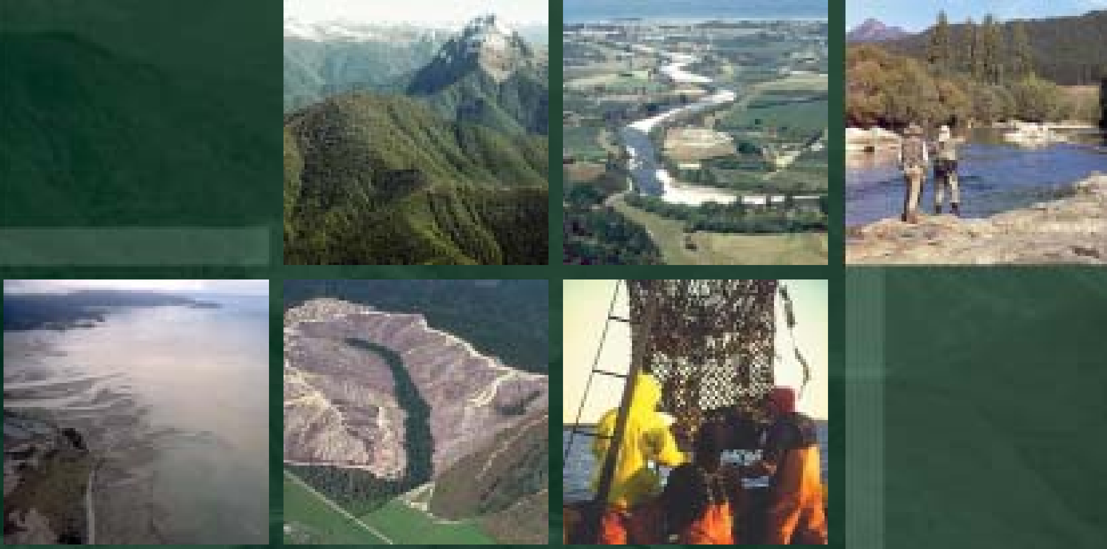

The Motueka and Riwaka Catchments

A technical report
summarising the present
state of knowledge of the
catchments, management
issues and research needs
for integrated catchment
management

Compiled by L. R. Basher

Manaaki Whenua
Landcare Research

TDC Tasman District Council

CAWTHRON

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The Motueka and Riwaka catchments

A technical report summarising the present state of knowledge of the catchments, management issues and research needs for integrated catchment management

Compiled by L.R. Basher[1]

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Preface

When beginning any new research programme, a key first step is to understand existing knowledge about the topic. This report is the synthesis of existing knowledge about the environment of the Motueka River catchment. This major catchment, incorporating its smaller neighbour the Riwaka, and the associated coastal ecosystem in Tasman Bay is the base for New Zealand's Integrated Catchment Management (ICM) programme. The ICM research programme, begun in 2000, is a partnership between Landcare Research, Cawthron Institute and Tasman District Council. It is a bold initiative to work with local government, sector groups and communities to provide solutions to the issue of identifying sustainable patterns of land and water uses. ICM research builds on a rich history of New Zealand research on natural as well as human impacts on land and water resources.

'Integrated Catchment Management', or ICM, is an approach, now accepted globally, to managing our land, rivers and coast in an interconnected holistic fashion. ICM encompasses the principles of integration among science disciplines, integration between communities, scientists and environmental managers, and management of natural resources within catchment or watershed boundaries. In New Zealand, it is reflected strongly in the purpose of our Resource Management Act 1991 in which section 30 requires our environmental management agencies (regional and unitary councils) to achieve "integrated management of the natural and physical resources of the region".

This Technical Report for the Motueka Catchment is a major milestone for this programme. The Motueka River catchment was chosen as a focus for study, not because its problems are unique, but rather because its problems are common. What we learn about the science of integration and the integration of science with management here will be transferable elsewhere, in New Zealand and internationally. Indeed, this is happening now.

The Motueka ICM Programme was singled out as a model for UNESCO's new *Hydrology for Life, Environment and Policy (HELP)* programme. The Motueka River provides an especially suitable case study because the range of management issues is wide and the cost of 'getting it wrong' is especially high. Fortunately, the stakeholders in the Motueka area have demonstrated a special willingness to develop shared visions and work toward common goals. This development of "social capital" is a critically important component of successful ICM efforts.

This Technical Report is neither a beginning nor an end. Rather, it is an important assessment of state. It is intended that this document to be treated as a living resource, to be periodically updated and improved as the participants develop new data and experiences. Ideally this document will serve as a model for other communities, to achieve the outcomes they share. It complements the information presented on the Motueka River ICM website (http://icm.landcareresearch.co.nz/) which provides up-to-date information on the research programme, and allows interested people to interact with the programme.

We would like to acknowledge the tremendous efforts of the scientists, collaborators and friends of the Motueka ICM programme who worked together to produce this summary of knowledge, upon which our research is building. We thank the Foundation for Research, Science and Technology for funding the preparation of this report under contracts C09X0014 and C09X0214. Special thanks to Tasman District Council for allowing us access to their records, for the contribution of staff time to the preparation of the report, for assistance with publication costs, and for being a partner in the programme. We thank the Cawthron Institute for their contributions to the report, and for their vision in becoming a partner in the ICM programme. Fish & Game New Zealand, Nelson Marlborough Region made available unpublished data and also contributed to the report. Staff of the Department of Conservation, Nelson Conservancy made a valuable contribution to the report. Thanks to Bob South (Fish & Game magazine), Terry Duval and Rowan Strickland for allowing us to use their photos to illustrate the report. We thank the numerous other people who contributed to the report, provided information or their perspective on the state of the Motueka River catchment, and discussed the important issues for catchment management with us – we have already learnt a great deal from you. Christine Bezar edited an earlier draft of the report, and Kirsty Cullen produced the final graphics and design layout.

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Executive Summary

The Motueka Integrated Catchment Management project is a programme funded by the Foundation for Research, Science and Technology, which aims to: *"Improve management of and social learning about land, freshwater, and near-coastal environments in catchments with multiple, interacting, and potentially conflicting land uses".* The project is a partnership between Landcare Research, the Cawthron Institute, and Tasman District Council, with contributions from other research providers and the community. It takes a "ridge tops to the sea" perspective, using the Motueka River as a case-study catchment, to address cumulative effects of past, present, and possible future natural-resource-uses on land, freshwater, and marine resources.

This Technical Report is a contribution to a knowledge base being developed for the Motueka River catchment to assist integrated catchment management. It:

- reviews existing information on the physical, social and cultural environment;
- lists the range of existing data sources (including maps, photos, satellite imagery; climatic, hydrologic, geologic, soils and ecological databases);
- describes the current statutory framework for land and water resource management (including the Resource Management Act, Tasman Resource Management Plan, the Motueka River Water Conservation Order, Department of Conservation Management Strategy for the Nelson Marlborough Conservancy and Management Plan for Kahurangi National Park);
- describes the key issues for land and water resource management in the catchment (water quantity, sediment, water quality, aquatic ecology, riparian management, Motueka Catchment – Tasman Bay interactions) and outlines research needed to underpin improved management of land and water resources.

The Motueka River drains the largest catchment in the Nelson Region, with an area of 2180 km^2 (including the Riwaka River) and a main stem length of about 110 km. It provides the major freshwater flow into Tasman Bay, a productive, shallow water body of high economic, ecological, and cultural significance. Environmentally the catchment is very complex with:

- annual rainfall ranging from about 950 mm to more than 3500 mm, marked wet (winter) and dry (summer) seasons, and high variability of rainfall (monthly and annual);
- elevation ranging from sea level up to 1850 m;
- a dominance of mountainous and hilly terrain, with limited (but agriculturally very important) areas of flat terraces and floodplains;
- a wide variety of rock types including old igneous and sedimentary rocks, young sedimentary rocks, a large area of clay-bound Moutere gravels, and small (but hydrologically very significant) areas of younger alluvium;
- a complex soil pattern resulting from the variety of landforms, climate and geology;
- vegetation dominated by native (35% of catchment area) and exotic forest, and smaller areas of pastoral grassland, scrub, tussock grasslands, and crops.

The major productive land uses are production forestry (25% of catchment area), sheep and beef farming (19%), and limited but increasing dairying. Horticulture (mainly pipfruit, berryfruit, hops, vegetables) occupies a small, but expanding, area and is a major water user. Most crops are irrigated from surface or groundwater during the summer. A large area of the catchment (55%), mainly in the high rainfall headwaters of the western tributaries (Kahurangi National Park) and upper Motueka (Mt Richmond Forest Park), is conservation land (forest, scrub and tussock grasslands). These areas are very important for soil and water conservation and biodiversity.

The catchment is sparsely populated with a total population of about 12,000, mostly in the town of Motueka (c. 7000). Rural population density is about 2/km^2. Population growth is estimated at about 2% per annum. Māori groups first settled the Motueka area before AD 1350 and four iwi (Ngāti Rarua, Te Ati Awa, Ngāti Tama, Ngāti Kuia) have a close spiritual and physical relationship with the Motueka – Tasman Bay area. European settlement began in the 1840s. Widespread deforestation occurred in response to settlement by both Europeans and Māori, although significant reforestation (especially with *P. radiata*) has occurred since then.

Annual flow of the Motueka River at Woodstock is 844 mm, compared to a mean annual rainfall for the contributing catchment of 1600 mm. The Motueka has a mean flow of 58,560 litres/second (L/s) (7-day running mean for Motueka at Woodstock), a median flow of 33,950 L/s, and a mean annual low flow of 10,216 L/s. The measured flow range is from about 5600 L/s to >2,100,000 L/s. Mean monthly flow is distinctly seasonal, with higher flow in the winter and spring, and lower flow in summer months. This seasonality is more marked for low flows. Periodic large floods and extended low-flow periods are a characteristic feature of the hydrology. River flow generation is controlled by rainfall distribution and geology, with large differences in specific discharge between catchments underlain by old, basement rocks (>40 L/s/km^2) and Moutere gravel (<20 L/s/km^2). Land use can have a significant effect on water yield in areas underlain by Moutere gravel. Aquifers under the floodplain and fans of the Motueka Plains near the coast, and the terraces and floodplains of the upper Motueka River around Tapawera contain groundwater resources. Water is extracted from both these sources, and from surface water, for irrigation and domestic use.

Water quality in the Motueka River tends to be high. Nutrient concentrations are relatively low compared to other parts of the New Zealand, but are highest in the small streams draining pasture and horticultural land and there is evidence of enrichment in the lower reaches of the river. Suspended sediment concentrations are generally low, but tend to be higher in small streams draining pasture and horticultural land, and in streams draining granite catchments particularly where forest harvesting is occurring. Relatively high concentrations of harmful bacteria can at times be found associated with dairy farming and horticulture.

The Motueka has a moderately diverse range of native freshwater fish species (14 of New Zealand's c. 40 native fish species, including galaxiids, bullies, and eels), and five estuarine and marine species in the lower reaches (black flounder, kahawai, yellow-eyed mullet, stargazers, cockabully). Macroinvertebrate communities are diverse (at least 119 taxa dominated by caddisflies, true flies, mayflies, and stoneflies) and generally dominated by animals characteristic of unpolluted habitats, unmodified streams, and high aquatic habitat quality. Algal growth in the river is prolific during low-flow periods and approaches nuisance levels in the lower reaches at times. High rates of algal production provide a large food source for macroinvertebrates, and support abundant macroinvertebrate and fish populations in the river.

The Motueka is a nationally important brown trout fishery, renowned for the abundance and size of trout. Maintaining high-quality habitat for fish and invertebrates is fundamental to maintaining the fishery. Recently the fishery has shown a decline, ascribed to influx of fine sediment from land disturbance on granite terrain.

The Motueka River flows into, and is a major influence on, highly productive coastal and shallow marine ecosystems in Tasman Bay. The estuarine and coastal area around the mouth of the river is important for a range of fish and shellfish, while Tasman Bay supports a wide variety of plankton, benthic organisms and fish. Scallops, oysters, mussels, cockles and snapper are important commercial and recreational fisheries. The river provides about 62% of the total freshwater inflow to Tasman Bay, carrying with it nutrients and organic matter. This causes water column stratification, spatial and temporal variation in nutrient concentrations, and affects the ecology of the bay (e.g., high sediment loads during floods cause poor recruitment and growth of scallops in the plume of the river). Following big storms, the Motueka River freshwater plume covers nearly the entire western side of Tasman Bay, extending more than 18 km offshore.

The Motueka Catchment is widely used for recreational activities, including trout fishing, eeling, whitebaiting, tramping, canoeing, rafting, and hunting. Kahurangi National Park, Mt Richmond Forest Park and the Motueka River itself are especially important recreational areas with many thousands of people visiting the river and its catchment each year.

Key resource management and environmental research issues in the catchment centre around:

1) *Water quantity*. Over much of the catchment demand for water exceeds supply, resulting in competition for water between land uses (e.g., horticulture and forestry), and between water abstraction and maintenance of in-stream values.
2) *Sediment*. Little is known of the influence of land use on sediment generation and transport, how sediment influences trout and native fish populations, and the role of gravel extraction in affecting bed and bank stability.
3) *Water quality*. Concentrations of nutrients (primarily nitrogen) and faecal indicator bacteria (and associated pathogens) can be high in the lower reaches of the river and may affect the expanding aquaculture industry in Tasman Bay.
4) *Aquatic ecology*. The Motueka River has a world-famous trout fishery, which has declined recently, but there is no consensus on the reasons for this decline. Little is known of the spatial and temporal distribution of native fish fauna, and how these are influenced by land use.
5) *Riparian management*. There is increasing

interest in the role of riparian vegetation in maintaining water quality and aquatic habitat, but little is known of which areas in the Motueka could benefit from changed riparian management and what would be the benefits of improved riparian management.

6) *Motueka Catchment – Tasman Bay interactions*. The Motueka Catchment is the major source of freshwater and land-derived nutrients into Tasman Bay, and is a major influence on its productivity. The influence of land use on the quantity and quality of freshwater delivered to Tasman Bay and on the food web within the bay is poorly understood, as are the opportunities for, and effects of, aquaculture on water quality.

The goal of the Motueka Integrated Catchment Management programme is to use historical research, biophysical experimentation, simulation modelling, and social learning to address these resource management issues.

1. Introduction

A research programme aimed at improving management of land and water resources[1] by adopting an integrated, catchment-based approach has been initiated in the Motueka River[2] catchment. The project originated from a workshop in March 1998 with a wide range of science stakeholders in Nelson who identified the main regional research issue as:

"the need to improve understanding of the effects of land use on freshwater, coastal and marine ecosystems".

Similar concerns exist elsewhere in New Zealand and the Motueka River study is intended as a case study to develop a framework for integrated catchment management (ICM) research that can be applied anywhere.

The research programme is based on the Motueka River for a number of reasons including:

- the diversity of resource management issues on the land, the rivers and streams, and in the coastal and marine environment;
- the wide variety of land uses including intensive horticulture, forestry, pastoral farming, dairying and a large area of national park in the headwaters;
- the complexity of environmental characteristics (climate, geology, soils) in the catchment;
- the large amount of existing knowledge about the catchment; and
- a willingness by a wide range of affected individuals and groups to be involved in, and contribute to, the research programme.

The major resource management issues in the Motueka Catchment include:

- debate over water resource allocation between different user groups, particularly horticulture and forestry;
- competition between in-stream and out-of-stream water uses, highlighted by the application

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[1] Where land and water resources or issues are referred to, this includes land, freshwater, coastal and marine components.

[2] Both the Motueka and Riwaka catchments are included in the research programme as they are managed under a single management plan, and both influence the marine environment of Tasman Bay. Where the Motueka Catchment is referred to throughout the text it includes the Riwaka River.

in progress for a Water Conservation Order on parts of the Motueka River;

- water management issues arising from uncertainty about the degree and extent of linkages between surface and groundwater and how to manage these in an integrated manner;
- concerns about sediment and nutrient delivery into rivers from some land-use activities, and the impact on the internationally renowned trout fishery in the Motueka River;
- the debate over aquaculture opportunities in Tasman Bay, with concerns about both the environmental impact of aquaculture and the potential impact of terrestrial land use on marine water quality and aquaculture.

Integrated catchment management is an approach that recognises the catchment[3] as the appropriate biophysical unit for organising research on ecosystem processes for the purpose of managing natural resources. It also recognises that social, economic and political frameworks are integral elements of the management of natural resources, and of resource management research.

Rather than focusing on small-scale processes or isolated activities, this ICM approach seeks to provide an integrative framework for understanding the cumulative interactions of past, present, and possible future natural resource uses on land, freshwater, and marine resources. It takes a "ridge tops to the sea" perspective to address large-scale, regional issues that often perplex communities and resource managers (e.g., water allocation, water quality, habitat quality, land and coastal productivity). As well as a biophysical focus in understanding how resource use influences land, freshwater, and marine ecosystems there is a strong focus on developing an understanding of how to create a favourable social environment in which science can best be used to make decisions about resource management. This ICM approach is receiving increasing international support, such as through the UNESCO/WMO programme "Hydrology for the Environment, Life and Policy" (HELP) which recognises that sustainable management is as much a social and economic question as a technical biophysical one (Fenemor, 2002a).

The Motueka ICM programme is a partnership between Landcare Research, the Cawthron Institute and Tasman District Council. It has the stated outcome of

"Improved management of and social learning about land, freshwater, and near-coastal environments in catchments with multiple, interacting, and potentially conflicting land uses".

The initial objectives of the programme are to:

- develop a knowledge base to promote information integration, synthesis and delivery about integrated catchment management of the Motueka River;
- construct catchment water-balance (and ultimately nutrient-balance) models to explore past, present and possible future connections between rainfall, land characteristics, land use and land management practices, surface and groundwater resources;
- identify the nature, value, and functions of riparian and in-stream habitats;
- quantify the processes and controls on productivity in the coastal sea environment of Tasman Bay; and
- promote social learning for integrated catchment management in the Motueka River catchment.

This report is a contribution to the first objective, namely the knowledge base aimed at promoting information integration, synthesis and delivery for the Motueka River catchment. It reviews the available information on the physical, social and cultural environment, lists the range of existing data sources, and describes the current statutory framework for land, fresh water and coastal resource management. From this synthesis it has been possible to identify a number of major resource management issues and the research needed to underpin improved management of land and water resources.

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[3] The land area drained by a river. In this case it also includes the marine area affected by river discharge.

2. Literature review and synthesis

2.1 PHYSICAL SETTING

The Motueka Catchment is situated at the western margin of the Moutere Depression and drains an area of 2180 km^2 – the largest catchment in the Nelson region (Fig. 1). It flows into Tasman Bay, a shallow but productive coastal water body of high economic, ecological and cultural significance. The Riwaka River drains a 105 km^2 catchment that flows into Tasman Bay 3 km north of the Motueka River mouth (Fig. 1 and Photo 1a).

The main stem[4] of the Motueka River rises in the Red Hills and flows north for about 110 km to the sea (Fig. 1). The river is joined from the east by a series of small and medium-sized tributaries (Stanley Brook, Dove, Orinoco, and Waiwhero) draining hilly terrain underlain by Moutere gravels, and from the west by a series of generally much larger tributaries, which drain both hilly terrain on Moutere gravels (Motupiko, Tadmor) and mountainous terrain underlain by a complex assemblage of sedimentary and igneous rocks (Wangapeka, Baton, Pearse, Graham, Pokororo, Rocky River and Brooklyn Stream). Similarly, the Riwaka River drains dominantly mountainous terrain underlain by sedimentary and igneous rocks. The major subcatchments and their areas are listed in Table 1. Elevation ranges from sea level up to 1600–1850 metres on the catchment divide in the upper reaches of the Motueka, Baton and Wangapeka rivers. Most of the catchment lies at relatively low elevation, with more than 50% being between sea level and 500 m.

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[4] This is the main stem of the Motueka only in a geographical sense; hydrologically the Wangapeka is more important as it drains a larger area and contributes more water.

Fig. 1 Map of Motueka catchment, showing localities mentioned in the text.

