APPENDIX 1 - E-Mail from Delta Utility Services

From: Paul Johnson <paul.johnson~del.co.nz
Date: 2002/03/26 Tue PM 02:12:09 GMT+12:00
To: "'kengo~xtra.co.nz"' <kengo~xtra. co .nz>
CC: Niel Frear <nielf@del.co.nz

Ken,

Eased on DEL policy and some long term scenarios the following may be of use.

Assumptions:

- 1000 lots would be ~5MW diversified load.
- DEL policy is to provide alternative feeder capability for more than say 50 lots - so multiple feeders would be required
- capital contribution from DEL would be based on 15KVA/lot — '-$585,000
- cost share for feeders and zone substation upgrades would be negotiated
- easements, resource consents and all the other authorities required are obtained.
- 11Kv supplied is the preferred option - as opposed to a 33Kv zone substation

The grid exit point (GXP) operated by Transpower from 110Kv lines has the capacity to supply the expected load increase as have the DEL Zone substations at Frankton and Queenstown.

However the 11Kv feeder lines into the area are at about 50% (~1.5MW) capacity now, as such there is insufficient capacity in these circuits to supply the subdivision and upgrading to twin circuits or different construction would be difficult re easements, access and resource consents.

We have a security of supply problem in Kelvin Heights - this area is served by one 11Kv overhead line via Frankton resulting in a 'spur feeder' arrangement with no backfeed ability should the line fail for whatever reason.

Longer term engineering planning is to construct a zone substation in the Commonage area of Queenstown — to provide greater security of supply to the Queenstown CBD. We plan to take an 11Kv feeder cable from the Commonage directly to the western end of Kelvin Heights Peninsula to provide greater capacity and a backfeed capability.

Should the 1000 lot scenario become a reality, this feeder would be extended along the eastern shore of the lake, into the subdivision and back onto the exiting 11KV overhead lines.

This work is purely in the 'policy' stages — however should your development gather momentum then the planning would be brought forward.

I appreciate this is a rather technical response — however it should provide sufficient background information for you to discuss the project with Council — if I can help further please contact me.

Regards
Paul Johnson
Distribution Designer (Central)
DELTA Utility Services Ltd

APPENDIX 2 - Wastewater Management Report by Iann Gunn

1.0 INTRODUCTION

1.1 Background

The proposed Jacks Point rural-residential and golf course resort village development is to occupy a 410 ha site located between SH 6 and Lake Wakatipu some 7 km south of Frankton. This report presents proposals for managing wastewater flows from residential lots together with communal facilities including accommodation units, restaurants, clubhouse and administration offices.

1.2 Site Information

Darby Partners have provided a preliminary structure plan for the overall development (Fig. 1) showing the general location of residential development (R), lodge accommodation units (L), village administration and clubhouse (V), and golfing and recreational areas (G). A site visit and briefing meeting was undertaken on 14 August during which access was provided to soils information based on bore logs associated with an earlier airfield proposal for part of the site.

2.0 ENVIRONMENTAL and CULTURAL OBJECTIVES

Given the location of the proposed development within the catchment of Lake Wakatipu and the high value placed on both lake water quality and the natural environment of the area, Darby Partners are seeking a wastewater management solution that will deliver the highest environmental performance consistent with best-available-technology. The proposed solution is also to be sensitive to cultural (Tangata Whenua) objectives. For these reasons the approach to wastewater management is to minimise the quantity of effluent residuals discharged into the environment by use of high performance pre-treatment units followed by land application of the resulting high quality effluent for further in-soil treatment and uptake by vegetation.

Indeed, the final effluent for land application will result in a "reclaimed" water source which following storage in dedicated ponding areas has value as irrigation water for controlled summer utilisation on the golf course and landscaping features of the resort area.

3.0 WASTEWATER FLOW QUANTITIES

The overall development is to be based on the following:

- 400 residential dwellings (single lot and cluster layout);
- 40 to 60 room accommodation lodge;
- restaurants;
- Clubhouse and administration offices.

Wastewater flow quantities are based on a communal water supply system sourced from lake water. A conservative allowance is thus made for flow volumes to be treated and then land applied. Given that the development will proceed in two stages, separate wastewater flow assessments are set out below. The Stage I portion of the development comprises the western area of the site (Fig. 1), with Stage II the eastern area.

STAGE 1	DESIGN CRITERIA	DESIGN FLOW
40 dwellings	4.5 persons/dwelling; 200 litres/person/day wastewater output; 900 litres/dwelling	36m³/day
60 room lodge	a. 150 residents plus staff; 200 litres person/day b. Extra diners; 65 at 30 litres/person/day	36m³/day
Village Service Area	a. 120 persons (staff, visitors) clubhouse and administration offices; 50 litres/person/day c. Public Toilets; 200 uses/day; 10 litres/use	6m³/day 2m³/day
	TOTAL FLOW STAGE 1	**82m³/day**

STAGE 11	DESIGN CRITERIA	DESIGN FLOW
360 dwellings	4.5 persons/dwelling; 200 litres/person/day wastewater output; 900 litres/dwelling	324m³/day
Village Service Area Expansion	a. 120 persons (staff, visitors) clubhouse and administration offices; 50 litres/person/day b. Restaurant(s); 400 diners/day; 30 litres/person/day c. Public Toilets; 200 uses/day; 10 litres/use	6m³/day 12m³/day 2m³/day
	TOTAL FLOW STAGE 11	**344m³/day**

The flow estimates set out above provide a basis for sizing the land application areas. Detailed design flows will be prepared in due course in support of resource consent applications for land application area discharge permits. The above flows are thus conservatively based to represent a potential maximum development scenario.

4.0 SITE and SOIL CONDITIONS

The site comprises two sections of rolling topography separated by a central plain area (Fig. 1). Its elevation is well above lake level, and generally slopes down from SH 6 towards an escarpment at the western edge of the development bordering the lake. Borehole investigation results are available along a north-south line approximately through the centre of Stage II. Borelog records indicate shallow topsoil layers (100 mm to 250 mm depth) overlying sandy gravels, with no water tables detected in the range of the investigation depths (6 to 10 metres). These soils are expected to be representative of the overall development area, and indicate permeability conditions, which will facilitate rapid infiltration of treated wastewater effluent when applied on or into the land.

However, the porous nature of such soils will result in very limited in-soil treatment capacity, thus necessitating high quality pre-treatment prior to land application. Such pre-treatment should achieve tertiary treatment quality.

5.0 WASTEWATER SERVICING PROPOSALS

5.1 Servicing Concept

The overall low density of residential development (some 400 units within 410 ha) together with the dispersed layout of accommodation lodge and service village results in extensive open space areas. Conventional wastewater centralised servicing to single treatment plant location and point discharge into the natural environment does not fit well with nor does it best serve the environmental objectives for the development. The alternative approach of DWM (decentralised wastewater management) involving a mix of individual on-site wastewater systems plus cluster development involving hybrid on-site/off-site (or full off-site) treatment together with communal land application, all under a centralised operational and management control, provides the best overall servicing solution. The DWM approach makes best use of on-lot and off-lot open space lands to assimilate effluent residuals into soils in a low intensity manner while utilising both carriage water and nutrients in the treated effluent to enhance landscape planting values. Centralised management of operation and maintenance procedures ensures a high quality and uniform service delivery across the whole development independent of the home owner involvement associated with traditional oversight of on-site wastewater systems. Body corporate structures can be readily set up to facilitate the overall implementation and administration of the DWM approach.

5.2 Wastewater Pre-treatment

Pre-treatment options, which fit within the servicing concept outlined above, include the following:

On-lot Option A
On-site enhanced performance septic tank (with effluent outlet filter) (EPST) plus intermittent dosed sand filter unit (ISF) plus UV (ultraviolet) disinfection unit. This system provides a tertiary effluent quality for individual on-lot land application and/or landscaping enhancement. It is suitable for both permanently or intermittently occupied dwellings.

