Te Anau (D43) 1:50,000, GR 017109



Whitestone River Photo 36, Lynwood Reach
View upstream at sample site WS5.
20.01.93 WH 1-13 Te Anau (D43) 1:50,000, GR 018107



Whitestone River Photo 37, Lynwood Reach
Highly irregular channel geometry downstream of sample site WS5. Note the meandering bank and the large number of clumps of organic debris in the channel and on bar surfaces.
20.01.93 WH 1/14 Te Anau (D43) 1:50,000, GR 018107



Whitestone River Photo 38, Lynwood Reach
View downstream showing the highly disrupted channel configuration downstream of Webb's and Stephenson's diversion channels.
21.01.93 WH 1-35 Te Anau (D43) 1:50,000, GR 008083



Whitestone River Photo River 39, Lynwood Reach
View of Whitestone River upstream from Hillside-Manapouri road bridge. The large compound point bar in the background is used for gravel extraction. Note the occasional large white boulders within the channel.
21.01.93 WH 1-36 Te Anau (D43) 1:50,000, GR 004069



Whitestone River Photo 40, Lynwood Reach
View of Whitestone River downstream of Hillside-Manapouri road bridge. Note the extensive within-channel sedimentation. This large bar is composed primarily of fine (fist-sized) gravels.
21.01.93 AO 1/00 Te Anau (D43) 1:50,000, GR 005069



Whitestone River Photo 41, Lynwood Reach
View looking upstream at sample site WS6. Note the highly jumbled, poorly sorted bar surface.
20.01.93 WH 1/16 Te Anau (D43) 1:50,000, GR 005064



Whitestone River Photo 42, Lynwood Reach
Whitestone River downstream of sample site WS6, a few hundred metres upstream of Mararoa River confluence. Note the distinct sheet of fine gravels at the tail of the bank-attached bar in the foreground.
20.01.93 WH 1-17 Te Anau (D43) 1:50,000, GR 005064