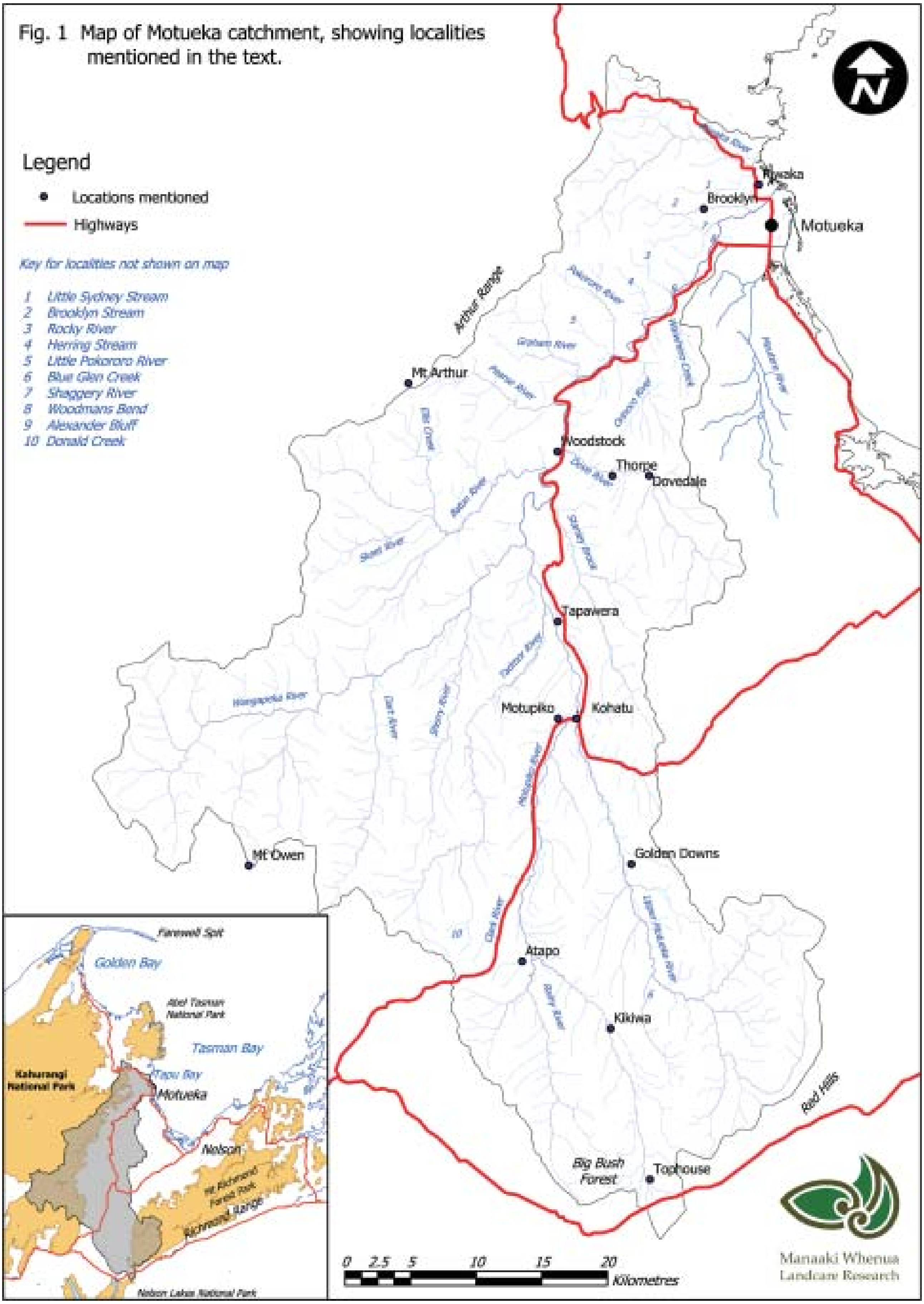

Photo 1a Broad, low-angle fan of the Motueka–Riwaka plains. Riwaka River enters Tasman Bay in the foreground and the Motueka in the middle distance. Note the prominent wetlands, delta and sandspit formed by the Motueka River.

Photo 1b Meandering channel of the lower Motueka River across the Motueka–Riwaka plains. Channel is confined between stopbanks. Note the old cutoff meander bends and intensive horticulture on the plains. Motueka township in the background.

TRIBUTARY	AREA (km^2)	AREA (%)
Upper Motueka	419	19
Motupiko	344	16
Tadmor	124	6
Stanley Brook	93	4
Dove	102	5
Orinoco, Waiwhero	92	4
Wangapeka	483	22
Baton	212	10
Pearse	49	2
Graham	40	2
Pokororo, Herring, Rocky	93	4
Brooklyn	17	1
Riwaka	105	5

Table 1: Subcatchment areas

2.1.1 Physiography

The catchment is dominated by mountains and hill country (Fig. 2). About 67% of the catchment has slopes greater than 15º (Fig. 3). The mountains are characterised by strong lithologic and structural control of landforms (Photos 2 and 3), with dip-and-scarp[5] topography common and notable areas of karst[6] on Mt Owen and Mt Arthur. The hilly terrain can be grouped into three types:

- intensely fluvially dissected hill country on Moutere gravels, with linear, regularly spaced valleys and ridges (Photo 4);
- smaller areas of dip-and-scarp topography on young sedimentary rocks; and
- smoothly rounded hill country on granite (Photo 5).

There are limited areas of gently sloping floodplain, terraces, and fans. The two most extensive flat areas are the 40-km^2 Motueka-Riwaka Plain near the coast (Photo 1) and the 33-km^2 upper Motueka Plains around Tapawera and Motupiko (Photo 4). Other significant areas of flat land flank the Dove, Tadmor, Stanley Brook, Motupiko, lower Wangapeka, and Sherry rivers. At the coast there is a small area of dunes and gravel ridges.

The New Zealand Land Resource Inventory (NZLRI) maps most of the catchment as Land Use Capability classes 6–8, with only 13.3% being classed as suitable for arable cropping (classes 1–4) and 1.8% as highly versatile classes 1 and 2 (Table 2).

The main features of the river system include:

- steep, narrow headwater channels (Photos 2 and 3);
- broad floodplain and terrace systems within hilly Moutere gravel terrain, from below the upper Motueka Gorge to the Wangapeka confluence (Photo 4);
- a confined granite section below the Wangapeka confluence to Woodstock (Photo 5);

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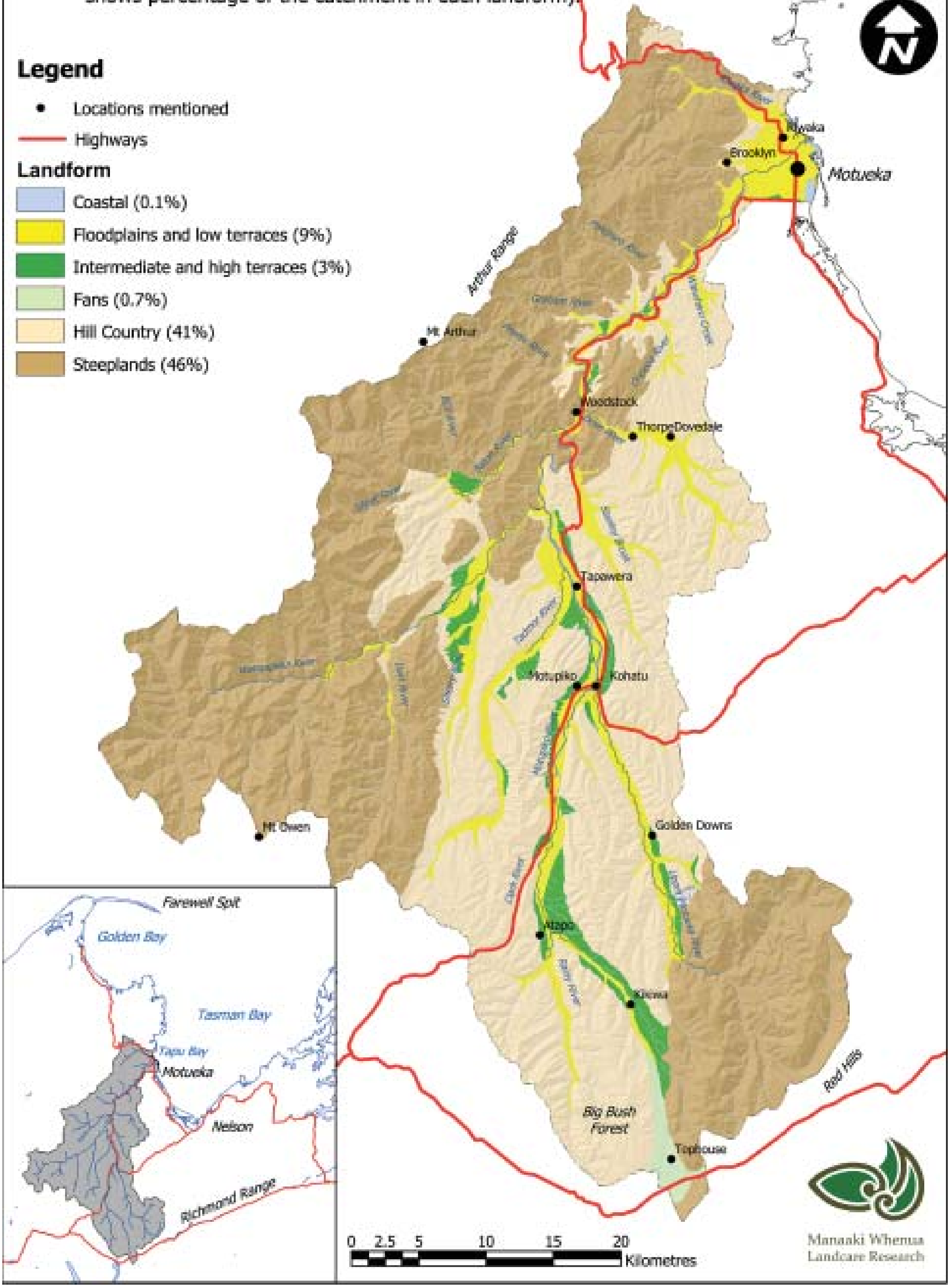
[5] Landscapes (usually in sedimentary rocks) characterised by a pattern of gentle dip slopes parallel to rock bedding and steep scarp slopes cutting across bedding.

[6] Landscapes formed from marble and limestone where solution of the rock is the major weathering process, characterised by sinkholes, caves, pitted relief, extensive bare rock and highly irregular drainage patterns.

Fig. 2 Map of Landforms in the Motueka catchment (legend shows percentage of the catchment in each landform).



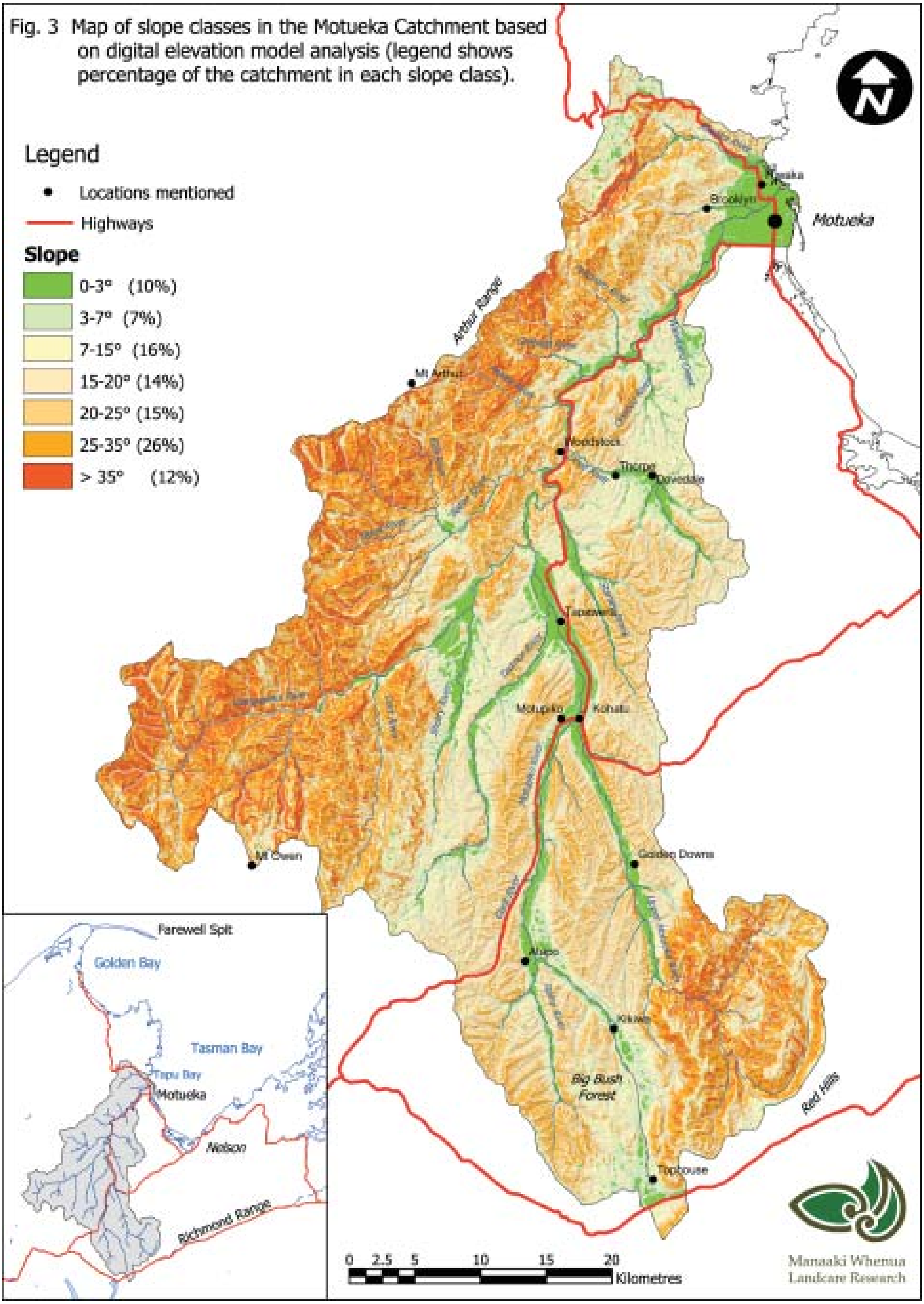


Fig. 3 Map of slope classes in the Motueka Catchment based on digital elevation model analysis (legend shows percentage of the catchment in each slope class).

Photo 2 Steep narrow headwater channels and mountainous terrain in the upper reaches of the Wangapeka River. A few landslides are visible on the left of the photo.

Photo 3 Steep headwater channels in the right branch, upper Motueka River. Note the sharp vegetation contrast between the scrub on Dun Mountain ultramafic rocks (to the right) and forest on the Maitai Group sediments (to the left), and the active sedimentation of the stream channel caused by a localised storm in 1998.

Photo 4 Motueka–Motupiko confluence with broad floodplain and terrace systems flanked by fluvially dissected Moutere gravel hill country with extensive plantation forestry.

Photo 5 Motueka River below the Wangapeka confluence with meandering channel cut into granite ranges.

LUC CLASS	AREA (km²)	AREA (%)
1	22.6	1.0
2	17.9	0.8
3	146.4	6.7
4	104.1	4.8
5	4.5	0.2
6	344.1	15.8
7	872.1	40.0
8	661.0	30.3

Table 2: Percentage of land in different Land Use Capability classes (derived from the New Zealand Land Resource Inventory)

Photo 6 Motueka River near Woodstock with narrow valley flanked by terraces confined between granite ranges.

2.1.2 River forms

Landforms, along with geology and rainfall, tend to be the key determinants of the type of rivers and streams found in the Motueka Catchment. The general form of rivers and streams can be grouped within three regional types: (1) those of the western and headwater ranges, (2) those of the lower-relief Moutere gravel hill country, and (3) those of the alluvial terraces and plains. Together these regions contain a diversity of river forms (or morphologies), providing a wide range of habitats for native fish and trout and locations for river-based recreation.

Streams in the western and headwater mountain ranges are characteristically bouldery, with steep gradients. Smaller stream channels at higher elevations tend to have cascade-step pool or riffle-pool morphologies, and bed materials range from boulder to cobble and gravel reflecting the wide variety of source lithologies. In many places bedrock controls the frequency of pools and the lateral form of the river. These streams show increasing entrenchment and the development of river terraces at lower elevations and lower river gradients. The banks of most of these rivers are clad in native forest and scrub, and the characteristically steep catchments remain in tussock, native forest, or scrub vegetation. The headwaters of the Wangapeka, Baton, Pearse and upper Motueka rivers are typical of these types of streams.

The lower-relief Moutere gravel hill country is characterised by high drainage density – with many small ephemeral streams – and generally lower gradients than for the mountain streams. River form tends to be riffle-pool or riffle-run with characteristically narrow, moderately entrenched channels, and generally well-developed alluvial terraces. Bed materials are typically cobble-gravel-sand-silt reflecting the dominance of Moutere gravel source lithologies. Surrounding land uses are varied and include grassland, exotic forestry, reverting scrub, and native forest remnants. Riparian areas are typically modified, particularly in areas of pastoral farming, with little or no tall vegetation.

Rivers and streams of the alluvial plains typically have low gradients and well-developed terrace sequences. River morphology tends to be riffle-pool with wide channels, and grain size tends to be cobble-gravel-sand. River channels are typically meandering though constrained by bedrock in some areas, particularly in the middle to lower reaches of the Motueka where the river cuts through Separation Point granite. These alluvial plains are predominantly in pastoral farming and horticulture. In many areas stopbanks control the lateral extent of the river course and some streams have been modified for drainage purposes in the area around Motueka (e.g., Little Sydney Stream).

2.1.3 Man-made modifications

Management of the river for flood control purposes has resulted in significant modification of the channel of the main stem of the Motueka River and some of its tributaries. An early map (1842) of the lower Motueka River shows a completely different configuration of the lower reaches of the river and the coastline (Fig. 4). Works have been undertaken as part of the Motueka Catchment Control Scheme (Green 1982) and earlier schemes. The Lower Motueka Flood Control Scheme provided flood control in the lower 12 km of the Motueka and the lower 3 km of the Riwaka River in 1954. River control works (fairway clearance and bank protection) were implemented in 18 km of the upper Motueka and 14 km of the Motupiko in 1958. Complementing these river control measures were soil conservation farm plans and erosion control schemes, primarily for gully and streambank stabilisation on Moutere gravel terrain with some on granite. The major works initiated in 1982 as part of the Motueka Catchment Control Scheme, (see Green 1982; Fenemor 1989), include:

- stopbanks – these are located along the lower Motueka from about 2 km below the Alexander Bluff bridge to the sea, the east bank of the middle Motueka between Tapawera and Kohatu, the lower reaches of the Brooklyn Stream, and the lower Motupiko;

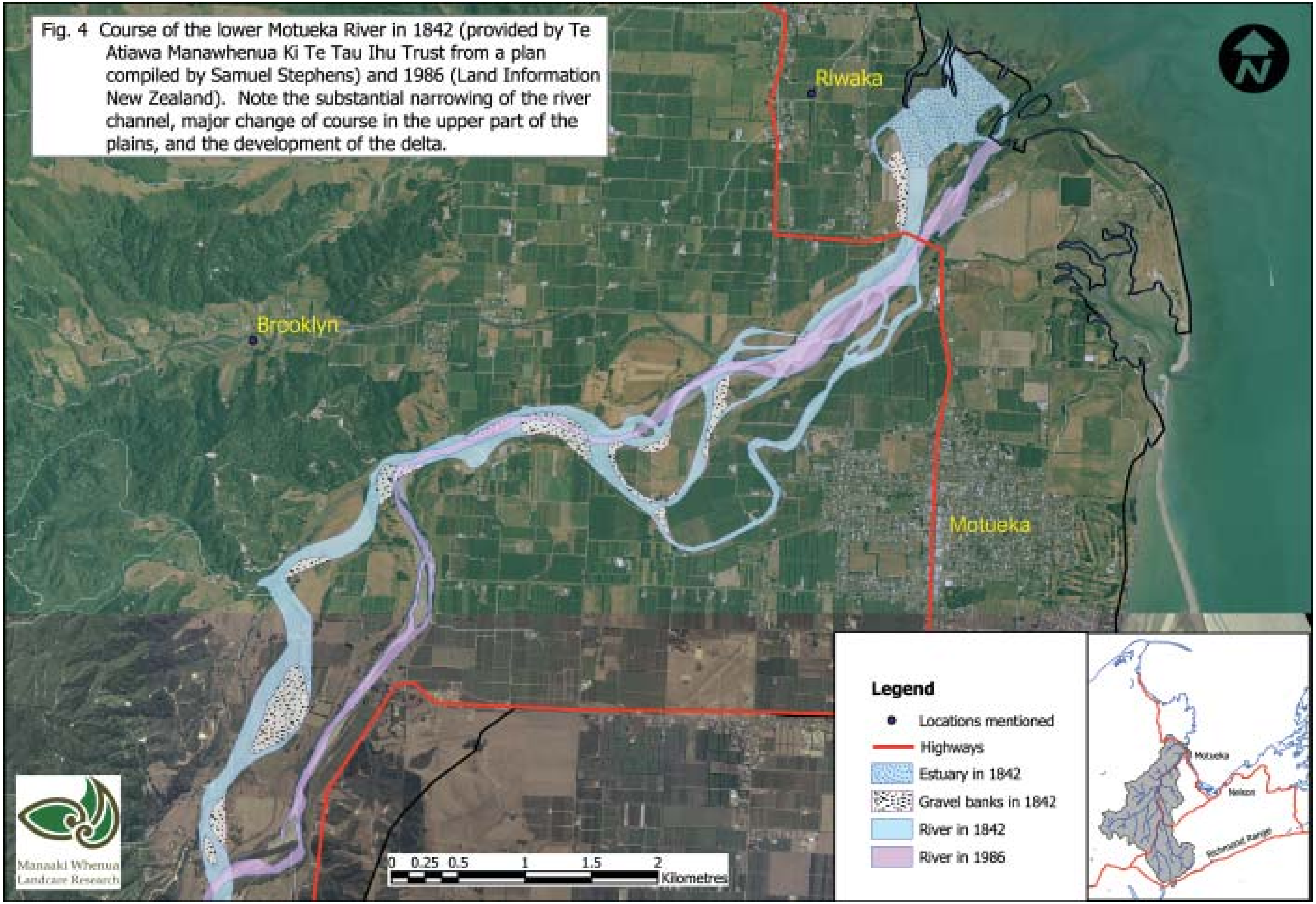


Fig. 4 Course of the lower Motueka River in 1842 (provided by Te Atiawa Manawhenua Ki Te Tau Ihu Trust from a plan compiled by Samuel Stephens) and 1986 (Land Information New Zealand). Note the substantial narrowing of the river channel, major change of course in the upper part of the plains, and the development of the delta.