On-lot Option B
On-site aerobic treatment plant (ATP) (household package unit) with UV disinfection. This system provides a tertiary effluent quality for individual on-lot land application and/or landscaping enhancement. It is primarily suitable for permanently occupied dwellings.

Cluster Option C
On-site EPST with 50 mm gravity MEDS (modified effluent drainage servicing) to communal RSF (recirculating sand filter) and UV disinfection unit serving groups of dwellings. It is suitable for both permanently or intermittently occupied premises. Where individual or a sub-groups of dwellings are located below the grade line of the MEDS system, individual on-site or communal off-site pumping units can feed into the gravity MEDS lines. This system is appropriate for either low or high density cluster layout of dwellings. It provides a tertiary effluent quality suitable for communal landscape enhancement within dedicated land application areas. Storage of reclaimed water can provide for seasonal use as irrigation water under controlled conditions.

Communal Option D
MCS (modified conventional sewer) of 100 mm diameter gravity lines to off–site communal EPST plus RSF and UV unit serving groups of dwellings, and/or accommodation lodge, and/or village service centre. In all other respects it replicates the servicing approach of Cluster Option C, but with no on-site pre-treatment. It provides the same servicing level to permanently or intermittently occupied premises, and produces a high quality effluent suitable for communal landscape enhancement and/or seasonal irrigation use.

Communal Option E
As for Option D above except that a communal ATP and UV unit replaces the EPST/RSF/ UV treatment combination. More suited to higher levels of permanently occupied premises.

Final design of the development is likely to result in a mix of the above pre-treatment options being utilised to fit with the layout and density of dwellings and the associated land application options for final effluent management.

Note:
In wastewater treatment terminology there are three degrees of effluent treatment performance. "Primary treatment" refers to basic settling and solids retention such as achieved by a septic tank. "Secondary treatment" refers to the aerobic biological processes provided by sand filter and aerobic treatment plant units. "Tertiary treatment" relates to the use of disinfection processes to remove human intestinal micro-organisms following secondary treatment. UV is accepted as the most environmentally acceptable disinfection process.]

5.3 Land Application of Treated Effluent

(a) General

The high quality tertiary treated effluent proposed as a minimum pre-treatment standard for this development can be returned to the environment for subsoil infiltration and plant evapo-transpiration. Environmental impact is confined mainly to the soil within a metre or so depth below the distribution lines. Rainwater infiltration and dispersion at depth into the groundwater will extensively dilute any nutrient not taken up by plant growth. Given the substantial depth to groundwater below the site, and the large volume of such groundwater into which any infiltration quantity of treated effluent can be diluted, it is likely it will be very difficult to detect nutrient impacts. There will be no bacteriological impacts because of the level of pre-treatment, and the capacity of the natural soil at the proposed effluent loading rates to retain any undisinfected micro-organisms beyond their natural dieoff times.

These matters will be subject to review during the discharge consents application procedures to be considered in due course by the Otago Regional Council. At that time the results of detailed environmental assessment will be available to confirm the extent of discharge permit conditions. Following dedicated storage, which enables the effluent through dilution and biological processes to become mature pond water, the resulting reclaimed water has potential for use as an irrigation water source. This option for effluent land application to golf course areas would similarly be subject to discharge permit conditions.

(b) Land application alternatives

Site and soil conditions within the development area present two land application options which best fit the environmental objectives for the project. These are:

Infiltration Option F
The use of pump-dosed loaded shallow trenches to take tertiary quality effluent and disperse into the subsoil by direct infiltration. A conservative design loading rate of 50 mm/day (50 litres for every square metre of trench base area) would enable low impact dispersion of infiltrated flows into the soil and ultimately into the groundwater.

However, this system this will result in minimal opportunity for evapo-transpiration and nutrient uptake by plant growth, and is the least preferred option. In addition, trench installation requirements within the gravel subsoils lack the flexibility in construction technique provided by the alternative of shallow subsurface and covered surface drip irrigation systems (Option G below).

Irrigation Option G

Drip irrigation of tertiary treated effluent utilising pressure compensating drip emitters provides maximum flexibility in locating and installing land application areas. The use of a conservative design loading rate will ensure maximum opportunity for plant uptake of nutrient (to enhance plant growth) and liquid (for evapo-transpiring to the atmosphere), thus reducing infiltration to groundwater. The recommended loading rate of 3 mm/day (3 litres for every square metre of irrigation area) is 60% of the design loading rate considered acceptable for the porous soil conditions at this location. This low intensity drip irrigation approach is the preferred option for the development. It presents an opportunity for utilisation of tertiary treated effluent for both on-lot and communal landscaping enhancement, as drip lines can be located to fit irregular shaped distribution areas, as well as handle moderate variations in elevation under the inherent pressure compensating capabilities of the system.

(c) Land area requirements: The footprint areas for Options F and G above are set out in the following tables. The aggregate areas for the preferred Option G (drip irrigation) are shown on Fig. 1 to illustrate the irrigation area requirement relative to those site areas currently identified for development facilities. The use of drip irrigation layout provides ultimate flexibility in distributing the aggregate area within on-lot and communal areas throughout the development so that the resulting dedicated effluent management land application areas form part of the overall landscaping and planting plan.

Option F: (Infiltration Trenches)

Aggregate Area Requirement	On-lot Area Requirement
Stage I 82 m^3/day; 4,100 m of 400 mm wide trenches spaced at 2 m centres results in 8,200 m^2 of trench system (0.82 hectare)	Stage I 900 litres/day per dwelling; 45 m of 400 mm wide trench spaced at 2 m centres results in 90 m^2 of trench system per lot
Stage II 344 m^3/day; 17,200 m of 400 mm wide trenches spaced at 2 m centres results in 34,400 m^2 of trench system (3.44 hectare)	Stage II 900 litres/day per dwelling; 45 m of 400 mm wide trench spaced at 2 m centres results in 90 m^2 of trench system per lot

Option F: (Drip Irrigation)

Aggregate Area Requirement	On-lot Area Requirement
Stage I 82 m^3/day; 27,330 m of dripline spaced at 1 m results in 27,330 m^2 of irrigation system (2.73 hectare)	Stage I 900 litres/day per dwelling; 300 m of dripline spaced at 1 m centres results in 300 m^2 of irrigation system per lot
Stage II 344 m^3/day; 114,670 m of dripline spaced at 1 m results in 114,670 m^2 of irrigation system (11.5 hectare)	Stage II 900 litres/day per dwelling; 300 m of dripline spaced at 1 m centres results in 300 m^2 of irrigation system per lot

5.4 Design and Operational Factors

Two aspects of the preferred drip irrigation system operation require consideration relative to the winter versus summer climate conditions in the Wakatipu basin. They relate to the effect of freezing conditions on effluent irrigation driplines, and the year round influence of evapo-transpiration on effluent uptake within landscaped areas.

(a) Cold climate conditions

Dripline systems are installed either at shallow depth within topsoil (100 mm being common), or are laid on the ground surface and covered with protective mulch or compost. Plantings of grasses, shrubs or trees are located between the driplines, with dripline spacing adjusted to suit the planting regime and configuration. Root systems do not penetrate the dripline emitters where soil moisture deficit is not a constraint, and/or where driplines drain between dose applications. Experience has been obtained over several years in the rigorous cold winter freezing conditions in North America where periodic soil freezing at depths below the drip lines have been recorded (see "On-site NewZ" Special Report 01/1, April 2001 which summarises Wisconsin research into this issue). Where driplines are located within a vegetated area, and where full drain-back to the distribution chamber is provided after each dose, then natural heat of the effluent relative to external temperatures together with the insulating effects of vegetation (such as long grass, shrubs or trees) ensures trouble free operation.

For the proposed application at this location, with driplines laid within soil to a depth of 100 mm (topsoil enhancement to be provided where necessary), with planting cover established from commissioning of the effluent distribution system, and with the system designed and operated on a drainback basis, then adequate cold weather protection can be maintained.