- a series of cuts to straighten the channel of the lower Motueka;
- establishment of clear channels of uniform width, using a combination of river training, fairway clearance, bank protection (using rock, plant materials, or a combination of both), and groynes;
- provision of vegetation screens along riverbanks to contain the spread of water and sediment from rivers during floods.

The river control works have been complemented by streambank and gully stabilisation works.

The major impact of river control has been to narrow and straighten the main channel of the river, particularly in the lower reaches (see Fig. 4). The within-channel works have been complemented by soil conservation works and land management practices aimed at stabilising small and ephemeral watercourses, reducing gully and streambank erosion, and controlling vegetation disturbance, particularly on Separation Point granite (Green 1982).

2.2 GEOLOGY

The Motueka Catchment is geologically very complex compared to many other South Island catchments. The geology is described by Grindley (1961, 1980), Beck (1964), and Johnston (1982a,b, 1983, 1990), and has recently been remapped by Rattenbury et al. (1998). A wide variety of rock types are present, including:

- old ultramafic and sedimentary rocks in the upper Motueka headwaters;
- a complex array of sedimentary and igneous rocks underlying the western tributaries;
- Moutere gravels and younger alluvium underlying the middle and lower reaches and eastern tributaries of the Motueka.

Each of these groups of rock types comprises several different lithologies whose distribution is shown in Fig. 5.

Ultramafic and old sedimentary rocks form the mountains at the south-western end of the Richmond Range in the headwaters of the Motueka. This group includes strongly indurated[7], ultramafic[8] rocks of the Dun Mountain Group (early Permian age, 260–290 Ma), and old sediments of the Maitai Group. The latter comprise well-bedded, strongly indurated, and weakly metamorphosed sandstone, siltstone, and argillite of late Permian age (c. 250 Ma).

Similarly, the headwaters of the western tributaries of the Motueka, and part of the middle reaches of the Motueka, are underlain by a complex array of sedimentary and igneous rock types including:

- old basement rocks of Devonian to Cambrian age (350–500 Ma). These include indurated and faulted marble, limestone, greywacke, argillite, and schist of the Mt Arthur, Mt Patriarch and Greenland groups, and diorite and gabbro of the Riwaka igneous complex;
- granitic rocks (granite and granodiorite) of the Separation Point Suite (dated to the Cretaceous period, 109–121 Ma). These rocks are often deeply weathered and highly erodible;
- younger and less-indurated sediments (marine mudstone, sandstone, limestone) of the Rapahoe, Nile and Blue Bottom groups. These are Eocene to Miocene in age (5–50 Ma). These rocks extend from the Tadmor Valley across the Sherry, to the lower Wangapeka and Baton catchments.

The hilly terrain of the Moutere Depression, making up most of the eastern side of the catchment and the Motupiko and Tadmor valleys, is underlain by much younger alluvial sediments of the Moutere gravel formation. This is a thick (0.7 km near Tapawera), weakly indurated, and deeply weathered gravel of late Pliocene to early Pleistocene age (1–3 Ma). It is dominated by

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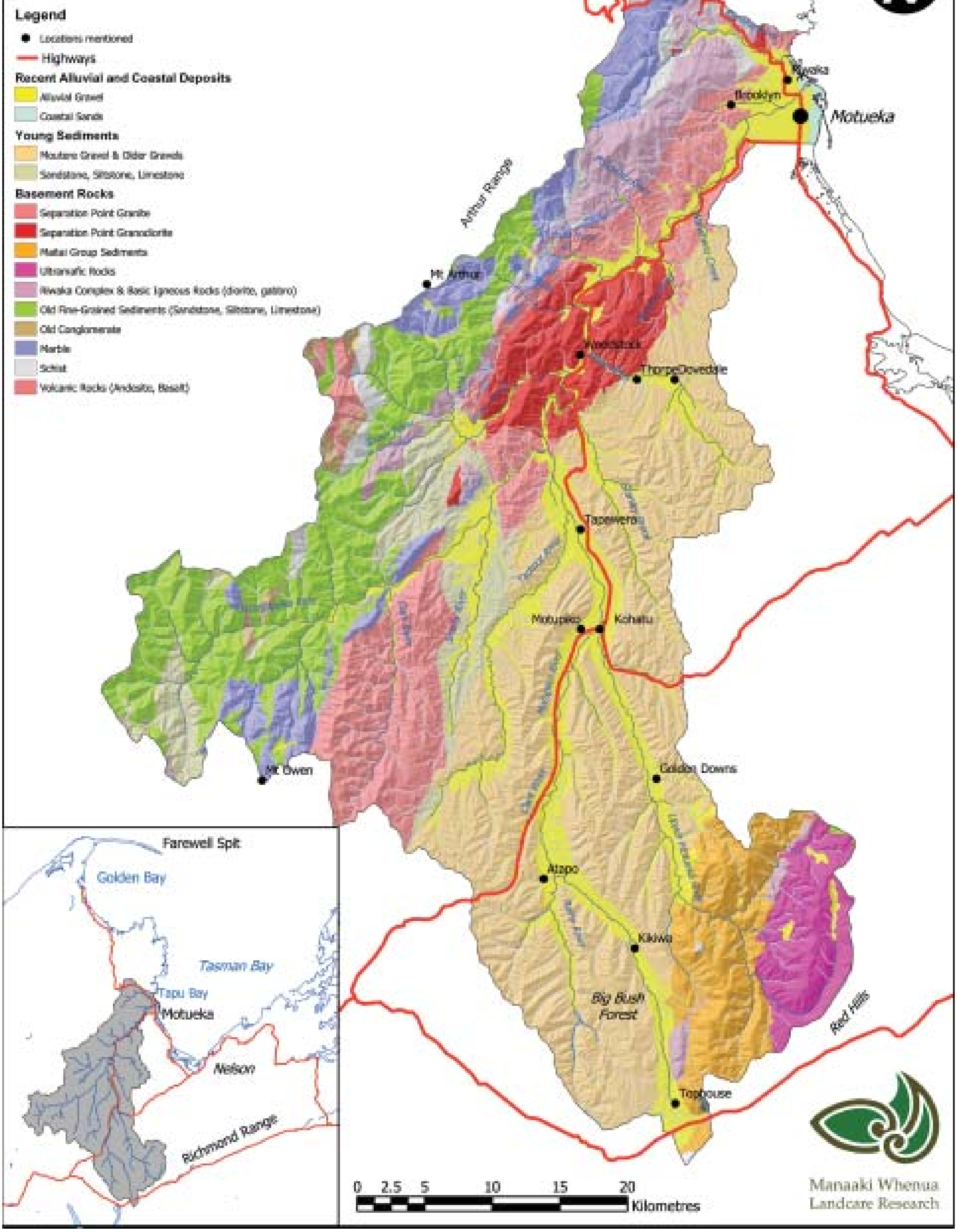
[7] Hardened by heat, pressure or cementation.

[8] Igneous rocks rich in iron, magnesium and nickel.

Fig. 5 Geological map of the Motueka Catchment (primarily derived from Rattenbury et al. (1998) with the southernmost part derived from the New Zealand Land Resource Inventory).



greywacke sandstone clasts[9], mainly <200 mm diameter, in a silt and clay matrix that cements the clasts together. Alluvial gravels of late Quaternary age underlie the terraces and floodplains of all the major valleys, and form the Motueka Plains. A series of aggradation surfaces, up to 100 metres above current river levels, dating back several hundred thousand years are recognised by Rattenbury et al. (1998). Young beach deposits are found along the coast at the mouth of the Motueka River.

Johnston (1980) groups the rocks of the catchment into three classes based on their influence on water yield.

- Indurated basement rocks of pre-Upper Cretaceous age. These include the Dun Mountain ultramafic rocks, the Maitai, Mt Arthur, Mt Patriarch and Greenland group sedimentary rocks, the Riwaka Igneous Complex, and the Separation Point Suite. This group has an important influence on water yield because although the rocks are strongly indurated and have low permeability, they are fractured to great depth allowing infiltration and storage of water that is released slowly to sustain streamflow. In addition this group of rocks is widespread, particularly in the higher rainfall areas of the catchment in the major western tributaries and the upper Motueka.
- Less-indurated rocks including the young sediments (mudstone, sandstone, limestone of the Rapahoe, Nile and Blue Bottom groups) and the Moutere gravels. These rocks have slow permeability and store limited amounts of water. They also occur mainly in the lower rainfall areas of the catchment.
- The unconsolidated late Quaternary gravels and sands underlying the terraces and floodplains. Although of limited extent in the Motueka, these young sediments are critically important to water yield as they are highly permeable, store large quantities of water, form the main aquifers from which groundwater is obtained, and play an important role in sustaining streamflow.

2.3 SOILS

The complexity of landforms, climate, and rock types in the Motueka Catchment results in a wide variety of soils. The catchment was mapped at 1:126,720 scale by Chittenden et al. (1966) and at 1:250,000 scale by New Zealand Soil Bureau (1968). This soil information was reinterpreted at 1:63,360 scale for the NZLRI maps (Hunter, 1974, 1975a,b; Lynn, 1975a,b, 1977a,b,c; Williams 1975). Fifty-six mapping units are depicted on the best available maps[10] of the catchment. Fig. 6 shows the distribution of soils and Appendix 1 lists key characteristics of each mapping unit.

Soil characteristics are closely related to geology, landform, elevation, rainfall and vegetation cover, and can be grouped into six broad classes:

- **Soils of the floodplains and low terraces** are formed from recent river alluvium of varying parent material composition. These are mainly Recent[11] (Riwaka, Sherry, Wangapeka, Tapawera, Motupiko, and Dovedale) and Gley soils (Riwaka wet phase, Braeburn),with Saline Gley Recent soils (Motukarara) near the coast. Fertility ranges from very low to high depending on the parent material from which the alluvium is formed. These soils are well drained except for the Gley, and Saline Gley Recent soils, which have high groundwater tables and are poorly drained.

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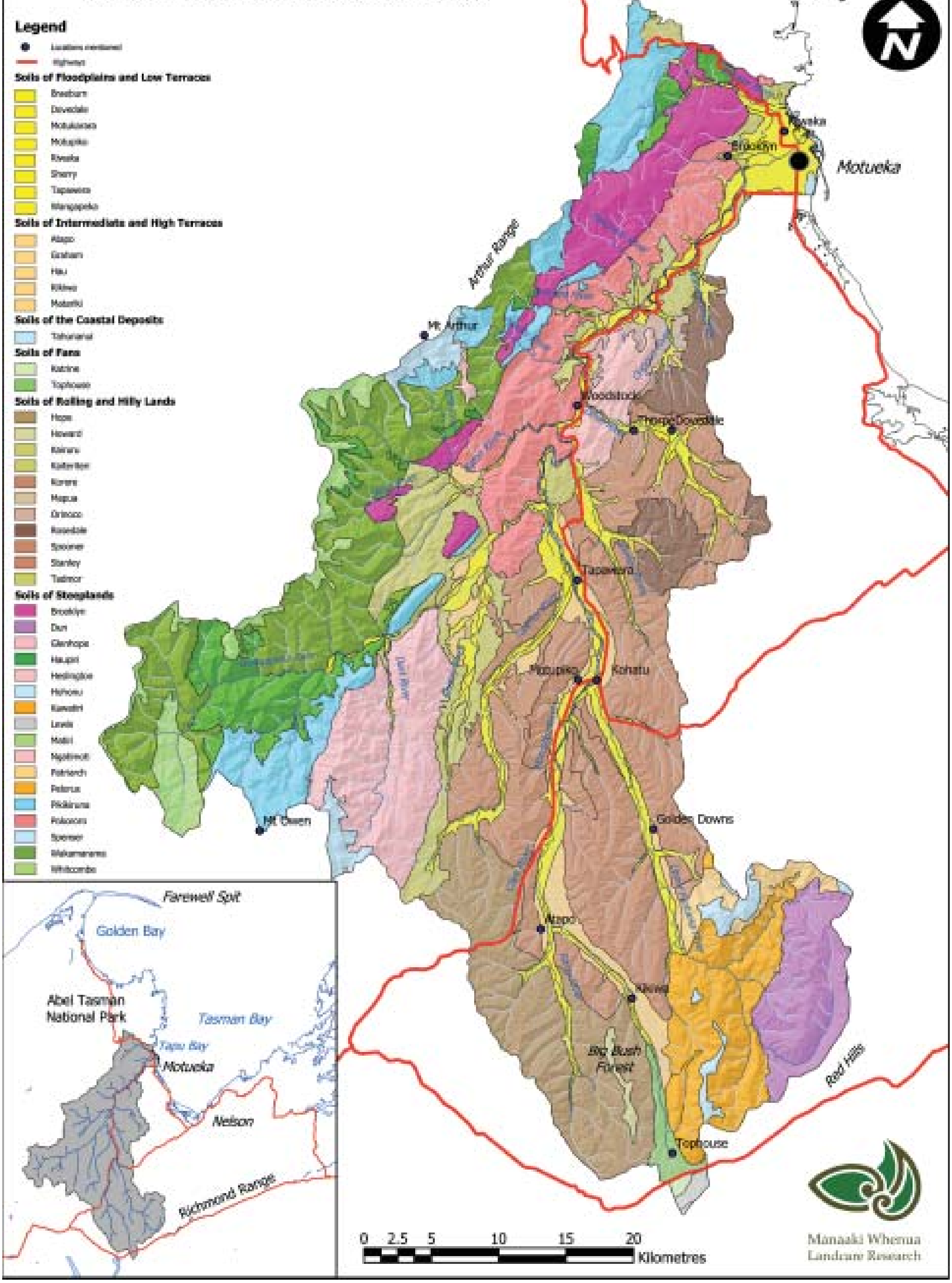
[9] Rock fragments.

[10] Cawthron Institute produced detailed soil maps of the plains and major valley floors at 1:15,840 scale in the 1940s, but these were never published. Map unit boundaries are currently being digitised by Tasman District Council to provide improved soil-map-unit information for these areas.

[11] Soils are classified according to the New Zealand Soil Classification (Hewitt 1992). Appendix 1 also lists the New Zealand Genetic soil classification (after New Zealand Soil Bureau 1968).

Fig. 6 Soil map of the Motueka Catchment (derived from the New Zealand Land Resource Inventory).



- **Soils of the intermediate and high terraces** are formed from older alluvium of varying parent material composition (Matariki, Hau, Graham, Kikiwa, Atapo). They are mainly Brown soils with low to very low fertility, and are mostly well drained.
- **Soils of the coastal sands** are formed in a small area of beach sands and gravels near the coast. Tahunanui soils are Recent soils with low fertility and are very free draining.
- **Soils of the fans** are formed from older alluvium (Tophouse soils) or till[12] (Katrine soils) and have a restricted extent in the upper reaches of the Motupiko River. They are Brown soils with low fertility, and are well drained.
- **Soils of the rolling and hilly lands**. This group comprises a wide variety of soils distinguished according to climate and parent material, including Moutere gravels (Mapua, Rosedale, Stanley, Spooner, Korere, and Hope soils form a climosequence), alluvium (Howard), basic igneous rocks (Brooklyn hill), young sedimentary rocks (Tadmor), granite (Orinoco, Kaiteriteri), greywacke (Pelorus hill) and marble (Kairuru). Most are classified as Brown soils (Rosedale, Stanley, Spooner, Korere, Howard, Orinoco, Tadmor, Brooklyn hill, and Pelorus hill), with some Podzols (Hope), Ultic (Mapua and Kaiteriteri) and Melanic (Kairuru) soils. Fertility depends on parent material, and is generally low on the Moutere gravels and granite, and higher on sedimentary and basic igneous rocks. Soils of this group are well drained, except on the Moutere gravels where there are many soils with slow subsoil drainage. The soils formed on Moutere gravel are prone to sheet and gully erosion when cleared, and runoff from these soils has in the past been considered a significant contributor to erosion rates and flood flows (Chittenden et al. 1966). The soils formed on weathered granite are prone to erosion when disturbed, and can release large quantities of sand into streams. Exotic forestry, once established and well managed, has stabilised some of this country.
- **Soils of the steeplands**. This group also comprises a wide variety of soils distinguished according to climate, parent material (basic igneous and volcanic rocks, Maitai Group and other old sediments, greywacke, schist, marble, young sediments, granite) and elevation. Most are classified as Brown soils (Kawatiri, Brooklyn, Heslington, Wakamarama, Whitcombe, Patriarch, Haupiri, Pelorus, Dun, Pokororo and Glenhope), with significant areas of Podzols (Lewis, Spenser, Matiri and Hohonu) and Melanic soils (Ngatimoti and Pikikiruna). Fertility depends on parent material, and is generally low on greywacke, schist, argillite, quartzite, and acidic igneous rocks (granite, diorite, granodiorite) and higher on calcareous sedimentary rocks and basic igneous rocks. These soils are dominantly well drained. They are mostly in the Motueka headwaters and western ranges, and are best suited for water and soil protection uses because of the steep slopes, high rainfall and potential for erosion. The soils from ultramafic rocks (Dun soils) contain some trace elements toxic to plant health (e.g., nickel, chromium) and rock exposures and screes are common (Photo 3).

Few of the soil mapping units have been characterised in detail, particularly for their physical and hydraulic characteristics. Basic chemistry of many of the soil types is included in Chittenden et al. (1966). The National Soils Database held by Landcare Research contains data for 14 of the mapping units (Table 3), but few were sampled in the Motueka Catchment.

Estimates for key physical and chemical attributes for all mapping units are contained in a Fundamental Data Layer extension of the NZLRI (Wilde et al. 1999). These attributes include soil temperature regime, soil drainage class, potential rooting depth, depth to a slowly

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[12] Sediments deposited by glaciers as moraine.

SOIL MAPPING UNIT	DATA TYPE	LOCATION OF SAMPLED SOIL
Motupiko	C*	88 Valley
Mapua	C, P, M, PSA	DSIR Research Orchard, Mapua
Korere	C, PSA	Korere
Hope	C, M, PSA	Big Bush
Kaiteriteri	C, M	Nelson (location unkown)
Pelorus	C, M, PSA	Whangamoa Saddle
Wakamarama	C, PSA	Grey Valley, north Westland
Lewis	C, P, M, PSA	Mt Misery, Lake Rotoiti
Spenser	C, P, M, PSA	Mt Misery, Lake Rotoiti
Whitcombe	C, P, M	Mt Misery plateau, north Westland
Haupiri	C, PSA	Head of Fyffe River near Mt Owen
Pikikiruna	C, M	Near Mt Patriarch
Matiri	C, M	Kiwi Saddle, Arthur Range
Dun	C, M	Bryant Range

* Data types are listed as chemistry (C), physics (P), mineralogy (M), particle size analysis (PSA).