(b) Evapo-transpiration assist

The utilisation of plant evapo-transpiration for nutrient uptake as well as carriage water transfer to the atmosphere is an important mechanism in treated effluent uptake and environmental effects management. The proposed dripline irrigation system maximises opportunity for evapo-transpiration (ET) assist. This ET assist is at a maximum during summer warm weather and high pan-evaporation conditions. However, ET assist is also important in winter even though pan-evaporation rates are at their lowest. This is due to the fact that effluent stimulated plant growth still draws moisture onto leaf surfaces where the "clothesline" effect of wind action passing over and through the plants draws that moisture into the atmosphere. This mechanism has been shown to enhance ET rates to 2 to 3 times that of pan-evaporation, and provide positive liquid transfer to atmosphere even during winter. Once again it is North American research (specifically Canada) that has provided leadership in investigating the mechanisms involved.

In the porous soil conditions prevalent throughout the site of this development, ample infiltration capacity exists to take all treated effluent applied to land without reliance on ET assist. However, plant uptake will be an important element in effluent management, as dripline systems will place that effluent within the rootzone of the landscape plantings. Where deciduous trees are used, or when low ET assist conditions prevail, then under winter conditions the effluent not taken up by plants will automatically drain away from the rootzone and infiltrate through the natural soil to groundwater at depth.

6.0 MANAGEMENT PROCEDURES

The management of all wastewater servicing facilities under central agency control administered by a Body corporate has already been referred to in 5.1 above.

Centralised operation and management oversight would have the following elements:

An operation and management plan dealing with all private and communal elements of wastewater servicing together with the environmental monitoring requirements related to resource consent conditions. (Where reclaimed water use via irrigation of recreation areas is involved, the management plan will detail the constraints associated with irrigation operations in meeting the consent conditions.)

- Body corporate ownership of all communal facilities (including pre-treatment and land application systems).
- Body corporate commissioning and supervision of operation and maintenance service contract(s). Unimpeded access for servicing agency staff to all privately owned pre-treatment and land application systems to undertake monitoring, repairs, and routine maintenance on a structured basis.
- A quick response system based on automatic alarm activation, and specialist service personnel callout to deal with faults.
- A centralised workshop/servicing base at which standby mechanical and electrical equipment is stored and maintained (such as replacement pump units, aerators, disinfection units, electrical control fittings, plus associated drainage system hardware).

Opportunity exists for the developer to engage an appropriate company on a design-build-operate (DBO) basis in accordance with an agreed concept plan. This would facilitate a unified approach to system design and hardware selection, and lead to long-term benefits in having standardised technical systems and operating procedures. The DBO approach can be centered on performance criteria that are aimed at securing the environmental objectives for the development. Remote sensing of equipment operation and treatment performance can deliver monitoring information to a centralised control centre (anywhere outside Queenstown if need be) so that specialist personnel can provide monitoring diagnosis and support of all system operations on a 24 hr basis.

7.0 SUMMARY

- Wastewater servicing proposals for the Jacks Point development are to deliver the highest environmental performance consistent with best-available-technology.
- Wastewater flow quantities for pre-treatment and land application have been adopted at 82 m^3/day for Stage I development, and 344 m^3/day for Stage II.
- Wastewater pre-treatment options include enhanced performance septic tank and sand filter systems with ultraviolet disinfection for on-site single property use. For communal cluster or service area use, either septic tank/sand filter/disinfection systems or aerobic treatment plant/disinfection systems are applicable.
- The preferred land application system is drip irrigation of tertiary treated effluent, with dripline system designed and operated to handle seasonal cold weather conditions.
- The aggregate area required for a conservative (low intensity) irrigation loading rate is 2.73 hectares for Stage I, plus 11.5 hectares for Stage II.
- However, the operational and installation flexibility offered by dripline land application enables the aggregate area to be split into a range of individual and communal irrigation areas for on-lot and dedicated open space landscaping enhancement.
- Tertiary treated effluent also offers a source of reclaimed water, which following maturing in storage pond(s) can be used for specific recreational area irrigation purposes.
- The decentralised wastewater management servicing of this development is to be subject to centralised management of operation, maintenance and monitoring procedures for both on-lot and communal facilities.

APPENDIX 3 - Revegetation Plant Schedule by Boffa Miskell Limited

1.0 Species Lists for Revegetation and Enhancement Planting at Coneburn

Species suitable for enhancement and creation of habitat types identified in this document are appended. These species list have been compiled from Meurk (1997) and Simpson (2001).

Additional comments on the suitability of species for particular locations or roles within the habitats are given. Such comments include the ability of the species to act as a colonising plant, ameliorating the habitat for the planting, or natural regeneration, of other native species. One species, bracken (*Pteridium esculentum*), that performs this role in the high-energy stream and lake forest habitats in the study area is not noted. It is capable of self-introducing and thus it does not need to be actively planted. In many instances, allowing bracken to develop prior to planting in areas that are desired to become forest habitats will benefit regeneration and revegetation.

Species mentioned here are those that will generally be available from nurseries. However, large quantities, and uncommon species, will need to be ordered in advance. There may be difficulties for nurseries in obtaining and growing some threatened species.

2.0 Beech Forest Regeneration

The development of beech forest, a habitat type that is now poorly represented in the study area, can be slow. To ensure good growth of beech forest the inclusion of appropriate mycorrhizal microbes in to the potting mix is essential. Initial shelter from companion plantings of kohuhu (*Pittosporum tenuifolium*) and mingimingi (*Coprosma propinqua*) will provide necessary shelter. However, beech does grow naturally in open locations so deep shade, or planting in copses of shrubs would not appear to be beneficial. Growth rates in excess of 0.2 - 1m per year have been reported by Meurk (1997), who further notes that beech has a 'fast' growth rate. He further comments that poor growth in plant species, such as that noted from some beech revegetation plantings in the study area (*pers. obs.*), are not an indication of poor potential. This poor growth may be the result of missing ingredient (mycorrhizal infections), a pathogen (Meurk 1997) or planting in an inappropriate location. To date, detailed research on revegetation requirements of beech, and other species (that Meurk (1997) notes need study), have not been completed.

In general, of the soil types that Meurk (1997) note as being suitable to sustain mountain and red beech forest, there are only small amounts in the study area. These Dunstan and Blackstone soils are sparingly distributed on the lakeshore terrace, and Jacks Point and Peninsula Hill rouches moutonées. Consideration of the appropriateness of beech revegetation in regard to the soils may increase the success of beech revegetation.

LAKESHORE FORESTS: species for revegetation planting in lakeshore forest locations