Table 3: Soil data in the National Soils Database for mapping units in the Motueka Catchment.

permeable layer, topsoil gravel content, rock outcrops and surface boulders, minimum pH (0.2–0.6 m), maximum salinity (0–0.6 m), cation exchange capacity (0–0.6 m), total carbon (0–0.2 m), phosphorus retention (0–0.2 m), profile available (PAW) and readily available water (PRAW), and macroporosity (at depths of 0–0.6 and 0.6–0.9 m). Maps of key soil attributes (derived from the fundamental data layers) affecting water storage and movement are shown in Figs 7–10.

Detailed studies of some of the soils within the Motueka Catchment include:

- an investigation of the reasons for poor growth of *Pinus radiata* on Kaiteriteri, Pokororo and Mapua soils (Adams 1970);
- a nutritional survey of Pokororo and Kaiteriteri soils at Pokororo Forest (Thorns 1997);
- soil distribution and fertility in Brooklyn, Brooklyn–Pikikiruna, and Kaiteriteri soils (Betitis 2000);
- soil distribution and soil–vegetation relationships on schist (Whitcombe) and marble (Pikikiruna) in the mountains of west Nelson (Bell 1970, 1973a,b; Heine et al. 1987);
- soil distribution, chemical and mineralogical properties of soils mapped as Hope soils on Moutere gravel at Big Bush (Campbell and Mew 1986). In this same area Davis (1999) describes a study of soil chemical differences between undisturbed beech forest and radiata pine soils 19 years after conversion from beech forest to pine;
- description of soil distribution in 10 small catchments mapped as Rosedale Hill soils on Moutere gravels (Duncan 1990), and analysis of soil moisture deficits under pasture and pine (Duncan 1992).

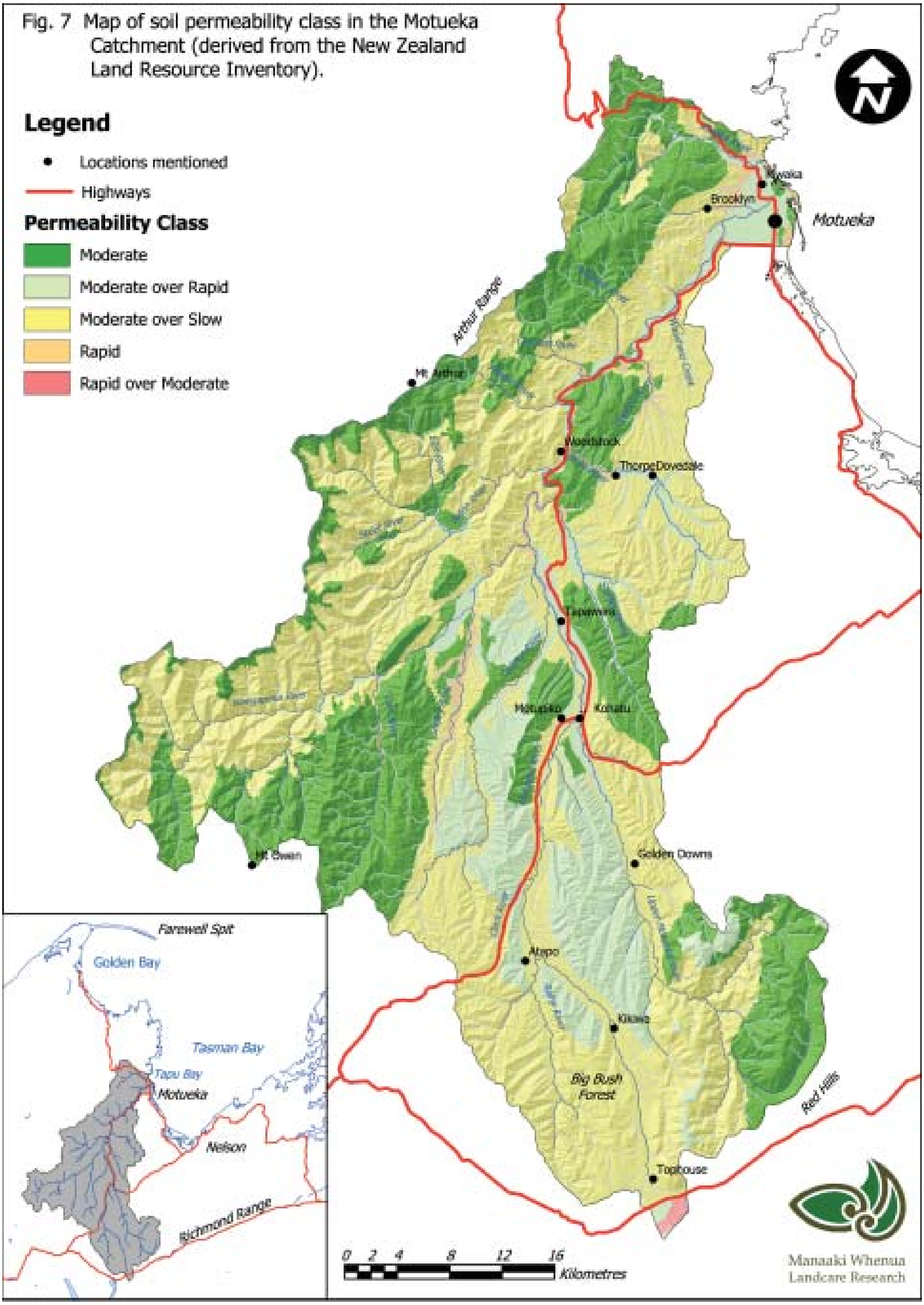


Fig. 7 Map of soil permeability class in the Motueka Catchment (derived from the New Zealand Land Resource Inventory).

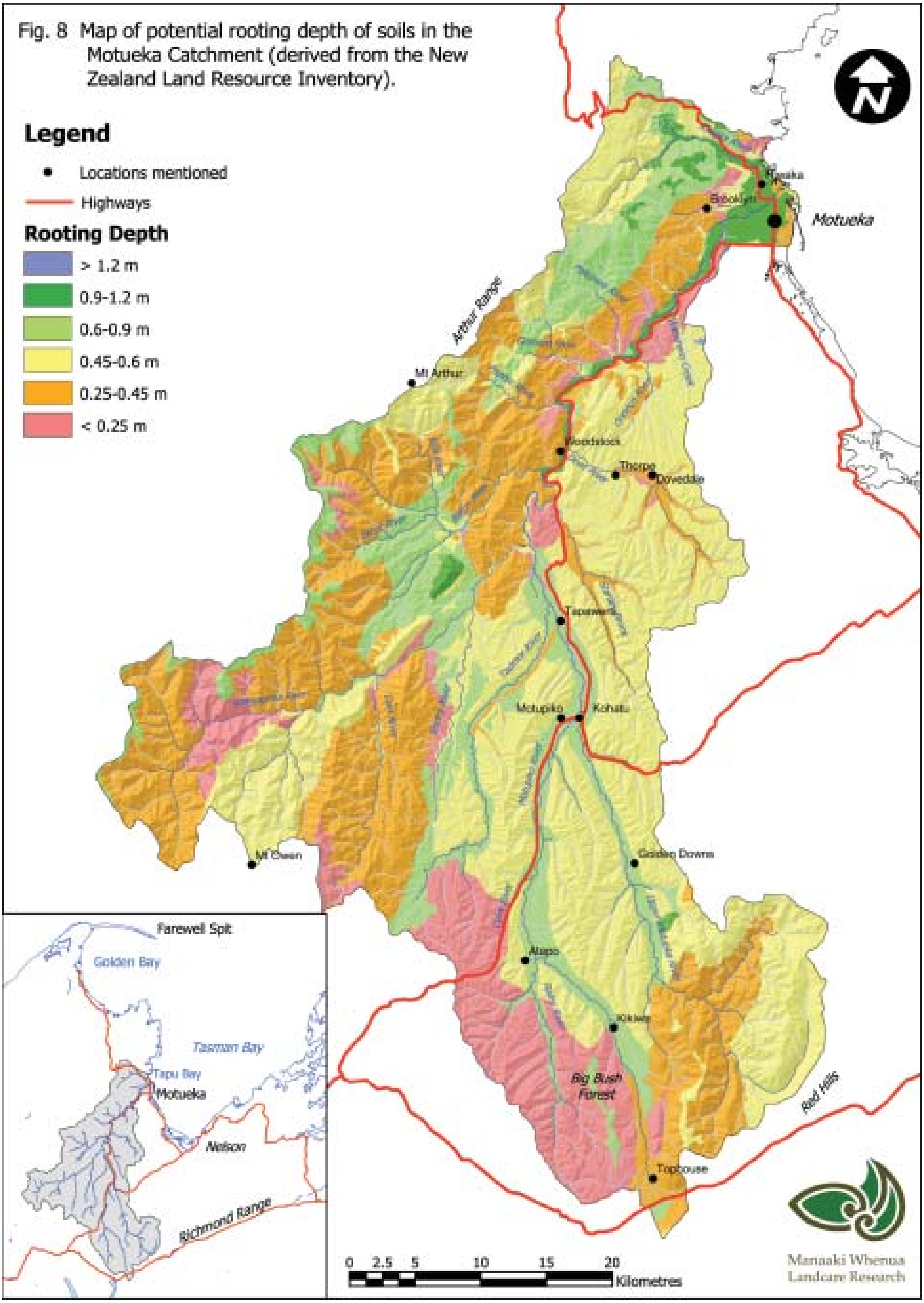


Fig. 8 Map of potential rooting depth of soils in the Motueka Catchment (derived from the New Zealand Land Resource Inventory).

Fig. 9 Map of profile available water for soils in the Motueka Catchment (derived from the New Zealand Land Resource Inventory).

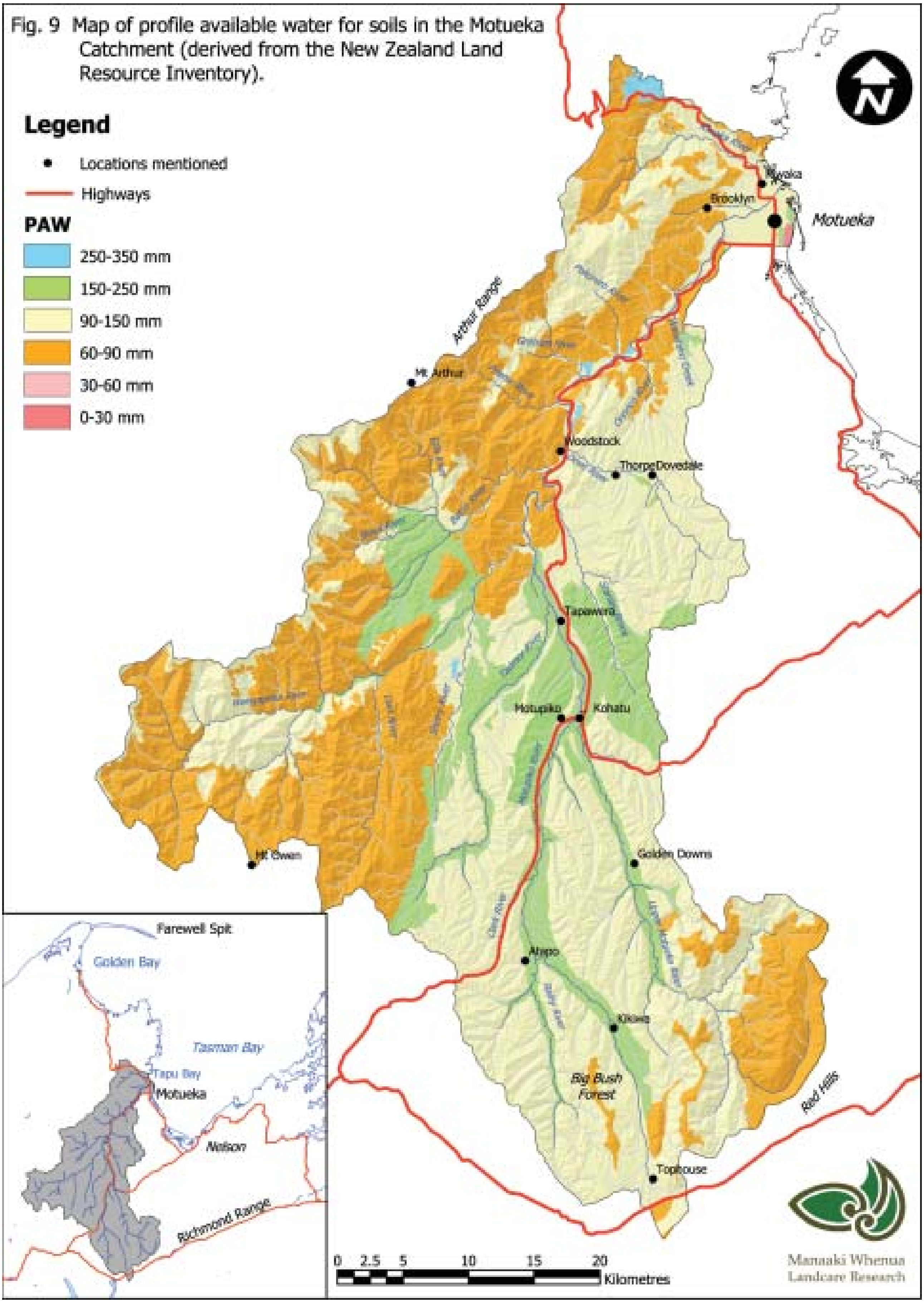
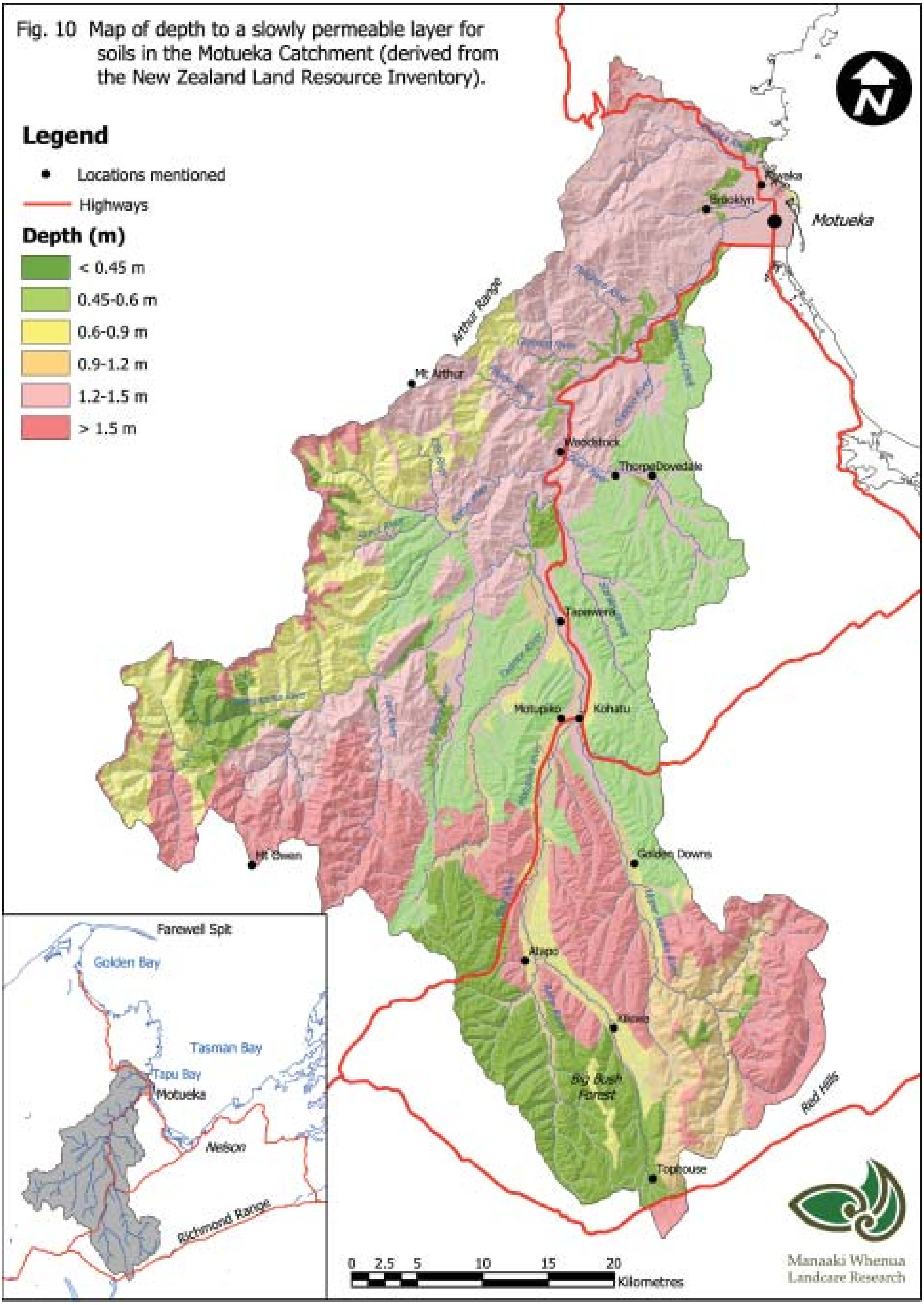


Fig. 10 Map of depth to a slowly permeable layer for soils in the Motueka Catchment (derived from the New Zealand Land Resource Inventory).



2.4 EROSION, SEDIMENTATION AND RIVER GRAVEL

2.4.1 Sources of erosion

Historically there have been concerns about erosion where land on the Moutere gravels has been cleared for pastoral or orchard development (e.g., McCaskill, 1973). Soil conservation reserves and experimental stations were operated at Appleby – to investigate erosion management in orchards (at the time, soils were cultivated and kept bare between the trees) –and at Moutere – to investigate erosion associated with clearing for pastoral development. McCaskill (1973) reports erosion rates from small plots at Moutere of 360 t/km^2/yr from bare soil, compared with 160 t/km^2/yr from pasture.

More recently attention has focused on land disturbance and forestry activities (e.g., roading, landing construction) on the Separation Point granite (e.g., Coker and Fahey 1993, 1994; Fahey and Coker 1989). Concern about fine sediment (silt and sand) in runoff has been heightened by its potential to affect the internationally renowned trout fishery in the Motueka River. The presence in the river of sand-sized sediment derived from Separation Point granite is thought to have affected trout spawning and growth, and trout habitat and cover. It may have been responsible for a recent decline in trout numbers by reducing water quality and primary production in the river, and smothering macroinvertebrate communities. There are also concerns about the offshore impacts of sediment on the developing aquaculture industry in Tasman Bay.

A wide variety of erosion types have been mapped throughout the catchment as part of the NZLRI (Hunter 1974, 1975a,b; Lynn 1975a,b, 1977a,b,c; Williams 1975).These maps show generally low severity erosion (Grades 1–2), with the most severe[13] erosion (wind and gully) mapped on the soils of the ultramafic rocks and on high-elevation soils on greywacke, schist and granite.

2.4.2 Sediment yields

The amount of sediment from the catchment carried to the coast by the Motueka River has been estimated at 277 tonne(t)/km^2/yr (Griffiths and Glasby 1985). However, this estimate was based on a relationship between suspended sediment yield and rainfall derived from catchments throughout the South Island (Griffiths 1981) and probably overestimates the yield. D. M. Hicks (pers. comm. 2002), using limited data on the relationship between sediment concentration and river flow for the Motueka at Woodstock, has calculated a lower yield of 180 t/km^2/yr. The distribution of sediment yield across the catchment is not well known. Mosley (1980), using the Griffiths (1981) method, suggests much of the yield is derived from the high-rainfall, steep terrain of the west-bank tributaries and estimates rates of 119 t/km^2/yr from the Dart River and 583 t/km^2/yr from the entire Wangapeka River. However, Hicks' (pers. comm. 2002) analysis of available suspended-sediment data suggests the east-bank Stanley Brook on Moutere gravel has a much higher sediment yield (169 t/km^2/yr) than the Wangapeka (46 t/km^2/yr). The relative contribution of erosion under native vegetation compared with erosion from areas converted to pasture or production forest is not known.

Sediment yield measured from small catchments at two sites underlain by Moutere gravels was relatively low. Under an annual rainfall of 1000 mm/yr, suspended sediment yields were 79 t/km^2/yr from pasture and 4 t/km^2/yr from pine forest (Hicks 1990). Similarly, Smith (1992) measured

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[13] Severity mapped in the NZLRI was largely a function of the extent of bare ground and has an undefined, but probably poor, relationship with rate of erosion. For example, most concern about sediment generation from erosion is on Separation Point granite under forestry land use yet this is ranked as low severity in the NZLRI.

21 t/km²/yr under pasture, and 32 and 67 t/km²/yr from two catchments under pasture with riparian pine. She suggested increased erosion was associated with poor ground cover in riparian forest causing overland flow and streambank erosion. At Big Bush under a higher rainfall (1700 mm/yr), sediment yield was 6–11 t/km²/yr under undisturbed native forest. Most sediment was derived from streambank erosion. Following harvesting of the trees, sediment yields increased up to 100 times, depending on the harvesting method, with most of the sediment delivered in a few high-intensity storms (O'Loughlin et al. 1978; Fahey et al. 1993; Fahey and Jackson 1993).

Several studies have been carried out on erosion under production forestry on Separation Point granite, which is well known for its erosion problems particularly associated with development of roads and landings. Mosley (1980) suggested the area of the Dart Valley that was roaded had a sediment yield of 710 t/km²/yr (derived from surface erosion, gullying, mass movement), compared with a background rate for the Dart of 119 t/km²/yr. However, he indicated that the high sediment yield from the relatively small roaded area had a minor impact on the Wangapeka River because this river has a naturally high sediment yield (583 t/km²/yr), and much of the sediment associated with roading was stored on slopes and in headwater channels. Rates of sediment production from surface erosion on existing roads in maturing forests were estimated by Fahey and Coker (1989) at 37 t/km²/yr. At the time of peak harvesting this was predicted to rise to 160–320 t/km²/yr, compared with a background erosion rate for the Wangapeka of about 580 t/km²/yr.

Infrequent high-magnitude storms are the major contributors to erosion rates. Four major storms in July and August 1990 caused erosion at rates up to 2800 t/km² (of which 50% entered streams), mostly from failures in the cutbanks and sidecasts of forest roads (van de Graaf and Wagtendok 1991; Coker and Fahey 1993, 1994).

Coker and Fahey (1994) provided a comprehensive evaluation of the erosion and sedimentation risk associated with forestry activities on Separation Point granite terrain. While natural erosion rates at the whole-catchment scale on Separation Point granite were higher (estimated at about 500 t/km²/yr) than those induced by disturbance associated with forestry at the local scale (37 t/km²/yr for surface erosion and 280 t/km²/yr for mass movement), they made a number of recommendations to limit sediment production. These included regulation of landing size, regulation of roading and cutbank formation, safe storage of excess sidecast material, avoidance of stream crossings by use of appropriate culverts, and promotion of revegetation following disturbance. These methods, including end hauling of roading spoil, are now used routinely in forestry activities on Separation Point granite (C. Michie, pers. comm.) and are included in the Tasman Resource Management Plan (Tasman District Council 1998).

2.4.3 Gravel supply

Supply of river gravel within the Motueka Catchment is low and extraction is limited by the Tasman District Council (Tasman District Council 1993a), based on an understanding of rates of gravel supply and riverbed stability. Peterson (1997) describes the geomorphic evolution of the Motueka spit and delta and calculates the long-term supply of gravel to the coast at about 9000 cubic metres per year (m³/yr) (of which 7000–7600 m³/yr accumulates in the delta and 1000–1500 m³/yr is transported along the coast). He suggests, from the volume of material trapped in the Motueka delta, that there has never been a large volume of gravel supplied to the coast or transported down the coast by long-shore drift. He suggests any gravel is being deposited in the lower Motueka River channel, with only sand and silt reaching the coast (Petersen 1997). The calculated rate of gravel

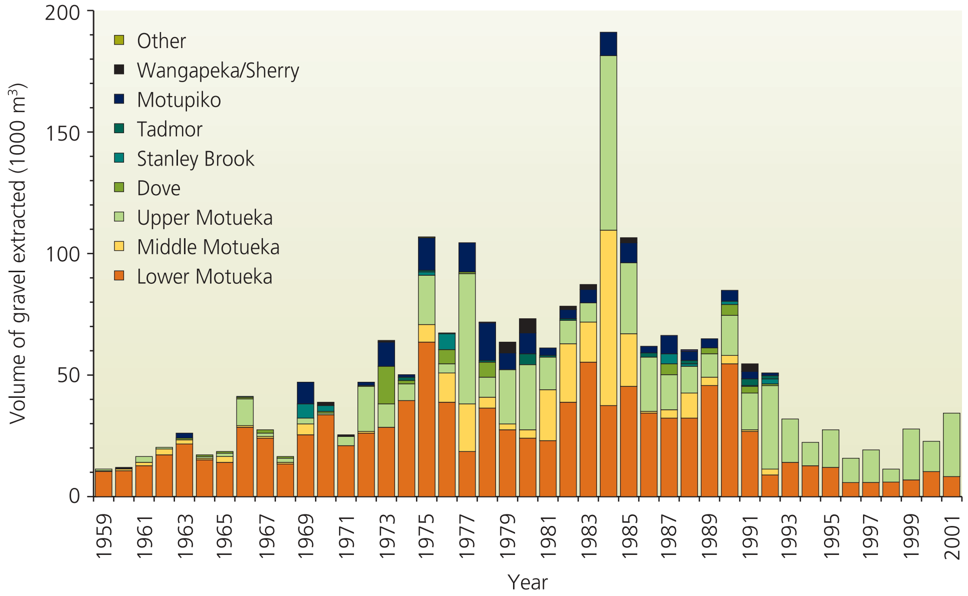

Fig. 11 Volumes of gravel extracted from the Motueka River 1959–2001 (source Tasman District Council).

supply is far less than historical gravel extraction rates, which exceeded 40,000 m^3/yr for most of the period between 1969 and 1991 (E. Verstappen, pers. comm. 2002). As a consequence gravel extraction has been limited by Tasman District Council (reduced from 34,000 m^3 in 1991/92 to 11,000 m^3 in 1995/96), although these restrictions have now been eased with 35,000 m^3 permitted in 1999/2000 (Tasman District Council 1993a, 2000e). Limits are set for the upper Motueka (above the Wangapeka confluence), middle Motueka (Wangapeka confluence to Alexander Bluff bridge), lower Motueka (below Alexander Bluff bridge), and Motupiko rivers (Tasman District Council 2000e). Historical changes in gravel extraction rates are shown in Fig. 11.

Current understanding (Tasman District Council 1993a) suggests riverbed levels in the lower Motueka are lower than natural levels, with bed degradation continuing upstream. In the lower Motueka River, gravel extraction has in recent years been limited to around 5000–6000 m^3/yr. There has also been a policy of limited to no extraction from the middle reaches of the Motueka River from 1991 to 2000. Comparison of river surveys in 1993, 1997 and 2001 indicates that by allowing material in the middle Motueka to flow through to the lower Motueka, a 5000-m^3/yr extraction rate from the lower Motueka River appears to be sustainable, as there is no significant net loss of material from the reach as a whole (E. Verstappen pers. comm. 2002). However, recent observations indicate a lack of replenishment of beaches in the deposition reach of the lower Motueka in the last 2 years. This may be indicative of the higher than desirable extraction rates in the upper Motueka, along with some extraction beginning to occur in the middle Motueka, limiting potential downstream aggradation. Any trends of this nature will become more evident after the upper and lower Motueka reaches are resurveyed in 2004 and 2005, respectively

The upper Motueka riverbed is in a degradation phase, due partly to natural post-glacial effects that influence most of the upper reaches of the river and partly to gravel extraction. The degradation rate, based on three river-surveys between 1960 and 1995 between North's

Bridge and the Wangapeka River confluence, is assessed as about 4000 m^3/year. Annual gravel extraction rates in the upper Motueka have significantly exceeded what is considered to be the long-term average supply rate, estimated at roughly 1000–2000 m^3/yr, from sources other than riverbed and bank erosion. Gravel extraction has resulted in accelerated bed degradation, particularly in the vicinity of bridge sites, where access is generally easiest.

The sources of gravel deposited within the Motueka Catchment have been analysed by Waterhouse (1996). Gravel composition varies systematically down the river as a function of the input of gravel from major tributaries. In the upper reaches of the river, clasts from the headwaters (ultramafics and Maitai Group) and Moutere gravels dominate, but below the Wangapeka confluence clasts from the western tributary lithologies and granite are most common. The bulk of the clasts in the lower Motueka are from the western tributaries, with negligible amounts from the headwaters of the Motueka or the Moutere gravel. In the lower Motueka more than half of the clasts are from the Baton and Wangapeka catchments, with the Rocky River also a substantial contributor to gravel at the river mouth.

2.5 VEGETATION AND LAND USE

2.5.1 Prehuman vegetation

The Motueka Catchment was originally almost entirely forested, with podocarp species in the fertile lowland areas and varying beech species elsewhere (Walls 1985). Alpine tussock grasslands would have covered the catchment above an elevation of about 1200–1400 metres (c. 5% of the catchment). In parts of the catchment vegetation had been burned by Māori by the time the early European settlers arrived, when further extensive clearing of forest occurred causing erosion and increased flooding (Fenemor 1989).

2.5.2 Present land use

The Motueka Catchment today is largely rural. Current vegetation (Fig. 12) is dominated by native (35%) and exotic (25%) forest with smaller areas of pastoral grassland (19%), scrub (12%) and tussock grasslands (7%). The only significant urban centre is the township of Motueka. Small but ecologically significant areas of wetland are found at the coast and scattered throughout the catchment (Preece 2000).

The largest areas of native forest are found in the headwaters of the western tributaries (Kahurangi National Park) and in the upper catchment (Mt Richmond Forest Park). These areas are managed by the Department of Conservation for recreation and protection purposes. Smaller areas of native forest occur in Big Bush Forest and scattered throughout the catchment (Park and Walls 1978; Walls 1985). Commercial production forests (mainly radiata pine, with smaller areas of Douglas fir) occupy large areas of the steeper and less fertile soils on both Moutere gravel and Separation Point granite. The largest single forest is at Golden Downs, where the first plantings began in 1927, largely as a result of failed attempts at pastoral farming on infertile hill country. Scrubland, dominated by fern, gorse and mānuka, occurs throughout the catchment, mainly on the poorer soils on steep hill country. Scrub reversion is a major challenge for pastoral farming in many parts of the catchment. Pasture grassland generally occupies the lower and easier slopes of the Moutere Depression, the west-bank tributaries, and the river flats and terraces. Pastoral land is mainly used for sheep grazing (52% of the grassland) and beef production (26%), with limited, but increasing, dairying (particularly in the Sherry and Rainy rivers). Horticulture is limited to the river flats and terraces, and makes up only 0.6% of the catchment area. Of this 46% is in pipfruit (mainly apples and kiwifruit), 18% in berryfruit, 16% in hops, 16% in vegetables, and 4% in other crops

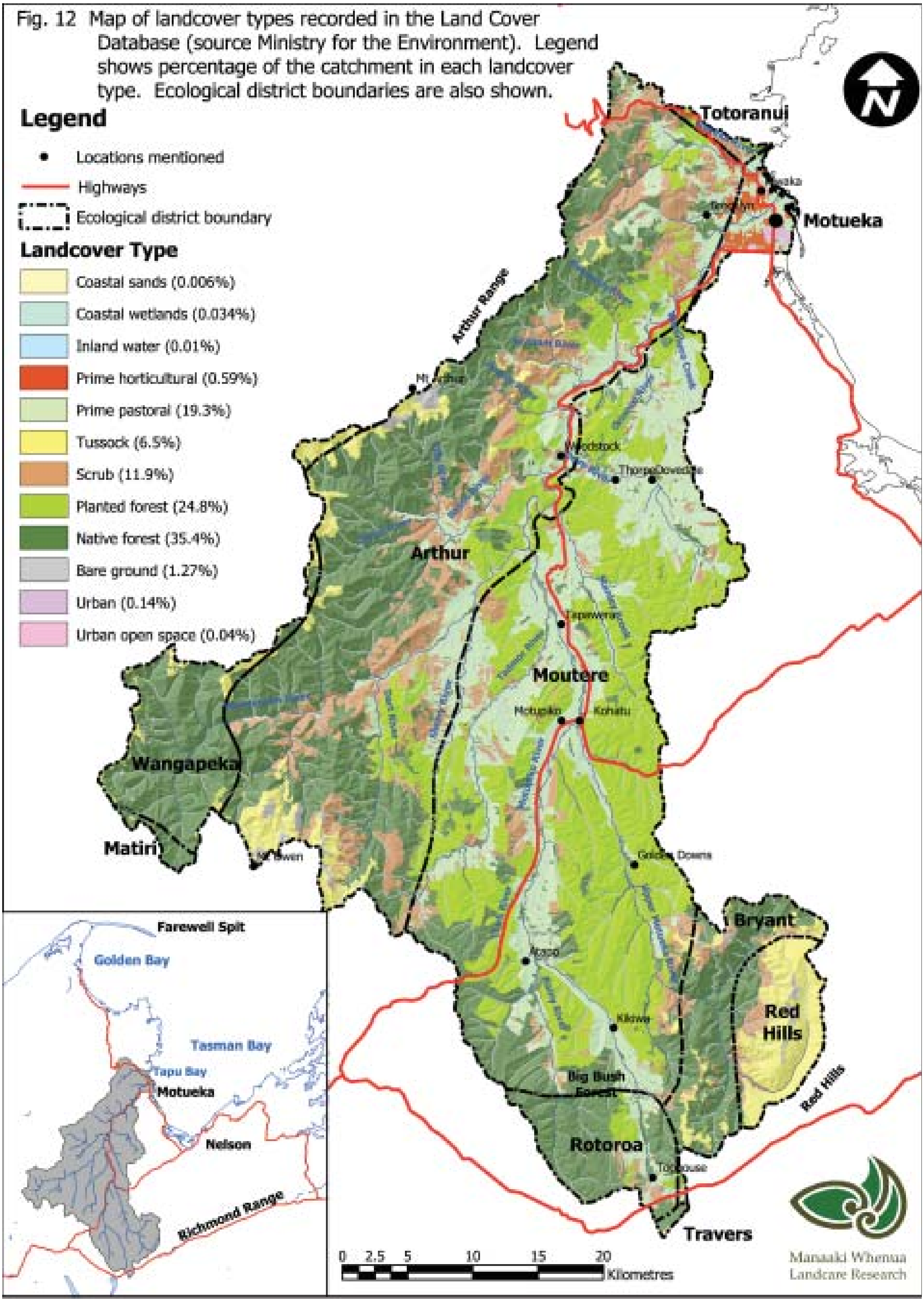

Fig. 12 Map of landcover types recorded in the Land Cover Database (source Ministry for the Environment). Legend shows percentage of the catchment in each landcover type. Ecological district boundaries are also shown.

(e.g., flowers, grapes). Fruit trees and hops are the main crops grown on the coastal plains, while berryfruit and hops are more commonly grown on the inland river flats and terraces. Horticulture is currently expanding on river flats and terraces in the Tapawera area. Most crops are irrigated from surface or groundwater during the dry summer months.

2.5.3 Ecological Districts

The ecological character of the catchment is described in ten ecological districts by McEwen (1987): Red Hills, Bryant, Rotoroa, Travers, Arthur, Wangapeka, Matiri, Moutere, Motueka, and Totaranui, (see Fig. 12). These are defined primarily on geology, topography, climate and natural vegetation. None of the ecological districts (EDs) has been covered by a Protected Natural Areas Programme survey to describe in detail their ecological character, and to identify those areas with high ecological value.

The Red Hills ED covers the ultramafic rocks in the Motueka headwaters and has a distinctive flora adapted to the soils of low fertility with high levels of magnesium, chromium, and nickel. The vegetation comprises red tussock, mountain beech forest and shrubland (mānuka), and includes a number of endemic species. The vegetation types and patterns have been strongly influenced by frequent burning since Polynesian times. Adjacent to the Red Hills ED is a segment of the Bryant ED on Maitai Group sediments, dominated by mixed beech forest. A small area of Travers ED, on greywacke parent materials under high rainfall, is characterised by beech forest (red, silver and mountain beech) and alpine tussock grasslands.

Most of the west-bank tributaries of the Motueka lie in the Arthur ED. This area is characterised by complex geology (old sedimentary rocks, volcanic rocks, and schist), moderate to high rainfall, and mountainous topography. It retains more of its original vegetation, bird, and animal life than most other EDs. The forests comprise podocarp and podocarp/beech forest on lower slopes and valleys, red beech and silver beech with black beech on lower alluvial terraces, silver beech and mountain beech at higher elevation, and above this, subalpine scrub, red tussock grassland, and alpine herbfield. Davis and Orwin (1985) describe the forests and scrublands of the upper Wangapeka River and the factors controlling their distribution (parent material/soil fertility, elevation, rainfall, drainage, topography). The main communities were grouped by Davis and Orwin (1985) as:

- low-altitude forests (red/silver beech, beech/rātā), high-altitude forests (mountain beech, mountain beech/silver beech, silver beech/mountain beech/red beech, silver beech);
- seral shrubland communities in the forest zone;
- subalpine shrublands;
- grasslands including tall-tussock (*Chionochloa*) grassland dominated by *C. rubra*, *C. flavescens* or *C. pallens*, and *Chionochloa*/carpet grass communities.

The Wangapeka ED has similar landforms and geology but occurs in the higher-rainfall headwaters of the Wangapeka River. A small area in the headwaters of the south branch of the Wangapeka on young sedimentary rocks under high rainfall is mapped in Matiri ED and is dominated by silver beech, mountain beech and tall-tussock grasslands. Similarly a small area of hilly terrain on granite in the northern headwaters of the Riwaka is mapped as Totaranui ED.

The Moutere ED covers the extensively modified hilly terrain of the Moutere Depression on Moutere gravel. This was originally forested throughout, with a progression from black beech in the north, hard beech and red/silver beech further inland, and mountain/silver beech forests in the south. Tall podocarps (tōtara, mataī, miro, rimu, and kahikatea) originally dominated the river valleys, and tall hardwood forests with podocarps (tawa, pukatea, tītoki, karaka, māhoe, tōtara, mataī, nīkau) occurred near the coast. Today there are only small remnants of the podocarp, hardwood and beech forests in the north of the ED. The large areas of continuous beech forest in the south of the Motueka Catchment at Big Bush (on Moutere gravel and alluvium, under higher rainfall) are mapped in the Rotoroa ED.

The Motueka Plains and estuary form part of the Motueka ED, originally covered in tall podocarp-hardwood-beech forest. Formerly extensive wetland and estuarine areas are now mainly drained.

More-detailed studies of native vegetation have been made at a few sites in the catchment including:

- the grassland and shrub communities, and soils, on marble and schist at high elevation near Mt Owen (Bell 1970, 1973a,b);
- subalpine and alpine plant communities on old sedimentary and volcanic rocks in the western ranges (Williams 1993);
- the remaining native forest and scrub stands on the Moutere gravels (Park and Walls 1978; Walls 1985).

2.6 TERRESTRIAL WILDLIFE

The distribution and abundance of native fauna have been severely affected by the removal of much of the forest from lowland areas of the Motueka Catchment. There are still large upland areas of native forest with a wide variety of birds and other animals, but few examples of large tracts of lowland forest or unmodified freshwater and coastal wetlands. Walker (1987) surveyed “sites of special wildlife interest” throughout the catchment and ranked their relative value. Large forested areas tended to have a greater variety of native birds than did small stands, and some species were restricted to large tracts (e.g., kākā, falcon, parakeet). Walker (1987) identifies a large number of key sites within the Motueka Catchment (Appendix 2). These include forest sites (e.g., Kahurangi National Park, Mt Richmond Forest Park and Big Bush Forest), freshwater wetland sites (e.g., the middle braided reaches of the Motueka riverbed around Tapawera) and coastal wetland sites at the Motueka River delta (the rivermouth, sandspit and Kumeras tidal flats). The ecological district descriptions of McEwen (1987) also include a brief description of important fauna in each district, including reptiles (geckos and skinks), birds, snails, and insects. The threatened blue duck has been reported from the Pearse, Baton, Wangapeka and upper Motueka rivers.