species	common name	large tree	small tree	tall shrub	small shrub	sedge, rush, tussock	comments
Nothofagus fusca	red beech	√					requires initial shelter
N.solandri var. *cliffortioides*	mountain beech	√					requires initial shelter and mycorrhizae
Prumnopitys taxifolius	matai	√					requires shelter, slow growing
Podocarpus hallii	Hall's totara	√					requires shelter, slow growing
Pseudopanax crassifolius	lancewood		√				requires initial shelter, slow growing
Pennantia corymbosa	kaikomako		√				requires shelter, lower (moist) lakeshore and wetland margin locations
Coprosma linariifolia			√				appropriate?, requires initial shelter, tolerance for a range of soils
Elaeocarpus hookerianus	pokaka		√				requires shelter, requires moist soils, lake margin locations
Griselinia littoralis	kapuka / broadleaf		√				requires initial shelter, tolerance for a range of soils and habitats
Hoheria lyallii	mountain ribbonwood		√				colonising species, tolerant & requiring moist soils in a range of habitats
Pittosporum tenuifolium	kohuhu		√				coloniser but requires initial shelter, tolerant of a range of soils & habitats
Aristotelia serrata	wineberry		√				requires shelter and moist soils, very palatable
Carpodetus serratus	putaputaweta/marbleleaf		√				requires shelter and moist soils
Cordyline australis	ti kouka / cabbage tree		√				colonising species, tolerance for a range of soils and habitats
Fuchsia excorticata	kotukutuku/tree fuchsia		√				requires shelter, palatable
Melicytus lanceolatus	mahoe wao		√				requires shelter, palatable
Melicytus ramiflorus	mahoe/whiteywood		√				requires shelter, palatable, good insect habitat
Metrosideros umbellata	southern rata		√				currently only present south of Cone Burn
Myrsine australis	red matipo		√				requires shelter
Pittosporum eugenioides	tarata/lemonwood		√				requires shelter
Sophora microphylla	kowhai		√				colonising species, tolerance for a range of soils and habitats, N fixer
Schelfflera digitata	seven finger		√				requires shelter, palatable, requires moist soils
Pseudopanax colensoi var. *ternatus*	mountain three finger			√			requires initial shelter only
Olearia avicenniifolia				√			colonising species, tolerant of a range of soils and habitats
Olearia fragrantissima				√			requires initial shelter, tolerant of a range of soils & habitats, uncommon.
Coprosma lucida	shining leaf Coprosma			√			requires shelter, palatable, tolerance for a range of soils
Olearia arborescens				√			requires initial shelter, tolerance for a range of soils
Hebe rakaiensis					√		requires initial shelter, tolerance for a range of moist habitats
Dracophyllum longifolium	inaka				√		open sites, requires moist soils
Myrsine divaricata	weeping mapou				√		requires initial shelter, tolerant of a range of moist soils and habitats
Aristotelia fruticosa	mountain wineberry				√		requires intial shelter, palatable, tolerant of a range of dry soils & habitats
Astelia nervosa						√	requires shelter, ground cover
Carex maorica						√	appropriate?, open sites on open,wet lakeshore forest margins
Astelia fragrans	bush lily					√	requires shelter, ground cover

GREY SHRUBLAND: species for enhancement of, and revegetation in, grey shrublands

species	common name	small tree	tall shrub	small shrub	sedge, rush, tussock	comments
Coprosma linariifolia		√				appropriate?, requires initial shelter, tolerance for a range of soils
Podocarpus hallii	Hall's totara	√				requires shelter, slow growing
Olearia bullata			√			open sites, tolerance for a range of dry soils
Olearia fragrantissima			√			requires initial shelter, tolerant of a range of soils & habitats, uncommon
Olearia hectorii			√			requires initial shelter, uncommon
Leptospermum scoparium	manuka		√			appropriate?, colonising species, tolerance for a range of soils & habitats
Olearia lineata			√			open sites, tolerance for a range of soils & habitats
Discaria toumatou	matagouri		√			colonising species, tolerance for a range of dry soils & habitats, N fixer
Aristotelia fruticosa	mountain wineberry			√		appropriate?, requires intial shelter, palatable, tolerant of a range of dry soils & habitats
Coprosma propinqua	mingimingi			√		colonising species, tolerance for a range of soils & habitats
Coprosma crassifolius				√		open sites, tolerance for a range of soils
Cyathodes juniperina	mingimingi			√		requires initial shelter, good lizard habitat
Olearia nummularia				√		open sites
Olearia odorata				√		open sites, good invertebrate habitat
Melicytus alpinus	porcupine shrub			√		open sites, tolerant of dry soils, good lizard habitat and food
Corokia cotoneaster	korokia			√		open sites, palatable, tolerant of a range of dry soils & habitats
Carmichaelia petriei	NZ broom			√		open sites, hardy, tolerates a range of dry soils & habitats, N fixer
Ozothamnus sp.	cottonwood			√		colonising species
Hebe cupressoides				√		open sites, tolerates and requires dry soils
Dracophyllum uniflorum	turpentine shrub			√		open sites, requires moist soils, high altitude shrubland only
Dracophyllum longifolium	inaka			√		open sites, requires moist soils
Aciphylla aurea	golden speargrass				√	open sites, tolerates a range of dry soils, sharp
Chionochloa rigida	narrow-leaved snow tussock				√	colonising species, requires moist soils
Festuca novae zelandiae	hard tussock				√	open sites, tolerates a range of dry soils
Poa cita	silver tussock				√	colonising species, tolerates a range of dry soils

BEECH FOREST REMNANTS: species for enhancement, revegetation and planting of remnant beech forests

species	common name	large tree	small tree	tall shrub	small shrub	sedge, rush, tussock	comments
Nothofagus fusca	red beech	√					requires initial shelter
N. solandri var. *cliffortioides*	mountain beech	√					requires initial shelter and mycorrhizae
Pseudopanax crassifolius	lancewood		√				requires initial shelter, slow growing
Pennantia corymbosa	kaikomako		√				requires shelter, lower (moist) lakeshore and wetland margin locations
Coprosma linariifolia			√				requires initial shelter, tolerance for a range of soils
Elaeocarpus hookerianus	pokaka		√				requires shelter, lower (moist) lakeshore locations
Griselinia littoralis	kapuka, broadleaf		√				requires initial shelter, tolerance for a range of soils and habitats
Hoheria lyallii	mountain ribbonwood		√				colonising species, tolerant & requiring moist soils in a range of habitats
Pseudopanax colensoi var. *ternatus*	mountain three finger			√			requires initial shelter only
Olearia avicenniifolia				√			colonising species, tolerant of a range of soils and habitats
Olearia hectorii				√			requires initial shelter, uncommon species
Hebe rakaiensis					√		requires initial shelter, tolerance for a range of moist habitats
Dracophyllum longifolium	inaka				√		open sites, requires moist soils
Myrsine divaricata	weeping mapou				√		requires initial shelter, tolerant of a range of moist soils and habitats
Olearia cymbifolia					√		open sites on upper terrace locations
Coprosma propinqua	mingimingi				√		colonising species, tolerance for a range of soils and habitats
Coprosma crassifolius					√		open sites, tolerance for a range of soils
Cyathodes juniperina	mingimingi				√		requires initial shelter, good lizard habitat
Hebe odora					√		open sites, requires moist soils
Coprosma rugosa					√		open sites
Gaultheria antipoda	tall snowberry				√		requires initial shelter, good lizard habitat
Astelia nervosa						√	requires shelter, ground cover

HIGH ENERGY STREAMS: species for enhancement of, and revegetation in, high energy streams

species	common name	small tree	tall shrub	small shrub	sedge, rush, tussock	comments
Griselinia littoralis	kapuka / broadleaf	√				requires initial shelter, tolerance for a range of soils & habitats
Hoheria lyallii	mountain ribbonwood	√				open sites, requires moist soils in a range of habitats
Pittosporum tenuifolium	kohuhu	√				coloniser, but can require initial shelter, tolerant of a range of soils & habitats
Carpodetus serratus	putaputaweta, marbleleaf	√				requires shelter and moist soils
Cordyline australis	ti kouka / cabbage tree	√				colonising species, tolerance for a range of soils & habitats
Fuchsia excorticata	kotukutuku/tree fuchsia	√				requires shelter, palatable
Melicytus ramiflorus	mahoe/whiteywood	√				requires shelter, palatable, good insect habitat
Pittosporum eugenioides	tarata/lemonwood	√				coloniser but requires shelter
Sophora microphylla	kowhai	√				colonising species, tolerance for a range of soils & habitats, N fixer
Pseudopanax colensoi var. *ternatus*	mountain three finger		√			requires initial shelter only
Olearia avicenniifolia			√			colonising species, tolerant of a range of soils & habitats
Olearia lineata			√			open sites, tolerance for a range of soils & habitats
Discaria toumatou	matagouri		√			colonising species, tolerance for a range of dry soils & habitats, N fixer
Hebe rakaiensis				√		requires initial shelter, tolerance for a range of moist habitats
Myrsine divaricata	weeping mapou			√		requires initial shelter, tolerant of a range of moist soils & habitats
Aristotelia fruticosa	mountain wineberry			√		requires initial shelter, palatable, tolerates a range of dry soils & habitats
Olearia cymbifolia				√		open sites on upper terrace locations
Coprosma propinqua	mingimingi			√		colonising species, tolerance for a range of soils & habitats
Coprosma crassifolius				√		open sites, tolerance for a range of soils
Cyathodes juniperina	mingimingi			√		requires initial shelter, good lizard habitat
Hebe odora				√		open sites, requires moist soils
Olearia nummularia				√		open sites
Hebe salicifolia	willow-leaved Hebe			√		requires initial shelter, tolerance for a range of moist soils & habitats
Hebe subalpina				√		open sites
Olearia odorata				√		open sites, good invertebrate habitat
Corokia cotoneaster	korokia			√		open sites, palatable, tolerant of a range of dry soils & habitats
Carmichaelia petriei	NZ broom			√		open sites, hardy, tolerates a range of dry soils & habitats, N fixer
Ozothamnus sp.	cottonwood			√		colonising species
Poa cita	silver tussock				√	colonising species, tolerates a range of dry soils
Astelia fragrans	bush lily				√	requires shelter, ground cover
Astelia nervosa					√	requires shelter, ground cover
Carex secta	pukio				√	colonising species, hardy and tolerant on moist margins
Chionochloa conspicua	bush tussock				√	open sites, requiring moist soils in a range of habitats
Cortaderia richardii	toi toi				√	colonising species, tolerant of moist soils in a range of habitats
Phormium tenax	harakeke/swamp flax				√	colonising species, tolerant of moist soils in a range of habitats
Phormium cookianum	mountain flax				√	colonising species, requires moist soils, tolerates a range of habitats

TUSSOCKLAND: species for enhancement of, and revegetation in, tussockland

species	common name	small shrub	sedge, rush, tussock	comments
Hebe odora		√		open sites, requires moist soils
Melicytus alpinus	porcupine shrub	√		open sites, tolerant of dry soils, good lizard habitat and food
Carmichaelia petriei	NZ broom	√		open sites, hardy, tolerates a range of dry soils & habitats, N fixer
Ozothamnus sp.	cottonwood	√		colonising species
Hebe cupressoides		√		open sites, tolerates and requires dry soils
Hebe subalpina		√		open sites, montane locations
Dracophyllum longifolium	inaka	√		open sites requires moist soils
Dracophyllum uniflorum	turpentine shrub	√		open sites, requires moist soils, high altitude shrubland only
Pimelia aridula	NZ daphne	√		colonising species on a range of dry soils
Carex coriacea	NZ swamp sedge		√	open sites, hardy and tolerant of a range of wet soils
Chionochloa conspicua	bush tussock		√	open sites, tolerant and requiring moist soils in a range of habitats
Cortaderia richardii	toi toi		√	colonising species, tolerant of moist soils in a range of habitats
Phormium tenax	harakeke/swamp flax		√	colonising species, tolerant of moist soils in a range of habitats
Phormium cookianum	mountain flax		√	colonising species , requires moist soils, tolerates a range of habitats
Aciphylla aurea	golden speargrass		√	open sites, tolerates a range of dry soils, sharp
Chionochloa rigida	narrow-leaved snow tussock		√	colonising species, requires moist soils
Festuca novae zelandiae	hard tussock		√	open sites, tolerates a range of dry soils
Poa cita	silver tussock		√	colonising species, tolerates a range of dry soils

WETLANDS: species for enhancement of, and revegetation in, wetland locations

species	common name	small tree	tall shrub	small shrub	sedge, rush, tussock	comments
Pennantia corymbosa	kaikomako	√				requires shelter, moist soils on wetland & lake margins
Pittosporum tenuifolium	kohuhu	√				requires initial shelter, tolerance for a range of soils & habitats
Pseudopanax crassifolius	lancewood	√				requires initial shelter, slow growing
Leptospermum scoparium	manuka		√			appropriate?, colonising species, tolerance for a range of soils & habitats
Olearia lineata			√			open sites, tolerance for a range of soils & habitats
Hebe rakaiensis				√		requires initial shelter, tolerance for a range of moist habitats
Hebe salicifolia	willow-leaved Hebe			√		requires initial shelter, tolerance for a range of moist soils & habitats
Olearia cymbifolia				√		open sites on upper terrace locations
Olearia nummularia				√		open sites
Carex maorica					√	appropriate?, open sites on open,wet lakeshore forest margins
Aciphylla glaucescens	blue speargrass				√	wetland margins and planted in moist areas with tussocks
Carex coriacea	NZ swamp sedge				√	colonising species, hardy and tolerant of a range of wet soils
Carex secta	pukio				√	colonising species, hardy and tolerant
Chionochloa conspicua	bush tussock				√	colonising species, tolerant & requiring moist soils in a range of habitats
Cortaderia richardii	toi toi				√	colonising species, tolerant of moist soils in a range of habitats
Juncus distegus	wiwi				√	open sites, requires moist soils
Juncus gregiflorus	NZ soft rush				√	colonising species, requires moist soils
Juncus sarophorus	wiwi				√	open sites, requires moist soils
Phormium cookianum	mountain flax				√	colonising species, requires moist soils, tolerates a range of habitats
Phormium tenax	harakeke / swamp flax				√	colonising species, tolerant of moist soils in a range of habitats
Typha orientalis	raupo / bullrush				√	colonising species, wastewater treatment, wetland bird habitat
Schoenus pauciflorus	bog rush				√	open sites, requires moist soils

species	common name	lake shore forest	remnant beech forest	wetland	grey shrubland	high energy streams	tussock land	large tree	small tree	tall shrub	small shrub	sedge, rush, tussock
Pseudopanax crassifolius	lancewood	√	√	√					√			
Pennantia corymbosa	kaikomako	√	√	√					√			
Hebe rakaiensis		√	√	√		√					√	
Coprosma linariifolia		√	√		?				√			
Dracophyllum longifolium	inaka	√	√		√		√				√	
Nothofagus fusca	red beech	√	√					√				
N. solandri var. *cliffortioides*	mountain beech	√	√					√				
Elaeocarpus hookerianus	pokaka	√	√						√			
Griselinia littoralis	kapuka / broadleaf	√	√			√			√			
Pseudopanax colensoi var. *ternatus*	mountain three finger	√	√			√				√		
Astelia nervosa		√	√			√						√
Hoheria lyallii	mountain ribbonwood	√	√			√			√			
Olearia avicenniifolia		√	√			√				√		
Myrsine divaricata	weeping mapou	√	√			√					√	
Carex maorica		√		?								√
Pittosporum tenuifolium	kohuhu	√		√		√			√			
Aristotelia fruticosa	mountain wineberry	√			?	√					√	
Podocarpus hallii	Hall's totara	√			√				√			
Olearia fragrantissima		√			√					√		
Prumnopitys taxifolius	matai	√						√				
Schelfflera digitata	seven finger	√										
Aristotelia serrata	wineberry	√							√			
Carpodetus serratus	putaputaweta / marbleleaf	√				√			√			
Cordyline australis	ti kouka / cabbage tree	√				√			√			
Fuchsia excorticata	kotukutuku / tree fuchsia	√				√			√			
Melicytus lanceolatus	mahoe wao	√							√			
Melicytus ramiflorus	mahoe / whiteywood	√				√			√			
Metrosideros umbellata	southern rata	√							√			
Myrsine australis	red matipo	√							√			
Pittosporum eugenioides	tarata / lemonwood	√				√			√			
Sophora microphylla	kowhai	√				√			√			
Coprosma lucida	shining leaf Coprosma	√								√		
Olearia arborescens		√								√		
Astelia fragrans	bush lily	√				√						√
Olearia cymbifolia			√	√		√					√	
Coprosma propinqua	mingimingi		√		√	√					√	
Coprosma crassifolius			√		√	√					√	
Olearia hectorii			√		√					√		
Cyathodes juniperina	mingimingi		√		√	√					√	
Hebe odora			√			√	√				√	
Coprosma rugosa			√								√	
Gaultheria antipoda	tall snowberry		√								√	
Leptospermum scoparium	manuka			√	√					√		
Olearia lineata				√	√	√				√		
Olearia nummularia				√	√	√					√	
Olearia bullata					√					√		
Hebe salicifolia	willow-leaved Hebe			√		√					√	
Aciphylla glaucescens	blue speargrass			√								√
Carex coriacea	NZ swamp sedge			√			√					√
Carex secta	pukio			√		√						√
Juncus distegus	wiwi			√								√
Juncus gregiflorus	NZ soft rush			√								√
Juncus sarophorus	wiwi			√								√
Schoenus pauciflorus	bog rush			√								√
Chionochloa conspicua	bush tussock			√		√	√					√
Cortaderia richardii	toi toi			√		√	√					√
Typha orientalis	raupo / bullrush			√								√
Phormium tenax	harakeke/swamp flax			√		√	√					√
Phormium cookianum	mountain flax			√		√	√					√
Olearia odorata					√	√					√	
Discaria toumatou	matagouri				√	√				√		
Melicytus alpinus	porcupine shrub				√		√				√	
Corokia cotoneaster	korokia				√	√					√	
Carmichaelia petriei	NZ broom				√	√	√				√	
Ozothamnus sp.	cottonwood				√	√	√				√	
Hebe cupressoides					√		√				√	
Aciphylla aurea	golden speargrass				√		√					√
Chionochloa rigida	narrow-leaved snow tussock				√		√					√
Festuca novae zelandiae	hard tussock				√		√					√