Forest sites contain a wide variety of birds (including kākā, yellow-crowned parakeet, falcon, kiwi, blue duck, fernbird, robin, rock wren, kea, long-tailed cuckoo) and are also notable for large land snails (*Powelliphanta*). Freshwater wetland sites are important for survival of a number of birds (e.g., fernbird, waterfowl, pūkeko), and are used seasonally for breeding by coastal species (including the banded dotterel, pied stilt, Paradise shelduck, South Island pied oystercatcher and black-fronted tern). The coastal wetlands, tidal flats and saltmarsh (see Photo 1a) provide feeding and breeding areas for a very large variety and number of birds including estuarine edge species (banded rail, and South Island fernbird until recently), waders (South Island pied oystercatcher, Eastern bar-tailed godwit, turnstones, banded dotterel, wrybill, New Zealand dotterel, royal spoonbill, white heron), coastal species (shags, gannets, gulls, white-fronted tern, black-fronted and caspian terns). These coastal areas include some of the most threatened (from stock grazing, drainage and land development) wildlife areas in the catchment. The Department of Conservation regards the Motueka delta as being of national importance (Davidson et al. 1993).

Introduced plants and animals are a threat to wildlife (Walker 1987). These include browsing animals (e.g., deer, goats, pigs, possums, hares), predators (e.g., stoats, ferrets, weasels, rats, mice, cats, dogs), competitors, and exotic plants (e.g., old man’s beard in forests, shrubland and river beds; *Spartina* grass on tidal flats – which has now largely been eradicated).

2.7 CLIMATE

Aspects of the climate of the Motueka Catchment are described by De Lisle and Kerr (1965), Coulter and Hessell (1980), and New Zealand Meteorological Service (1983, 1985). The data presented in this section are derived from these sources, from the New Zealand Meteorological Service database (CLIDB) and Tasman District Council climate stations. Currently climatic data are recorded by NIWA (the National Institute for Water and Atmospheric Research) at Riwaka (rainfall, air, grass and earth temperature, wind run, vapour pressure and radiation), Graham (rainfall), Motupiko (rainfall), Tapawera (rainfall), and Lake Rotoiti (rainfall, air, grass and earth temperature, vapour pressure). Tasman District Council record rainfall at Woodstock, the upper Motueka Gorge, Baton Flats, Wangapeka (at Walters Peak), Tadmor (at Mudstone), Motupiko (at Christies), and Biggs Tops (immediately adjacent to the Wangapeka headwaters). Landcare Research record rainfall at Donald Creek in Big Bush Forest. NIWA also holds historical rainfall data for Motueka (1899–1985), Riwaka Valley (1947–1998), Kairuru (1961–1979), Takaka Hill (1947–1959), Dovedale (1947–1985), Thorpe (1959–1981), Stanley Brook (1911–1983), Hogden Valley (1947–1955), Baton (1952–1998), Wangapeka (1924–1928 and 1963–1996), upper Sherry River (1913–1923), Golden Downs (1929–1980), Atapo (1947–1955), Kaka (1947–1998), Kikiwa (1947–1965), and Tophouse (1913–1931 and 1961–1971). The location of these sites is shown in Fig. 13.

The climate of the Motueka Catchment is characterised as “cool humid”. In general terms it tends to be sunny and mild, less windy than other areas of New Zealand, and prone to frost in sheltered areas. Elevation has a major influence on both rainfall and temperature patterns. The catchment tends to be sheltered from both southerly and easterly weather systems, and from westerly storms except in the headwaters of the western catchments. It is most exposed to weather from the north and north-east. Intense localised storms are also a feature of the climate. Summer droughts may occur, usually between December and March, and are occasionally prolonged.

Mean annual rainfall for the catchment is estimated at 1600 mm. However, there is a strong spatial pattern of rainfall variation, primarily related to topography (Fig. 14). Rainfall ranges from <1000 mm/yr on the eastern side of the catchment to about 3500 mm/yr in the headwaters of the Wangapeka. Annual rainfalls in the mountainous, western tributaries are far higher (1500–3500 mm/yr) than in the eastern tributaries (1000–1400 mm/yr), and within the main valley rainfall increases slightly from the coast (c. 1300 mm/yr) to the headwaters (c. 1500 mm/yr). The lowest rainfall occurs in the headwaters of the Dove River and the middle reaches of the Stanley Brook. Annual rainfall totals are relatively well characterised in the mountainous areas of the western tributaries, but are poorly known in the upper Motueka. Rain falls on average between 100 and 150 days per year, increasing at higher elevation to 200 rain days per year. The northerly aspect and western ranges shelter the catchment from severe westerly storms, except in the headwaters of the Baton and Wangapeka catchments. High-intensity rainfalls can occur from north and north-easterly weather systems. Characteristics of rainfall depth, duration, and frequency for the Motueka Catchment are shown in Fig. 15 (Coulter and Hessell 1980; M. Doyle pers. comm. 2002). Rainfall of short- to-medium duration is often of high intensity and can cause severe flooding and erosion. However, as high-intensity short-duration rainfalls come from thunderstorms, such flooding and erosion tends to be localised. The most severe and extensive flooding and erosion tend to come from long-duration, moderate-intensity north-easterly storms.

In the lower-elevation, drier areas of the catchment (e.g., Motueka) rainfall is markedly seasonal, with a winter maximum in rainfall distribution (Fig. 16). In the wetter areas (e.g., Biggs Tops), and probably at

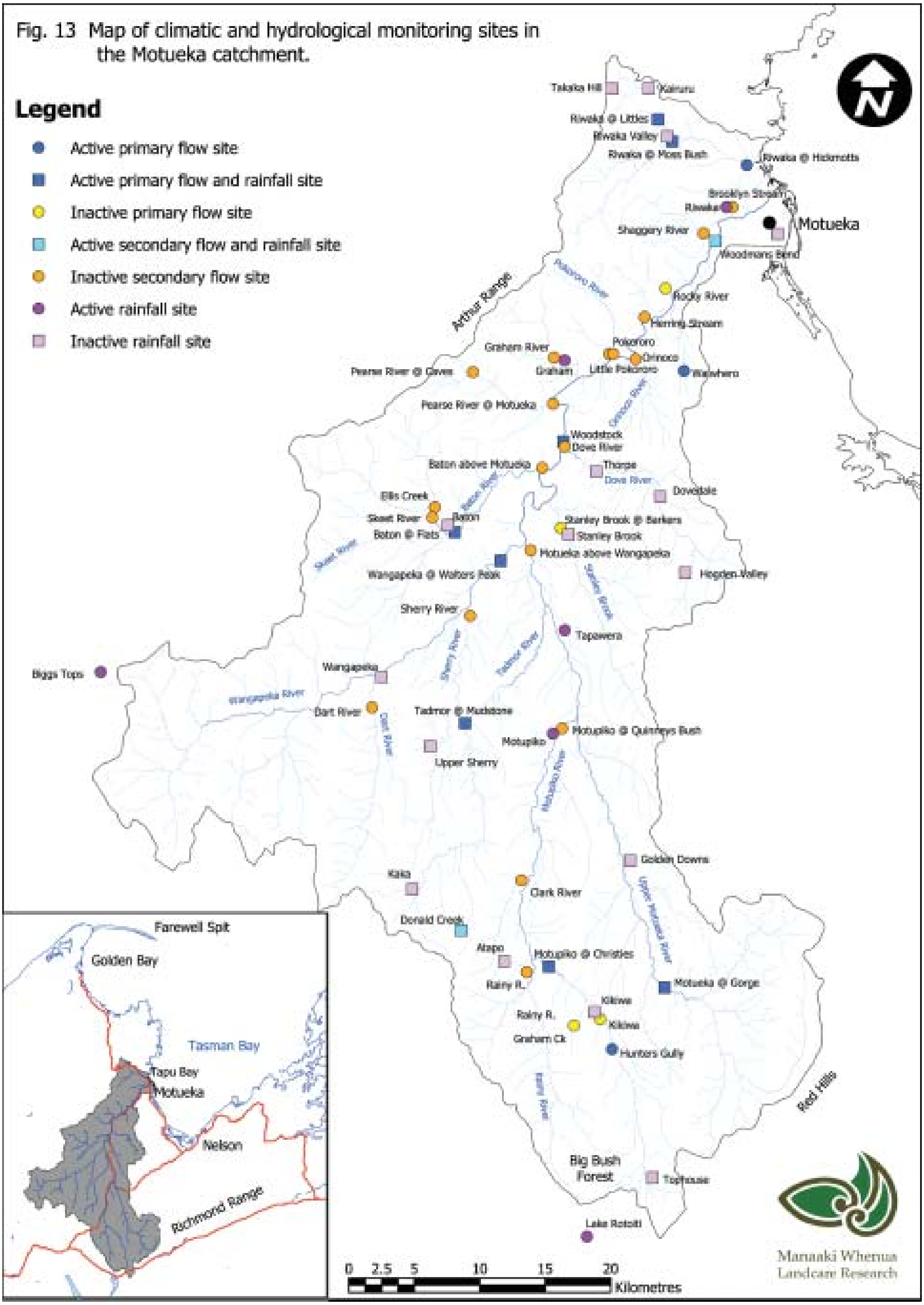

Fig. 13 Map of climatic and hydrological monitoring sites in the Motueka catchment.

Manaaki Whenua
Landcare Research

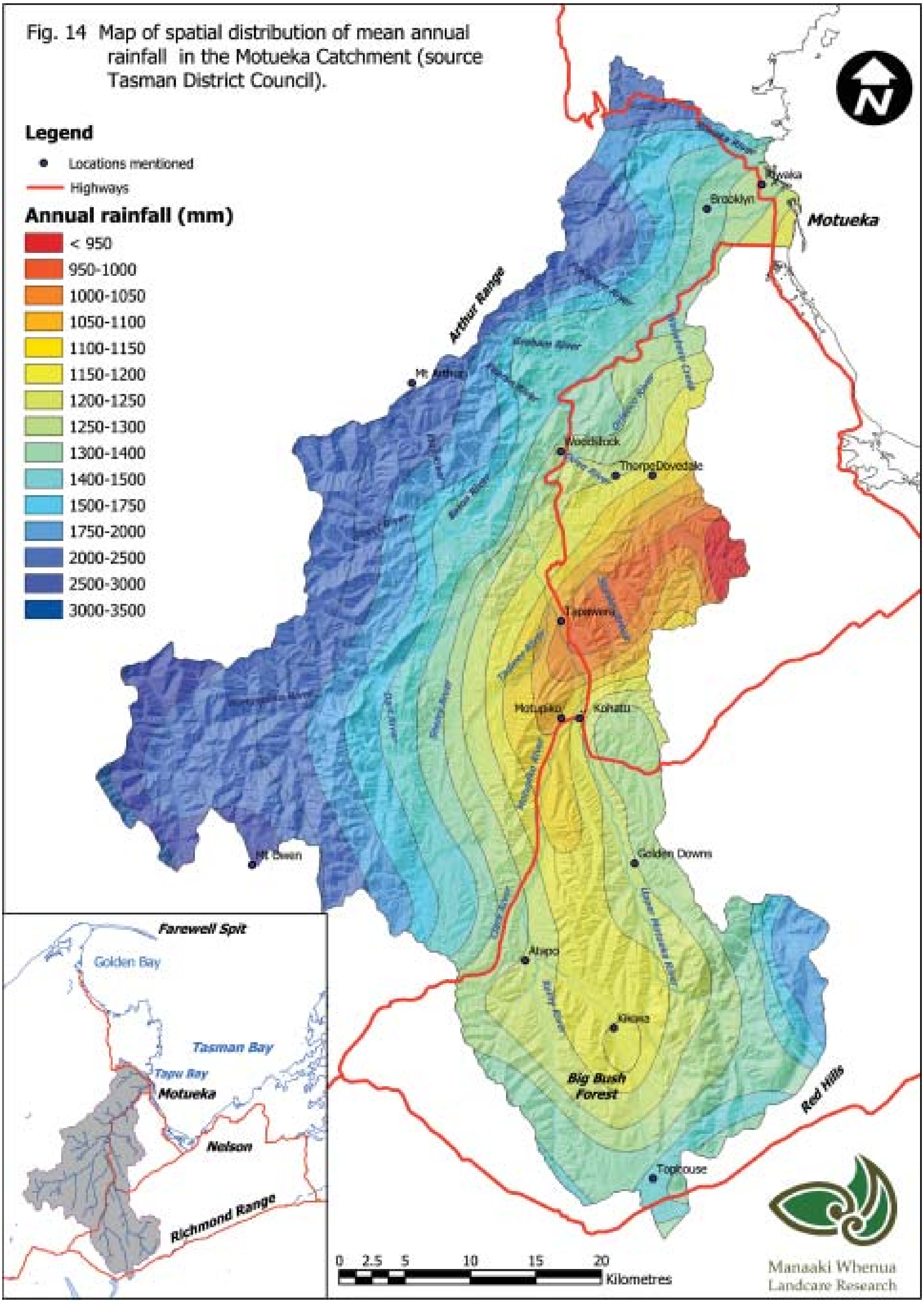
Fig. 14 Map of spatial distribution of mean annual rainfall in the Motueka Catchment (source Tasman District Council).

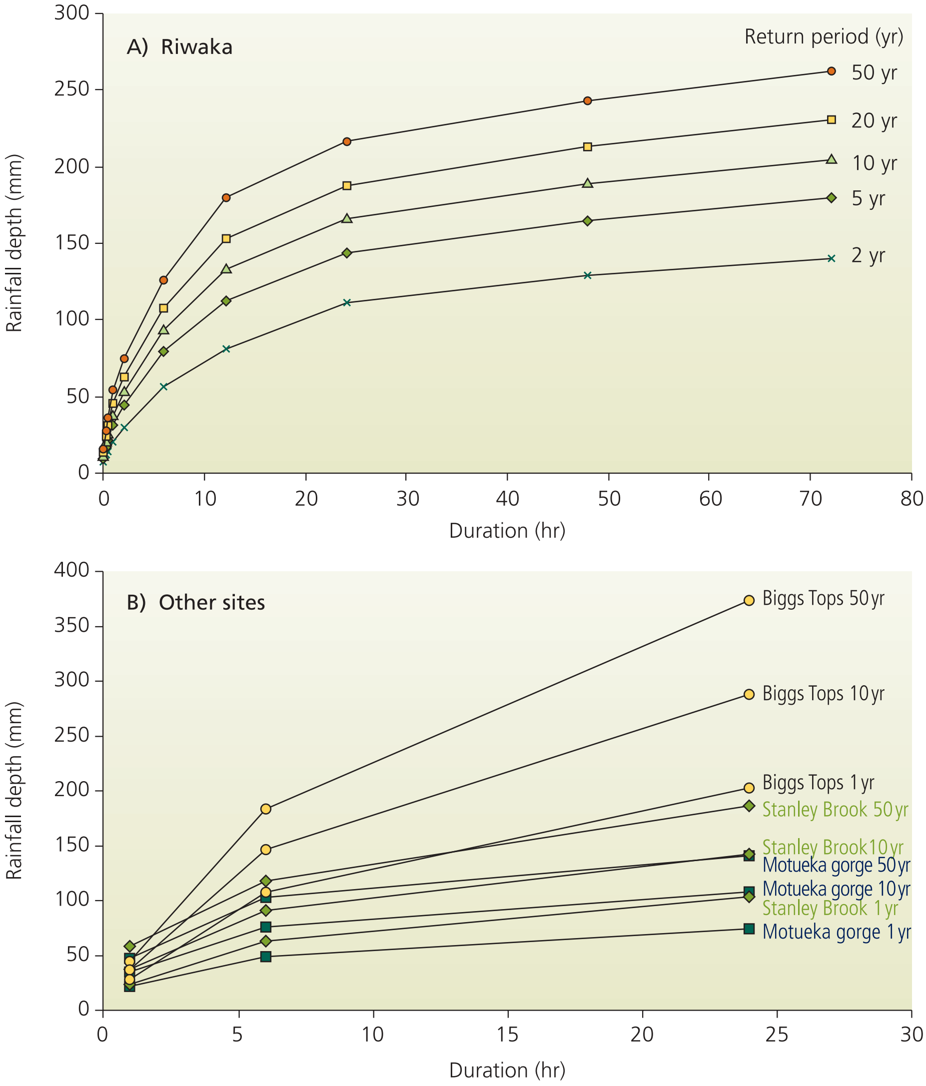

Fig. 15 Rainfall depth-duration-frequency statistics at (a) Riwaka (from Coulter and Hessell 1980), and (b) other sites in the Motueka Catchment (source Tasman District Council).

higher elevation, rainfall appears to be less seasonal, although the summer months tend to have lower rainfall than other months. Another characteristic feature of the rainfall pattern is marked variability of annual rainfall totals. For example, at Motueka between 1900 and 1985 annual rainfall ranged from 687 to 1747 mm and at Biggs Tops between 1990 and 1999 it ranged from 3043 to 5116 mm (Fig. 17). At the monthly level, rainfall is even more variable (Fig. 16).

Temperatures are milder in the north and east of the catchment and nearer the coast, and decrease inland and with elevation. At lower elevations summers are very warm and winters mild. Mean monthly temperature at Riwaka (8 metres elevation) ranges from 7.0ºC in July to 17.4ºC in January (Fig. 18). By comparison, at Golden Downs (274 metres elevation) mean monthly temperature ranges from 4.6ºC in July to 15.7ºC in January. The daily range of temperature is often large, with an average daily range of 11–12ºC. Annual days of air and ground frost also increase away from the coast and with

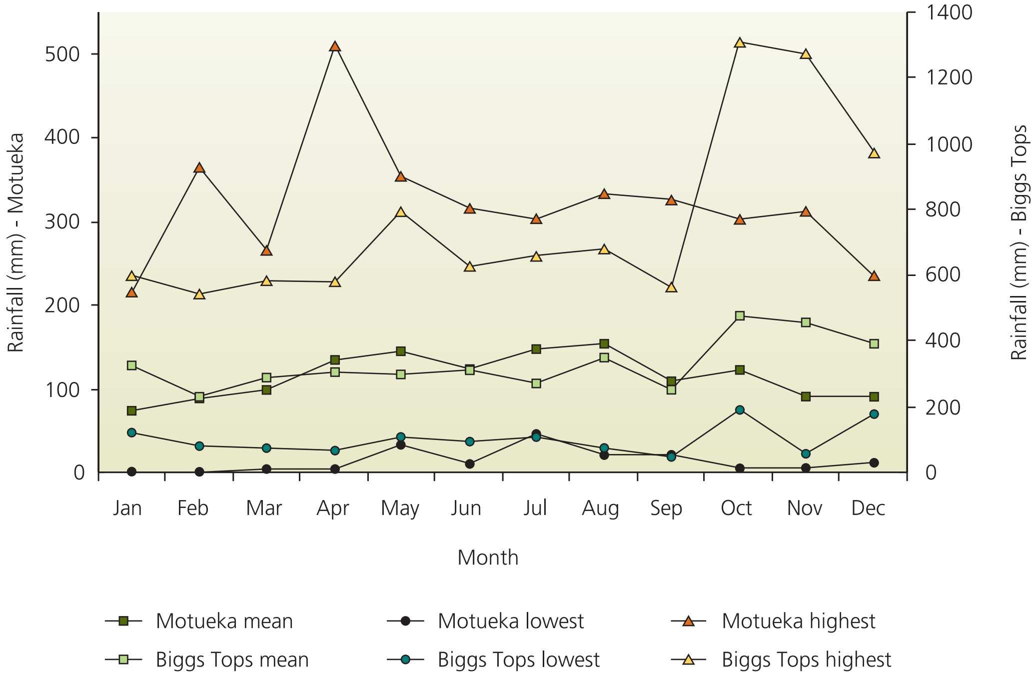

Fig. 16 Variation in mean monthly rainfall at Motueka and Biggs Tops (source NIWA and Tasman District Council).