TUSSOCKLAND: species for enhancement of, and revegetation in, tussockland

species	common name	small shrub	sedge, rush, tussock	comments
Hebe odora		√		open sites, requires moist soils
Melicytus alpinus	porcupine shrub	√		open sites, tolerant of dry soils, good lizard habitat and food
Carmichaelia petriei	NZ broom	√		open sites, hardy, tolerates a range of dry soils & habitats, N fixer
Ozothamnus sp.	cottonwood	√		colonising species
Hebe cupressoides		√		open sites, tolerates and requires dry soils
Hebe subalpina		√		open sites, montane locations
Dracophyllum longifolium	inaka	√		open sites requires moist soils
Dracophyllum uniflorum	turpentine shrub	√		open sites, requires moist soils, high altitude shrubland only
Pimelia aridula	NZ daphne	√		colonising species on a range of dry soils
Carex coriacea	NZ swamp sedge		√	open sites, hardy and tolerant of a range of wet soils
Chionochloa conspicua	bush tussock		√	open sites, tolerant and requiring moist soils in a range of habitats
Cortaderia richardii	toi toi		√	colonising species, tolerant of moist soils in a range of habitats
Phormium tenax	harakeke/swamp flax		√	colonising species, tolerant of moist soils in a range of habitats
Phormium cookianum	mountain flax		√	colonising species , requires moist soils, tolerates a range of habitats
Aciphylla aurea	golden speargrass		√	open sites, tolerates a range of dry soils, sharp
Chionochloa rigida	narrow-leaved snow tussock		√	colonising species, requires moist soils
Festuca novae zelandiae	hard tussock		√	open sites, tolerates a range of dry soils
Poa cita	silver tussock		√	colonising species, tolerates a range of dry soils

WETLANDS: species for enhancement of, and revegetation in, wetland locations

species	common name	small tree	tall shrub	small shrub	sedge, rush, tussock	comments
Pennantia corymbosa	kaikomako	√				requires shelter, moist soils on wetland & lake margins
Pittosporum tenuifolium	kohuhu	√				requires initial shelter, tolerance for a range of soils & habitats
Pseudopanax crassifolius	lancewood	√				requires initial shelter, slow growing
Leptospermum scoparium	manuka		√			appropriate?, colonising species, tolerance for a range of soils & habitats
Olearia lineata			√			open sites, tolerance for a range of soils & habitats
Hebe rakaiensis				√		requires initial shelter, tolerance for a range of moist habitats
Hebe salicifolia	willow-leaved Hebe			√		requires initial shelter, tolerance for a range of moist soils & habitats
Olearia cymbifolia				√		open sites on upper terrace locations
Olearia nummularia				√		open sites
Carex maorica					√	appropriate?, open sites on open,wet lakeshore forest margins
Aciphylla glaucescens	blue speargrass				√	wetland margins and planted in moist areas with tussocks
Carex coriacea	NZ swamp sedge				√	colonising species, hardy and tolerant of a range of wet soils
Carex secta	pukio				√	colonising species, hardy and tolerant
Chionochloa conspicua	bush tussock				√	colonising species, tolerant & requiring moist soils in a range of habitats
Cortaderia richardii	toi toi				√	colonising species, tolerant of moist soils in a range of habitats
Juncus distegus	wiwi				√	open sites, requires moist soils
Juncus gregiflorus	NZ soft rush				√	colonising species, requires moist soils
Juncus sarophorus	wiwi				√	open sites, requires moist soils
Phormium cookianum	mountain flax				√	colonising species, requires moist soils, tolerates a range of habitats
Phormium tenax	harakeke / swamp flax				√	colonising species, tolerant of moist soils in a range of habitats
Typha orientalis	raupo / bullrush				√	colonising species, wastewater treatment, wetland bird habitat
Schoenus pauciflorus	bog rush				√	open sites, requires moist soils

species	common name	lake shore forest	remnant beech forest	wetland	grey shrubland	high energy streams	tussock land	large tree	small tree	tall shrub	small shrub	sedge, rush, tussock
Pseudopanax crassifolius	lancewood	√	√	√					√			
Pennantia corymbosa	kaikomako	√	√	√					√			
Hebe rakaiensis		√	√	√		√					√	
Coprosma linariifolia		√	√		?				√			
Dracophyllum longifolium	inaka	√	√		√		√				√	
Nothofagus fusca	red beech	√	√					√				
N. solandri var. *cliffortioides*	mountain beech	√	√					√				
Elaeocarpus hookerianus	pokaka	√	√						√			
Griselinia littoralis	kapuka / broadleaf	√	√			√			√			
Pseudopanax colensoi var. *ternatus*	mountain three finger	√	√			√				√		
Astelia nervosa		√	√			√						√
Hoheria lyallii	mountain ribbonwood	√	√			√			√			
Olearia avicenniifolia		√	√			√				√		
Myrsine divaricata	weeping mapou	√	√			√					√	
Carex maorica		√		?								√
Pittosporum tenuifolium	kohuhu	√		√		√			√			
Aristotelia fruticosa	mountain wineberry	√			?	√					√	
Podocarpus hallii	Hall's totara	√			√				√			
Olearia fragrantissima		√			√					√		
Prumnopitys taxifolius	matai	√						√				
Schelfflera digitata	seven finger	√										
Aristotelia serrata	wineberry	√							√			
Carpodetus serratus	putaputaweta / marbleleaf	√				√			√			
Cordyline australis	ti kouka / cabbage tree	√				√			√			
Fuchsia excorticata	kotukutuku / tree fuchsia	√				√			√			
Melicytus lanceolatus	mahoe wao	√							√			
Melicytus ramiflorus	mahoe / whiteywood	√				√			√			
Metrosideros umbellata	southern rata	√							√			
Myrsine australis	red matipo	√							√			
Pittosporum eugenioides	tarata / lemonwood	√				√			√			
Sophora microphylla	kowhai	√				√			√			
Coprosma lucida	shining leaf Coprosma	√								√		
Olearia arborescens		√								√		
Astelia fragrans	bush lily	√				√						√
Olearia cymbifolia			√	√		√					√	
Coprosma propinqua	mingimingi		√		√	√					√	
Coprosma crassifolius			√		√	√					√	
Olearia hectorii			√		√					√		
Cyathodes juniperina	mingimingi		√		√	√					√	
Hebe odora			√			√	√				√	
Coprosma rugosa			√								√	
Gaultheria antipoda	tall snowberry		√								√	
Leptospermum scoparium	manuka			√	√					√		
Olearia lineata				√	√	√				√		
Olearia nummularia				√	√	√					√	
Olearia bullata					√					√		
Hebe salicifolia	willow-leaved Hebe			√		√					√	
Aciphylla glaucescens	blue speargrass			√								√
Carex coriacea	NZ swamp sedge			√			√					√
Carex secta	pukio			√		√						√
Juncus distegus	wiwi			√								√
Juncus gregiflorus	NZ soft rush			√								√
Juncus sarophorus	wiwi			√								√
Schoenus pauciflorus	bog rush			√								√
Chionochloa conspicua	bush tussock			√		√	√					√
Cortaderia richardii	toi toi			√		√	√					√
Typha orientalis	raupo / bullrush			√								√
Phormium tenax	harakeke/swamp flax			√		√	√					√
Phormium cookianum	mountain flax			√		√	√					√
Olearia odorata					√	√					√	
Discaria toumatou	matagouri				√	√				√		
Melicytus alpinus	porcupine shrub				√		√				√	
Corokia cotoneaster	korokia				√	√					√	
Carmichaelia petriei	NZ broom				√	√	√				√	
Ozothamnus sp.	cottonwood				√	√	√				√	
Hebe cupressoides					√		√				√	
Aciphylla aurea	golden speargrass				√		√					√
Chionochloa rigida	narrow-leaved snow tussock				√		√					√
Festuca novae zelandiae	hard tussock				√		√					√