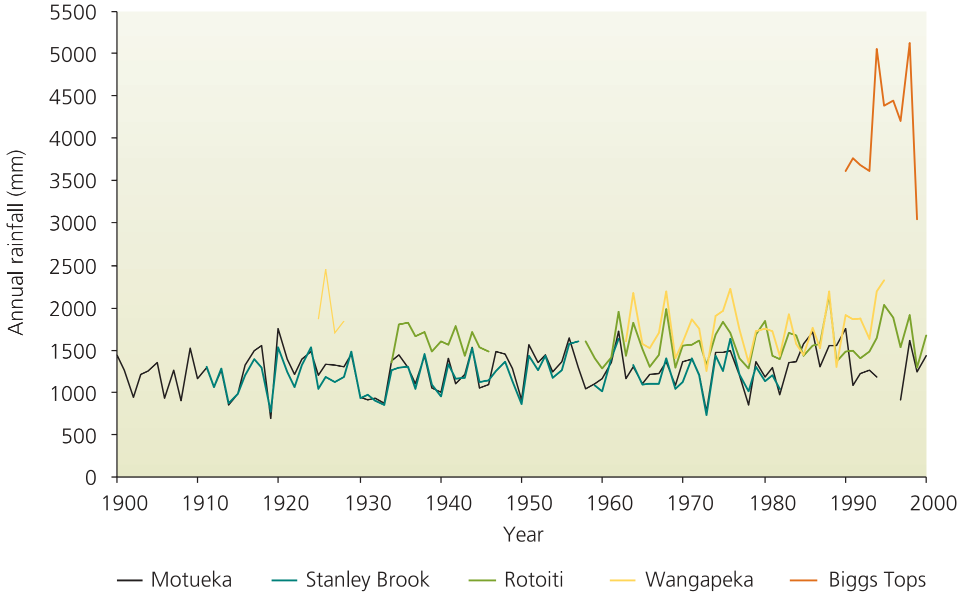

Fig. 17 Temporal variation in annual rainfall at Motueka, Stanley Brook, Lake Rotoiti, Wangapeka and Biggs Tops (source NIWA and Tasman District Council).

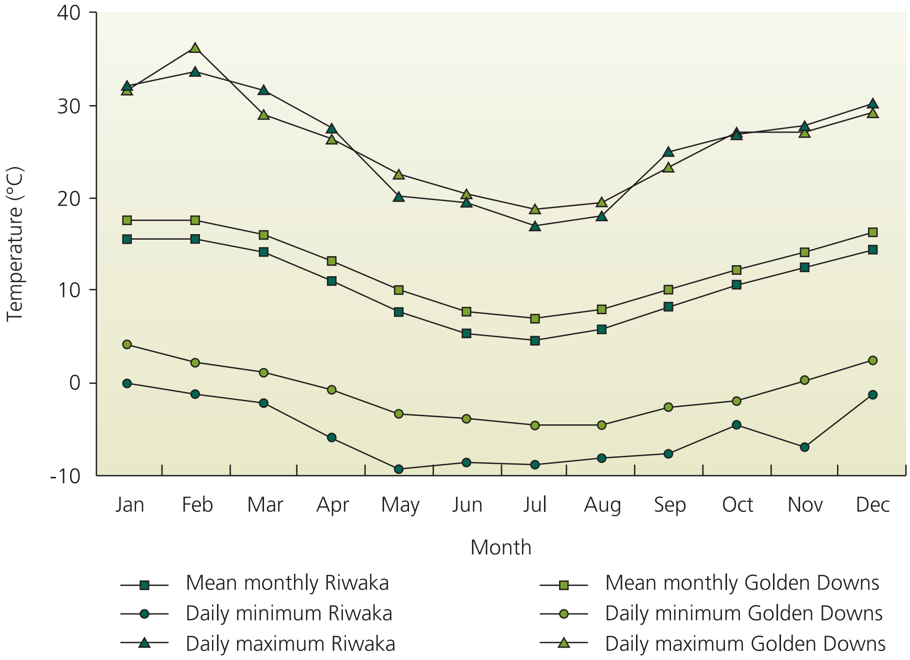

Fig. 18 Monthly mean temperature, highest and lowest daily temperatures at Riwaka (8 metres elevation) and Golden Downs (274 metres elevation) (data from New Zealand Meteorological Service 1983).

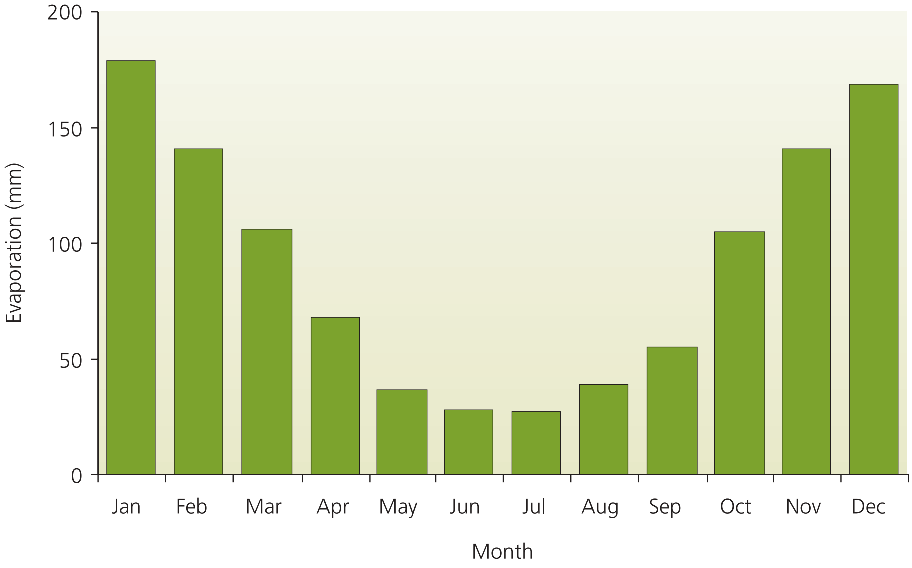

Fig. 19 Monthly mean open pan evaporation at Motueka (data from New Zealand Meteorological Service 1983).

elevation (31 and 82 days, respectively, at Riwaka, compared to 74 and 118 days at Golden Downs). Sunshine hours are among the highest in New Zealand averaging over 2400 hours at Riwaka, with mean monthly values ranging from 264 hours in January to 157 hours in July.

Annual open pan evaporation[14] at Motueka is 1106 mm and is strongly seasonal, with mean monthly values ranging from 27 mm in July to 179 mm in January (Fig. 19). While annual evaporation is less than annual rainfall, soil moisture deficits are common in summer when evaporation exceeds rainfall and irrigation is required on many crops. Scarf (1972) estimates annual potential evapotranspiration[15] to vary across the catchment from 540 to 700 mm.

2.8 FRESHWATER HYDROLOGY AND WATER QUALITY

2.8.1 Surface water

Surface water hydrology statistics are summarised in Green (1982), Fenemor (1989, 2002b) and Tasman District Council (2000a, b, c). Data presented in this section are derived from these sources. Tasman District Council and its predecessors have operated a network of 16 primary sites with flow recorders in the Motueka Catchment (Fig. 13, Table 4). At 19 secondary sites flow statistics have been derived by correlation of streamflow gaugings with a similar nearby primary site. Currently flow is monitored on the main stem at Woodmans Bend, Woodstock and the upper Motueka Gorge, and on the Baton at Baton Flats, the Wangapeka at Walters Peak, the Tadmor at Mudstone, the Motupiko at Christies Bridge, the Waiwhero, Hunters Gully at Weir, and at three sites on the Riwaka River (north and south branches, and main stem below the confluence of the north and south branches). Long-term flow records are available for the main stem sites at Gorge (since 1965) and Woodstock (since 1969), the Baton (since 1971), the Wangapeka (since 1986), the north branch of the Riwaka (since 1981) and the south branch of the Riwaka (since 1961). Flow is also measured by Landcare Research from four small catchments in Donald Creek at Big Bush Forest – one of these catchments is a control catchment in beech forest and in the other three the beech was harvested by different techniques and then the catchments were replanted in pines.

Annual flow[16] of the Motueka River at Woodstock is 844 mm, compared to a mean annual rainfall for the contributing catchment of 1600 mm. It is a reasonably large river with a mean flow of 58,560 L/s (7-day running mean for Motueka at Woodstock), and a measured flow range from about 5600 L/s to >2,100,000 L/s. River flow is lower than the mean flow about 70% of the time with a median flow[17] of 33,950 L/s (Fig. 20). The mean annual low flow ranges from 9,552 L/s (1-day mean flow) to 10,216 L/s (7-day mean flow). River flow lies between the mean annual 1-day low flow and the median flow 46% of the time. Like rainfall, mean monthly flow shows a distinctly seasonal fluctuation, with higher values in winter and spring, and lower values in the summer months (Fig. 21). This seasonality is more marked for low flows. River flow statistics for primary and secondary sites in the Motueka are listed in Table 4 and a comprehensive analysis of the low-flow characteristics of the river is included in Fenemor (2002b) and Waugh (2002).

Periodic large floods are a characteristic feature of the hydrology of the Motueka River and were a

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[14] Measured using raised, open pans of water – a measure of maximum potential evaporation from the land surface.

[15] Evaporation from the ground and plant surfaces, plus transpiration by plants (expressed in *L*, or for comparison with rainfall in *mm*).

[16] Total volume of water carried on an annual basis, converted to *mm* by dividing by catchment area.

[17] Discharge which is exceeded 50% of the time.

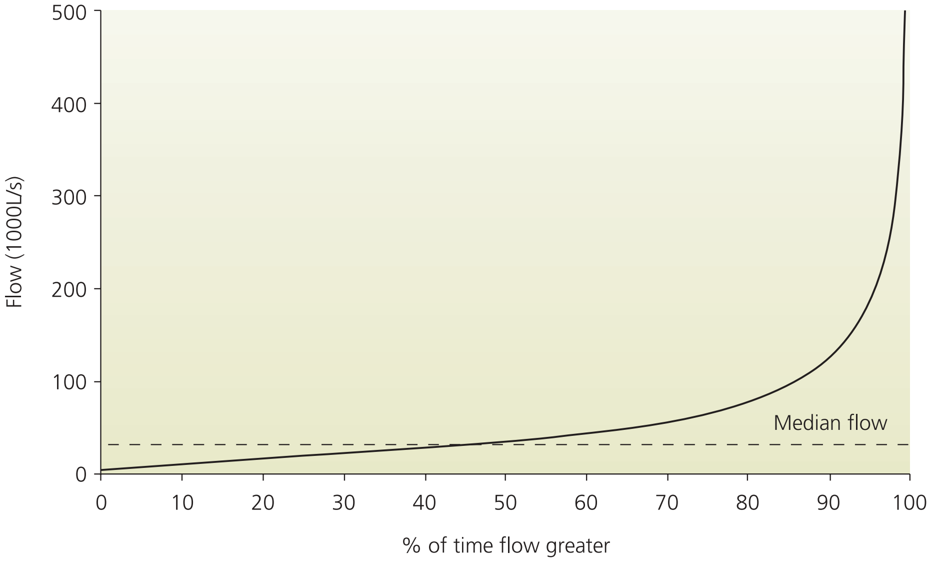

Fig. 20 Flow duration curve for the Motueka River at Woodstock (source Tasman District Council). Shows the percentage of time that flow is lower than a given value.

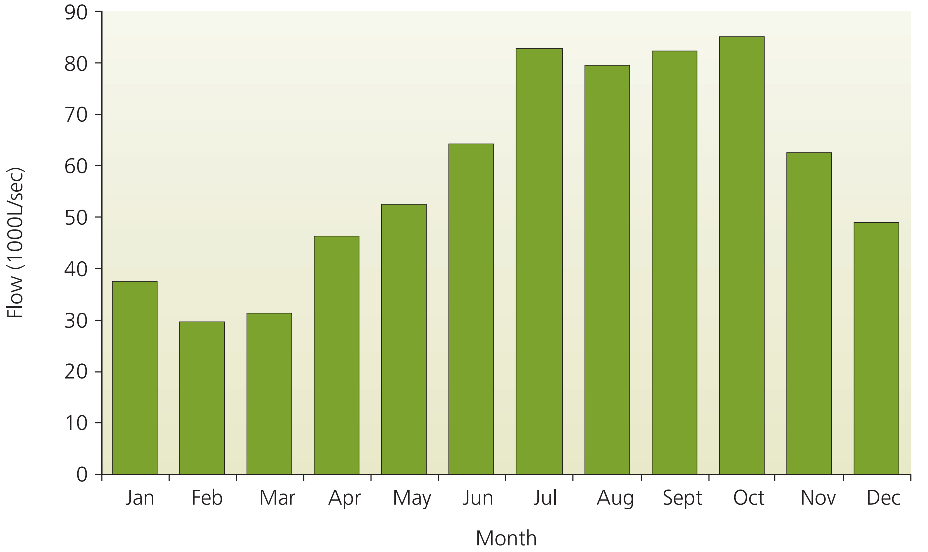

Fig. 21 Mean monthly flow for the Motueka River at Woodstock (source Tasman District Council).

severe hazard to transport and land use prior to the implementation of the Motueka Catchment Control Scheme (Green 1982). The largest flood is thought to be the "Big Flood" of February 1877[18] with a maximum flow at Woodstock estimated to lie between 2,500,000 L/s (M. Doyle, Tasman District Council, pers. comm. 2002) and 3,500,000 L/s (Green 1982). Other large floods occurred in January 1895, July 1929, June 1954, April 1957, August 1972, April 1974, July 1983, October 1988, and August 1990 (Green 1982; Fenemor 1989). Rainfalls in excess of about 150 mm over the

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[18] Brereton (1947) and Beatson and Whelan (1993) provide good historical accounts of the character and impact of this "earth" flood, which caused many landslides, widespread erosion and sedimentation, and changed the character of the river in many areas.

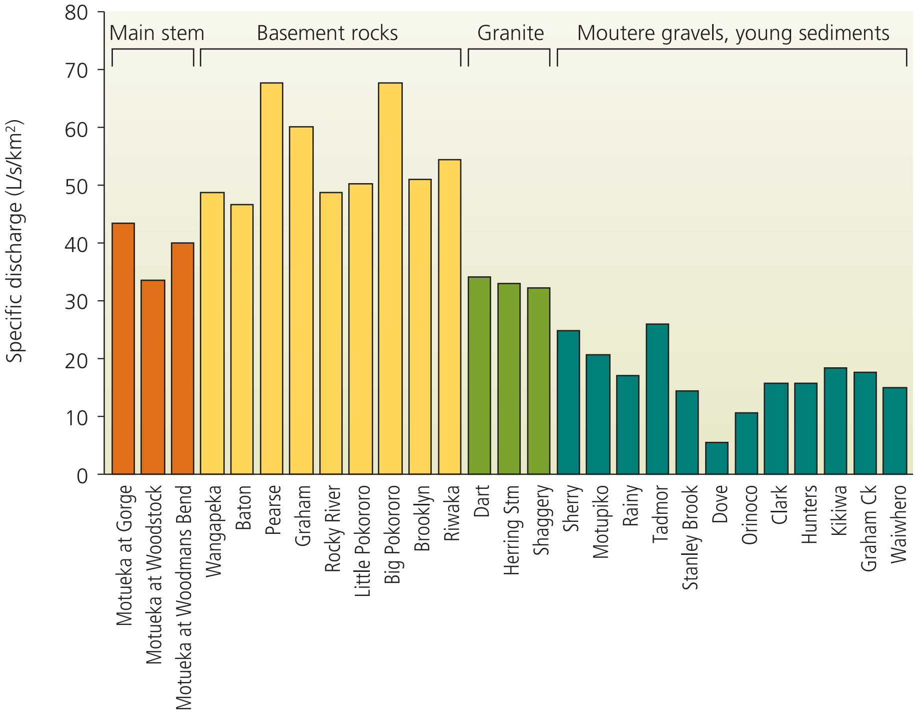

Fig. 22 Variation in specific discharge in the Motueka Catchment (source Tasman District Council).

catchment produce large floods on the main stem, while more-localised flooding can occur in any of the smaller tributaries in response to localised high-rainfall events. This is particularly true of the Wangapeka and Baton catchments, which can produce large floods at Woodstock from heavy westerly rainfall in their headwaters alone.

River flow generation is controlled by rainfall distribution (section 2.7) and geology (section 2.2), with striking contrasts between subcatchments in specific discharge (Table 4, Fig. 22). The largest contributors to flow in the lower Motueka are the mountainous catchments of the west and south-east (Wangapeka, Baton, upper Motueka) as they cover the largest area, have the highest rainfall, and are underlain by basement rocks that provide the highest sustained water yields (specific discharges >40 L/s/km^2). These areas provide a large proportion of the mean annual flow for the Motueka at Woodstock. The Wangapeka (27% of the catchment area above Woodstock) and Baton (9% of area) supply 40% and 13%, respectively, of the mean flow[19] of the Motueka at Woodstock. The proportion of flow contributed by these catchments increases as flow declines. The Wangapeka and Baton contribute 49% and 17%, respectively, of the mean annual low flow at Woodstock. Similarly, the upper Motueka is 9% of the catchment area above Woodstock, but provides 12% of the mean flow and 15% of the mean annual low flow.

The Moutere gravels are relatively impervious and make a significant contribution to flood events, but they have very low specific discharges (<20 L/s/km^2) and provide a small low-flow contribution. Flow in many tributaries underlain by Moutere gravel ceases completely during longer droughts. Strong seasonality of rainfall and evapotranspiration in areas underlain by Moutere gravel causes river flow to have high seasonal variability, with the

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[19] All mean and median flows are quoted as 7-day averages.

Table 4 Motueka Catchment flow statistics (from Fenemor 1989, 2002b; Tasman District Council 2000a,b,c)

SITE	Area	Mean	Median	Specific discharge		7-day low flow (L/s)				Period of
	(km^2)	(L/s)	(L/s)	(L/s/km^2)[A]	MALF	5 yr	10 yr	20 yr	50 yr	record
Primary sites										
Motueka at Gorge	163	7067	3966	43.4	1550	1243	1109	1005	894	1965– 2001
Hunters at Weir	5.02	79.5	30.5	15.8	3.5	1.1	0.3	0	0	1977– 2001
Kikiwa at Weir	2.85	52.5	23.4	18.4	1.6	0.21	0	0	0	1977–1986
Graham Creek at Weir	4.74	84.4	37.3	17.8	1.3	0	0	0	0	1977–1986
Motupiko at Christies	105.4	2173	1136	20.6	347	239	182	-	-	1990– 2001
Tadmor at Mudstone (prior to Hope River diversion)	88	2289	1060	26.0	195	121	96	77	-	1983– 2002
Tadmor at Mudstone (after Hope River diversion)	88	2347	1098		256	172	143	122	-	1988– 2002
Wangapeka at Walters Peak	479	23400	13590	48.9	4975	4005	3586	3261	2917	1986– 2001
Stanley Brook at Barkers	81.6	1185	428	14.5	30	18.5	0	0	0	1969–1994
Baton at Baton flats	168	7854	4748	46.8	1764	1387	1259	1165	1070	1971– 2001
Motueka at Woodstock	1750	58560	33950	33.5	10216	7422	6472	5774	5067	1969– 2001
Waiwhero Creek at Rosedale	3.79	57	21	15.0	8.9	-	-	-	-	1994–1998
Rocky River at Old Kiln	10.9	532	330	48.8	142	-	-	-	-	1981–1985
Riwaka River at Littles (north branch)	41[B]	1500		36.6	304	232	209	190	173	1981– 2001
Riwaka River at Moss Bush (south branch)	46[B]	2510	1412	52.2	619	469	418	380	342	1962– 2001
Secondary sites										
Rainy River below Big Gully	105	1794	882	17.1	187					
Clark River at SHB	21.5	339	179	15.8	25					
Dart River at Devils Thumb	80.6	2750	1600	34.1	820					
Sherry River at Blue Rock	78.4	1953	1070	24.9	218					
Ellis River at Baton confluence	35.8	930	580	26.0	260					
Skeet River at Baton confluence	38.2	1550	1100	40.6	610					
Dove River at Motueka confluence	102.3	582	331	5.7	89	61	51			
Pearse River at Caves	N/A	2200	1300		400					
Pearse River at Motueka confluence	51.2[B]	3464	2293	67.7	1163					
Graham River below forks	34.9[B]	2100	1450	60.2	800					
Little Pokororo at Motueka confluence	8.5	426	236	50.1	99					
Pokororo at Motueka confluence	25.2	1706	913	67.7	340					
Orinoco at Ngatimoti	33.4	360	240	10.8	140					
Herring Stream at Motueka confluence	9.8	323	179	33.0	76					
Shaggery River at Tom Evans	9.2	295	172	32.1	83					
Brooklyn Stream at West Bank Bridge	17.52	891	509	50.9	233					
Motupiko at Quinneys Bush	344	5152	2504	15.0	488	212	67			
Baton above Motueka confluence	212	9032	5460	42.6	2029	1595	1448			
Motueka above Wangapeka confluence	845	12030	6990	14.2	2132	1560	1421			
Motueka at Woodmans Bend[C]	2047	82148	47275	40.1	13318	9778	8656			

Primary sites – flow is recorded *Secondary sites* – flow is estimated by correlation with primary sites

MALF = mean annual low flow calculated as the average of each year's minimum flow for the period of record, or synthesised for secondary sites by correlation with adjacent primary sites; [A] discharge per unit area, calculated from mean flow; [B] Actual area is larger because of cave contribution to flow; [C] This site is recently established (2000) so flow statistics have been derived by correlation with primary sites lowest flows in summer and highest flows in the winter months.