APPENDIX 4 - Geological Survey by Royden Thomson

Geological Evaluation of an Area Between The Remarkables and Lake Wakatipu and South of the Kawarau River - APRIL 2002

CONTENTS

SUMMARY

The area bounded by The Remarkables mountains, Lake Wakatipu, the Kawarau River and Wye Creek has a highly variable terrain that varies from precipitous to flat and a relative elevation difference in excess of 2000 m. Glacial sculpturing has progressively modified the area over time but the relief is in part due to active, tectonic uplift.

A variety of glacially and non-glacially-related sediments and deposits overlie the schist basement west of The Remarkables. These surficial materials locally form a layered sequence as a consequence of the advances and retreats of the various intrusive glaciers in the last million years approximately. This study did not attempt to resolve temporal and spatial issues associated with most of the lithologies that were mapped. On steeper slopes there are landslides and rockslides that only locally intrude into developed regions.

Rockfall, floods and debris flows pose small-scale hazards to part of the study area. Where necessary they should be avoided or mitigated. There is no evidence for active faulting but earthquake shaking effects, and liquefaction occurrences in lake sediments, should be considered in any development.

1. INTRODUCTION

This outline geological report has been prepared as a component of the strategy plan for the area generally lying east of Lake Wakatipu and extending south from the Kawarau River to Wye Creek, as outlined on Figure 1. It incorporates the more intensively mapped Jacks Point development area (Fig. 1), the geological report for which addresses many of the issues and features pertinent to the larger region.

In this study mapping has been achieved both by photogeological studies and field inspections in more accessible areas. The constructed geological map (Fig. 2) incorporates interpretations from both mapping types and, as a consequence, has varying degrees of reliability. It should also be noted that only the surface expressions of the various lithologies are presented on Figure 2; in many areas there will be a layered sequence of younger deposits some of which can only be inferred at depth or established as 'blind' formations where encountered in drill holes. No subsurface interpretations have been included as part of this study.

2. PHYSIOGRAPHY

The Remarkables range dominates both the local and more regional terrains. At an altitude of 2319 m the Double Cone peak is the highest mountain east of the main divide in Otago and there is a relative relief difference between it and Lake Wakatipu of more than 2000 m. Western slopes of the range, strongly affected by glacial erosion in the past, remain steep to precipitous and there are few embayments.

Peninsula Hill also has a marked visual impact when viewed from most perspectives. It is a roche moutoneé with a steep eastern flank but the smooth overall surface texture contrasts sharply with the craggy west face of The Remarkables.

From the toe of the latter to the lake most slopes are west-facing at moderate to low angles. Exceptions include a north-south elongated valley, with an almost flat floor, that extends from just east of Jacks Point to the Kawarau River, and an undulating spur extending south from Peninsula Hill to Jacks Point. Lake margins, and adjacent terrains, are irregularly gentle to precipitous and there are marked variations in slope element heights.

3. TECTONIC STRUCTURE

No faults have been identified in the area of interest during recent studies and there are no identified lineal features of local extent that could be interpreted as possible surface expressions of basement rupture.

However, the regional terrain is acknowledged as being structurally controlled and relief is in part a consequence of plate boundary deformation. The Remarkables are being relatively elevated on a west-dipping, NNE-SSW- trending fault that daylights in the Nevis Valley and the reverse movements on this regionally extensive feature generate shallow depth micro and macro-seismic events that have epicentral positions beneath The Remarkables and Hector Mountains, and to a lesser extent beneath Lake Wakatipu. It can be interpreted that a low angle thrust zone may underlie Lake Wakatipu near the study area at shallow depths but there is no indication it could bifurcate to intersect either the south arm of the lake or the valley axis between Jacks Point and the Kawarau River.

4. GLACIAL EFFECTS - GENERAL

The region has been repeatedly glaciated during the Quaternary period by large to small glaciers that have been sourced both in the main divide and in tributary Central Otago valleys. Evidence for glacial events is widespread and includes characteristic erosional and depositional landforms and deposits over a wide range of elevations. During the last million or so years there appears to have been a spatially diminishing sequence of glacial events that have left 'footprints' in the Wakatipu region identifying their presence.

The most significant glacier of interest is the proto Wakatipu Glacier. It split near Queenstown, with tongues extending into valleys both to the east and south, and had surface elevations of up to about 1500 at the north end of The Remarkables and along its west flank. The last advance occurred approximately 18.000 years ago, at which time the glacial tongues extended to Kingston in the south and Lake Hayes in the east. Within the study area the glacier surface is estimated to have been at about RL 440 m, thus all glacial deposits above this elevation are assumed to be related to earlier, larger advances.

Previous work has established a glacial chronology with altitudinal relationships for the Wakatipu Basin. Event differentiation has not been attempted for this study, however.

5. LAKE WAKATIPU EVOLUTIONARY CHANGES

With the melting of the 18,000 year BP glacier a lake formed in the depression with a surface much higher than that at present and an outlet within the terminal moraine at Kingston. Large deltas were constructed on the lake margin at the mouths of tributary rivers (e.g. Shotover River) and benches were constructed or eroded along the lake margin within intervening segments.

At some indeterminate time, but possibly only 5-6,000 years ago, the lake was captured by a Kawarau River tributary and a relatively rapid drop in surface level appeared to have occurred in the subsequent short time span. The lake dropped to lower than its present level but an indicated landslide blockage at the outlet raised it to the existing RL 308 m mean elevation. Various shoreline positions, commonly mantled by beach deposits, are visible both along the west margin and internally within the study area.

Tributary fans also record very clearly the rapid drop in lake level. Well-developed fan surfaces grade out to effective 'space' at many localities and these surface remnants have been strongly incised by the tributary streams that now grade to arcuate fan elements at much lower levels.

6. ROCK TYPES AND DISTRIBUTION

The following discussion largely involves the surficial deposits of mid to late Quaternary age that in part are present as layered sequences, as previously noted.

6.1 Schist

This is the basement lithology in the region. In the interest area it has an intermediate metamorphic rank (Textural Zone III) and an irregular outcrop distribution. Foliation dips are generally to the south-east at low to moderate angles.

The schist is essentially a competent rock mass although there are prominent, persistent joint sets and some of the landslides appear to be on foliation dip slopes; some local weakness along foliation can be inferred.

6.2 Glacial Till

In the central and western parts of the study area deposits of till can be defined or inferred on the basis of morphology and the presence of greywacke erratics. The majority of the visible exposures suggest a direct association with the equivalent glacier at the appropriate height (rock clasts in a commonly silty matrix; heterogeneous composition) but there are remnants with a fluvial composition indicating marginal or englacial streams were actively transporting debris at the time.

Till thicknesses will be highly variable; sometimes deceptively so. For example, in the deeply incised gully to the south of the initial zigzag in the ski field road, till is merely a mantle on a thick deposit of coarse debris interpreted as 'fan'.

Small to intermediate sized areas of till are preserved within the cirques and tributary valleys east of the spine of The Remarkables. Most appear to be very young.

6.3 Pro-glacial River Alluvium

On both sides of SH 6, generally at and below RL 400 m, there are remnants of hummocky terrain that appear to be glacial moraine both on the aerial photos and from a distance in the field, but close inspection reveals a grading and bedding nature suggestive of a fluvial (river) origin.

The limited field mapping has defined three fundamentally different types:

(a) outwash alluvium (fluvioglacial), accumulating in front of the advancing glacier and being overtopped by it with local preservation; e.g. adjacent to the north fringe of Drift Bay.

(b) kame terrace, where ice marginal streams transported and deposited glacial and tributary sediment. Subsequent ice melting may disrupt sedimentary bedding. Combination of schist and greywacke clasts, plus silt lenses, suggestive of pro-glacial association. Examples in working borrow pits just south of the ski field road; also within Jacks Point development area.

Some till cappings suggest a pre 18,000 year age.

(c) river alluvium that is schistose in composition and clearly Shotover River sourced; on the basis of weathering and grading as well. Examples are present just south of the ski field road (high knob; previously quarried) and in the north-east corner of the Jacks Point development area.

This formation lies at higher levels than known 'kame terrace' sediment and is therefore likely to be the younger of the two There is no obvious glacial association and it may therefore be a product of a normal but constrained river system rather than that in an 'ice-contact' situation.

6.4 Post-glacial River Alluvium

Wye Creek is the only river in the area that is transporting coarse debris thus limiting the category to this catchment. The fan/delta complex at the mouth has a fan morphology and could overlap with subsection 6.5 below.

6.5 Fans, Fan/Delta Complexes

Numerous streams, mostly ephemeral, drain to the west off The Remarkables. These have constructed extensive debris fans over time that have partially or completely buried other lithologies of differing ages. There is evidence that early fans have also been overtopped by younger glacial tills so the relationships are complex.

Features of particular note include:

(a) Pertinent to younger fan deposits is the stepped sequence close to the margin of the high level, former position of Lake Wakatipu. Discussed above.

(b) Fans continue to aggrade onto the floor of the central elongate valley, although the rate of sediment accumulation is uncertain.

(c) Significant streams entering the lake in the Drift Bay vicinity do not appear to have created shoreline fans. Sediment transport is assumed to be small, therefore.

(d) Thick loess (to 3-4 m) mantles at least some fans in the distal (western) segments. This modifies fan surface morphologies in part and also suggests the sediment supply below SH 6 is generally small.

6.6 Beach Deposits

One or more benches are locally preserved along the band of erosion and accumulation formed along the former lake edge as the water level dropped. These benches are mantled with a varying thickness of poorly graded 'gravel' that is a distinctive, but surficial lithology.

Beach deposits are veneers on other formations.

6.7 Lake Sediments

At higher lake levels fine sediments accumulated offshore to form a laminated sequence of silt and sand that is visible in outcrop at both ends of the narrow, central valley south of the Kawarau River.

Much of the sediment would have been Shotover River sourced.

6.8 Landslides/Rockslides

Mass movement deposits irregularly mantle schist slopes on The Remarkables and Peninsula Hill. Some are obviously failures on foliation but a few of the slides on the steep west flank of The Remarkables are controlled by the persistent joint sets. Failures in surficial deposits are small, rare and probably confined to the lake margin.

No attempt has been made to classify the slides by activity. Some are clearly moving, either in part or as a whole, whereas others have an uncertain status. It is unlikely that large slides are dormant or inactive over a longer time interval.

6.9 Colluvium

Clastic and fine material, washed or rolled down steep slopes or formed by small ephemeral streams (transitioned to 'fans'), form local deposits on The Remarkables and along Wye Creek.

7. GEOLOGICAL HAZARDS

7.1 Seismotectonic Hazards

There is no evidence for active faulting within the study area although the elongate valley at and west of SH 6 may be structurally controlled. Quaternary movements cannot be disproved as the cover beds are all relatively young but the risk of direct displacement is considered to be very low in the next couple of hundred years.

Shaking effects due to earthquakes generated on faults in Central Otago, and the Alpine Fault in particular, need to be considered in the design of any buildings constructed in the area with a particular emphasis on the region underlain by lake sediments. There are mapped depressions in this lithology, very likely resulting from earthquake-induced liquefaction, albeit at an unknown period of time and with uncertain relationships to the level of Lake Wakatipu.

7.2 Landslides/Rockslides

Most have formed on steep terrain away from prospective development areas. There are no evident occurrences of catastrophic failures since glaciers last intruded to the toes of the steeper slopes and major embayments on the flanks of The Remarkables are absent, suggesting an inherent slope stability.

First time failures in the future cannot be dismissed but the risk is considered to be very low on the basis of observed (lack of) incidences in a long time frame.

7.3 Rockfall

At several locations along the toes of the west-facing slopes of The Remarkables individual or clusters of large schist blocks lie on the fan surfaces. These have clearly originated as rockfall on the steep terrain.

Most are close to, or perhaps within 100 m of, the base of the steep slope but one boulder is approximately 300 m out and this distance should be kept in mind as a possible travel path. As the total slope morphology changes laterally along The Remarkables the prospective hazardous zone should be uniquely evaluated for particular circumstances.

7.4 Floods and Debris Flows

Tributary streams off The Remarkables obviously flood during rainstorm events and occasionally transport debris to varying distances down the fan. At this time most tributaries have defined channels within the peripheral fans but avulsion must occasionally occur with resulting redistribution of flood waters and debris.

All fans and fan elements have the potential to be affected by flooding. Debris flows are prospective on upper fan segments, particularly where slope gradients are relatively steep but the debris flow risk must diminish in more distal, flatter areas.

8. CONCLUSIONS

(a) The terrain generally west of The Remarkables, and between the Kawarau River and Wye Creek, varies from flat to precipitous and there is a relative relief difference between Lake Wakatipu and the mountain crest in excess of 2000 m.

Most slopes are west-facing in the area studied.

(b) No faults have been located in the study area but some structural control is likely as inferred from the lineal nature of the valley at and west of SH 6. An active fault daylighting further east in the Nevis Valley dips west beneath The Remarkables and Lake Wakatipu. There is ongoing seismic activity associated with this feature.

(c) Repeated glacial erosion during Quaternary times has sculptured the area and routinely removed surficial deposits. The last glacial incursion was 18,000 years ago. When the ice melted a proto Lake Wakatipu formed at higher levels then dropped to its present dimension after capture by the Kawarau River. The changing lake margin is evident through the study area.

(d) Surficial deposits of various ages and types are present throughout much of the moderate to low relief terrain. These include glacial till, glacially-related fluvial sediments, lake deposits and fans. In many localities there is a sequence of lithologies, the lower of which are imprecisely understood.

(e) Landslides and rockslides are present on many steep slope elements in schist. No catastrophic failures have been identified.

(f) Obvious hazards are posed by rockfall, floods and debris flows. However, these are relatively minor and should be able to be avoided or mitigated should developments occur in the future in the study area. Seismotectonic effects need to be addressed in line with standard practice for the Queenstown area.