Areas underlain by Separation Point granite tend to be intermediate in hydrological character between the Moutere gravel and the complex geology of the western catchments, with specific discharges of 20–35 L/s/km^2.

Some general features of subcatchment hydrology are listed below.

- The upper Motueka drains a large area of steep, relatively high rainfall terrain on ultramafic and Maitai Group rocks and makes a significant contribution to both low flows and flood flows. Median flow at the Motueka Gorge flow recorder is 3966 L/s and specific discharge is 43.4 L/s/km^2.
- The Motupiko is a large catchment on Moutere gravels, and with a large area of exotic forest it has low base flows[20]. Although rainfall is generally not too intense in this catchment, during the longer-duration storms the large catchment area means it provides a significant contribution to flood flows in the Motueka. Median flow at Christies Bridge in the upper catchment is 1136 L/s and specific discharge is 20.6 L/s/km^2.
- The Tadmor is partly underlain by Moutere gravel and partly by granite and young sedimentary rocks. It has a higher annual rainfall than the Motupiko. Summer river flows are heavily used for irrigation (mainly of berry crops). Flows have been augmented by diverting water from the Hope River (a tributary of the Buller River) into the Tadmor – this contributes up to 500 L/s from 1 October to 30 April. In drought conditions, the diverted flow can be as little as 62 L/s. Median natural flow at the Mudstone recorder (halfway down the catchment) is 1060 L/s and specific discharge is 26.0 L/s/km^2; with the diversion operating, the median flow increases to 1098 L/s.
- The Stanley Brook is one of the largest eastern, low rainfall tributaries draining Moutere gravels and it has a high proportion of its catchment in exotic forestry . At the Barkers recorder in the lower catchment it has a low median flow (428 L/s) and specific discharge (14.5 L/s/km^2), and makes a small contribution to low flows in the Motueka.
- The Dove, Orinoco and Waiwhero have similar runoff characteristics to the Stanley Brook. They have estimated median flows of 331, 240, and 21 L/s, and specific discharges of 5.7, 10.8, and 15.0 l/s/km^2, respectively.
- The Wangapeka is the largest tributary and drains steep, high-rainfall terrain on fractured basement rocks, providing sustained base flow and a major contribution to flood flows. Median flow at the Walters Peak recorder in the lower catchment is 13,590 L/s and specific discharge is 48.9 L/s/km^2.
- The Baton is hydrologically similar to the Wangapeka but covers a smaller area. At the Baton Flats recorder it has a median flow of 4748 L/s and specific discharge of 46.8 L/s/km^2.
- The smaller west-bank tributaries (Pearse, Graham, Pokororo, Brooklyn, Rocky, and Shaggery) are short, steep rivers draining basement rocks and granite and have relatively high estimated median flows (2293, 1450, 913, 509, 330, 172 L/s, respectively) and specific discharges (67.7, 60.2, 67.7, 50.9, 48.8, 32.1 L/s/km^2, respectively). The Pearse has a major karst spring in its headwaters, while the Graham and Pokororo have smaller areas of karst that influence their hydrology.
- At Woodstock (until recently the most downstream recorder site on the main stem) the median flow is 33,950 L/s and specific discharge is 33.5 L/s/km^2.
- Below Woodmans Bend the river flows across the Motueka Plains, constrained within stopbanks to a meandering single-thread channel. In this reach the river loses a small percentage of its flow to groundwater, with the pattern of flow

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[20] Proportion of stream flow carried between flood flows.

loss being highly variable (Fenemor 1989). River flow has been monitored at Woodmans Bend only since 2001. Median flow is estimated at 47,275 L/s and specific discharge is 40.1 L/s/km^2.

- The Riwaka comprises two main tributaries, which are hydrologically similar. Both drain steep catchments underlain by marble, granite and schist, and have high median flows and specific discharges (36.6 L/s/km^2 for the north branch and 52.2 L/s/km^2 for the south branch). Both tributaries have a significant karst influence on their hydrology. The two tributaries join at Moss Bush and below this junction the Riwaka flows across a small alluvial plain to the sea.

Water is taken from the Motueka River mainly for irrigation, but also for public and private water supply. As at March 2002, Tasman District Council has allocated surface water abstractions of 172 L/s above Woodstock, with 28 existing permits irrigating 305 hectares of land, and 215 L/s between Woodstock and Woodmans Bend, with 43 permits irrigating 395 ha. An assessment of water use in 1997/98 indicated that up to 62% of the allocations below Woodstock, and 43% of those above Woodstock, were actually being used (Shaw 1998). On the Motueka Plains a further 78 L/s from surface water (from the Motueka River and Brooklyn Stream) are allocated. The Riwaka River has an allocation limit of 200 L/s, with an agreed rostering regime by water users to maintain a minimum flow of 400 L/s in the river.

2.8.2 *Effect of land use on water yields*

The effects of changing land use and vegetation cover on streamflow from the Moutere gravels have been the subject of several small experimental catchment studies because of concerns about the impact of land-use change on water yield[21] and streamflow. These studies have been undertaken at Moutere, Big Bush, and Kikiwa. While the Moutere study catchments lie outside the Motueka Catchment, with an annual rainfall of 1020 mm they are representative of the drier part of the Moutere gravel hill country. The Big Bush and Kikiwa catchments are representative of the wetter part of the Moutere gravel hill-country, with 1200–1550 mm annual rainfall. Results of these studies are reported in Scarf (1970), Duncan (1980, 1995), McKerchar (1980), O'Loughlin (1980), Pearce (1980), Pearce et al. (1982), Rowe (1983), Jackson (1985), Fahey and Rowe (1992), Fahey et al. (1993), Jackson and Fahey (1993), Fahey (1994), Jackson and Payne (1995), Fahey and Jackson (1993, 1995a,b, 1997a,b), Jackson and Rowe (1996) and summarised in Rowe et al. (1997).

At Moutere, converting small (<10 ha) hill-country catchments in pasture and gorse to *Pinus radiata* forest, and subsequent felling of the mature forest, resulted in major changes in water yield and flow patterns due to changes in interception and evapotranspiration (Duncan 1980, 1995). Afforestation of pasture led to reduced flow and water yield, an increase in the number of days with no flow, and a reduction of peak flows in small storms. Scrub clearance led to short-term increases in peak flows, a decrease in the number of days with no flow, and an increase in the magnitude and persistence of low flows. Mean annual flood peaks from pines averaged 35% of those from pasture, while 50-yr-flood peaks averaged about 50% of those from pasture. Flood peaks following harvesting of pines were 20% (yr 1) and 62% (yr 2) of those from a pasture catchment (due to very low soil moisture levels under the pines at harvest). Harvesting of pines increased base flow (compared to pasture).

The effects on the hydrological regime at Moutere of the development of small gorse catchments by cultivation and cropping are discussed by Scarf (1970). This change in land use resulted in an increase in annual total

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[21] Total quantity of water discharged from a catchment on a storm, seasonal or annual basis.

runoff and peak flows, but a decrease in the number of days on which runoff occurred. Peak flows increased in small to moderate-sized floods but showed little change for large floods.

At Big Bush the changes in water yield, flood hydrology, and low flows caused by replacing beech forest with radiata pine forest were studied in catchments ranging in size from 5 to 20 ha. For the first 4 years after harvesting native forest, the average water yield increased 60–70%. Mean flood peaks increased on a skidder-logged catchment after harvesting, especially for small and medium storms (75–100%). The response of storm quickflow[22] to harvesting was similar but much more subdued. Low flows also increased after harvesting. Planting the harvested areas caused the water yield from both catchments to return to preharvesting levels within 8 years. Tree growth brought storm peak flows, quickflows, and low flows back to the levels of those in the original beech forest within 10 years.

At Kikiwa, rainfall and flow from four catchments (ranging in size from 2.8 to 4.8 km^2) – in native forest, cutover and replanted exotic forest (50% replanted in 1969), reverting pasture (recently (1975) planted in exotic forest), and pasture – are described by McKerchar (1980). In contrast to the Moutere and Big Bush studies, preliminary analysis suggested the pasture catchment had similar runoff to the adjacent native forest catchment, while water yield from the two catchments in young pines was slightly higher. A later analysis (1978–1983) by Hewitt and Robinson (1983) suggested no major changes in total water yield, but significant reductions in summer water yield in the afforested catchment. However, the changes in water yield are very small and may largely reflect understorey regrowth (Jackson 1995).

2.8.3 Water quality

Bruce et al. (1987) summarised existing water quality data (from Nelson Catchment Board, MAF, Ministry of Works and Development, Wildlife Service, Nelson Acclimatisation Society) and the results of a one-off sampling exercise (spread over 1986 and 1987) that sampled the Motueka main stem (7 reaches), Wangapeka, Motupiko, and Tadmor rivers for water chemistry and nutrients. This showed that water quality in the Motueka River was high, but there was evidence of enrichment in the lower reaches. The enrichment was greater in 1987 than in 1980-81, suggesting that changes within the catchment were affecting water quality. Water quality was strongly influenced by variation in catchment geology as well as land use. During winter, nitrate concentrations were high and phosphorus low, while in summer the reverse was true (due to uptake by algae and in-stream flora). Ratios of nitrogen to phosphorus were high enough in both the 1986-87 and 1980-81 surveys to suggest that biological productivity was limited by the availability of soluble reactive phosphorus. No mass-flow data[23] were available for the catchment, severely restricting the interpretation of water quality data and identification of enrichment sources.

Bruce et al. (1987) recommended a systematic survey of the catchment to describe the present water quality, nutrient status, and biological communities during low flow, winter base flow, and spring – prior to peak aquatic production; collection of mass-flow data to identify the contribution of each tributary and identify enrichment sources; and routine water quality monitoring at the mouth, Woodstock, and the Gorge, as well as some tributaries, to improve understanding of variation in concentrations of suspended solids and nutrients downstream and seasonally.

Fenemor (1989, 2002b) summarised variation in water quality characteristics throughout the catchment. He suggests water quality is generally

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[22] Proportion of flow which occurs during floods.

[23] Estimates of the total quantity of nutrients, derived from combining estimates of nutrient concentrations with river flow.

high although it depends on adjacent land use:

- faecal coliform bacteria and increased nitrate and phosphate are often associated with agricultural land use;
- elevated concentrations of suspended sediment are associated with forestry activities (particularly at harvesting).

He suggests water quality and clarity are particularly high in rivers and streams draining the western ranges and in the headwaters of the upper Motueka.

The "100 Rivers" survey (Close and Davies-Colley 1990a,b) characterised the water quality of a wide range of New Zealand rivers, including one site on the Motueka River at Woodstock. The Motueka River was grouped into a cluster of 35 rivers characterised by very low concentrations of major ions, phosphorus, organic matter, and nitrogen.

Biggs and Gerbeaux (1993) sampled water quality and periphyton[24] monthly for a year at five sites down the Motueka River and at one site in the Riwaka River. They found no systematic variation in water quality down the length of the Motueka River, although nitrate concentrations tended to be highest in the middle reaches, and were similar to the Riwaka River. Measurements of cellular nitrogen concentrations in periphyton indicated that their growth appeared to be limited by nitrogen concentrations for much of the year, but by phosphorus concentrations during low flow. Average periphyton biomass (mass per volume of water sampled) was strongly correlated with the proportion of marble geology in the catchment upstream. Nitrogen turnover and export is expected to be higher from soils overlying marble geology because of reduced acidity and enhanced microbial populations in the soil. Seasonal changes in periphyton biomass were influenced by flow variability, and during low flows biomass was negatively correlated with water velocity.

Two sites in the Motueka River catchment (at Woodstock and Gorge) have also been monitored since 1989 as part of the New Zealand National River Water Quality Network. The main water quality parameters (except suspended sediment and indicator bacteria) are measured monthly at 77 sites around the country. Maasdam and Smith (1994) used the first two years of data to classify the sites, and trends in water quality parameters for the first five years of the network's operation have been reported by Smith et al. (1996). The two Motueka River sites were classified in groups described as pristine waters, although water quality downstream at Woodstock was not as good as that in the upper reaches at the Gorge (Maasdam and Smith 1994). Over the first five years there were significant reductions in water temperature and nitrate at both sites and an increase in water clarity. At the Woodstock site there was also an indication of increasing dissolved oxygen and pH, and decreasing phosphorus concentrations, over time (Smith et al. 1996). Trends in mean annual water clarity, nitrate-nitrogen, and dissolved reactive phosphorus from the two Motueka sites up until June 2001 are shown in Fig. 23. Water in the upper reaches of the Motueka River at the Gorge site has a consistently higher clarity and lower concentrations of dissolved nutrients than in the middle to lower reaches at the Woodstock site (Fig. 23). Changes in these parameters from year to year are largely the result of differences in flow on the sampling days, rather than consistent trends.

As part of the ICM Programme an environmental sampling network has been initiated to provide an improved understanding of the variation in water quality through the catchment, and of the influence of land use and geology on water quality. This network provided monthly values over a 13-month period for a range of chemical and biological parameters (dissolved oxygen, temperature, water clarity, turbidity, total

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[24] Organisms that live attached to a riverbed.

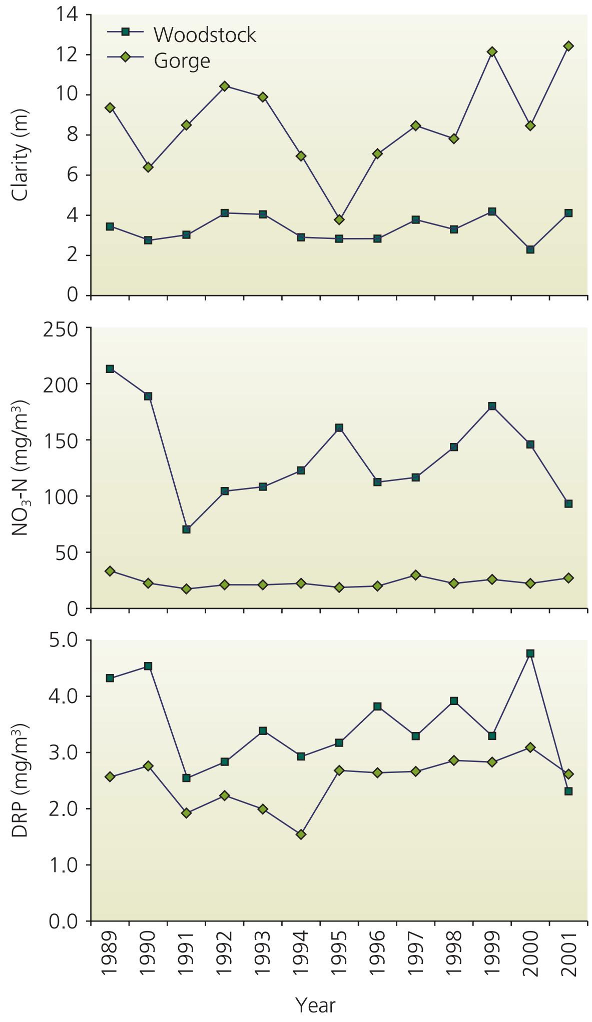


Fig. 23 Mean annual water clarity and concentrations of nitrate-nitrogen (NO_3-N) and dissolved reactive phosphorus (DRP) in the Motueka River at the Gorge and Woodstock 1989–2001 (data from NIWA National River Water Quality Network).

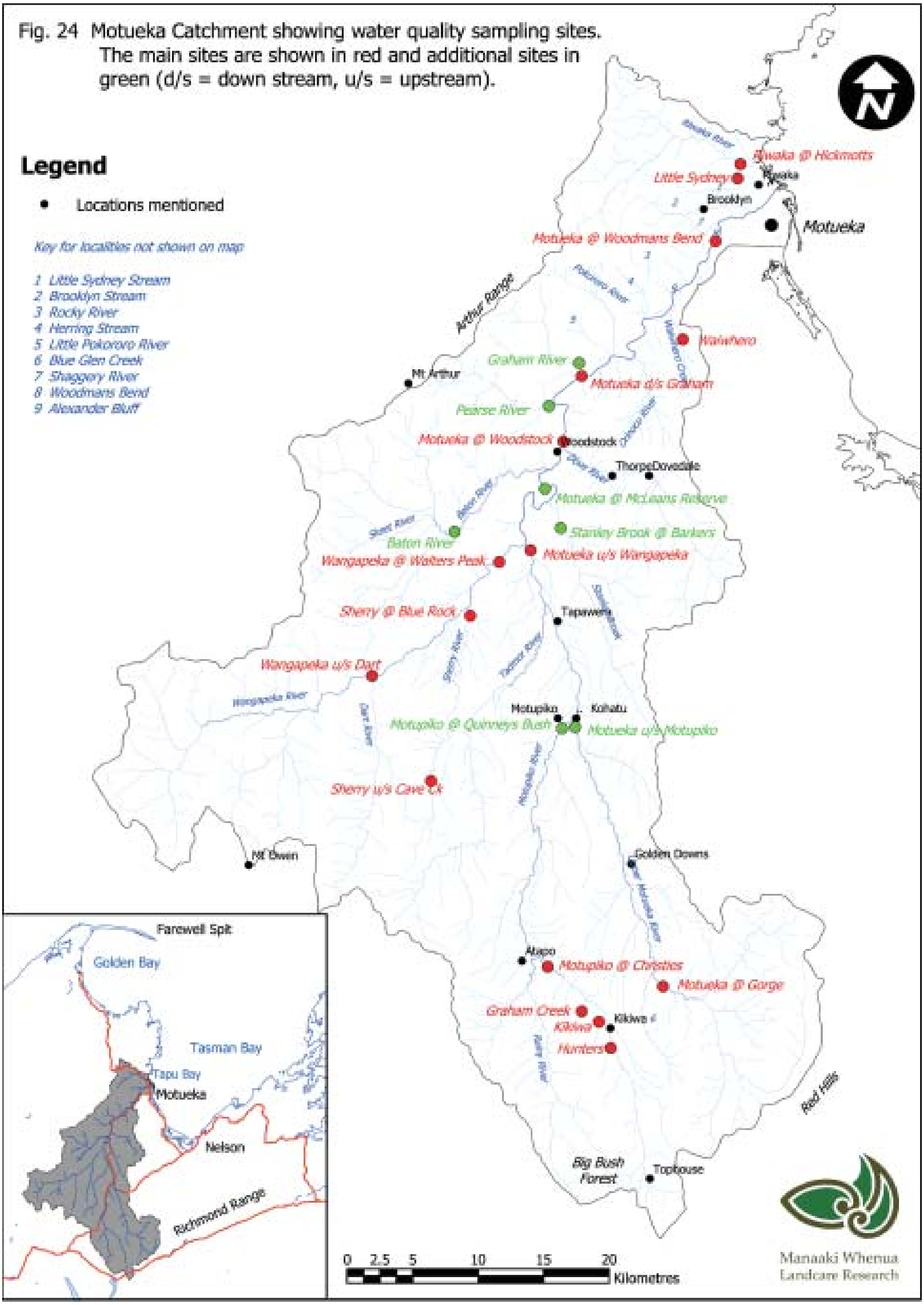
suspended solids (as inorganic and organic fractions), conductivity, pH, dissolved reactive phosphorus, total phosphorus, nitrogen (as ammonia, nitrate, total nitrogen), *Enterococci coli*, total faecal coliforms, and *Campylobacter*). The network continues to be monitored quarterly as part of the Tasman District Council's State of the Environment monitoring. Sixteen main sites and seven additional sites were chosen to cover a longitudinal profile of the river, and sample the key geological types (ultramafic rocks, basement rocks, Moutere gravels, Separation Point granite, marble), land uses (native forest, production forest, mixed agriculture, dairying, horticulture) and stream sizes found throughout the catchment. The sites and their key characteristics (size, land use, geology, location) are given in Table 5 and their location is shown in Fig. 24.

Preliminary analyses of the results (Roger Young, unpublished) have shown marked differences among sites. Some variables appeared to be primarily linked with geology (e.g., conductivity), some were related primarily to land use (e.g., bacteria, nutrients), and others were strongly controlled by both geology and land use (e.g., temperature,

Table 5 List of sites in the Motueka environmental sampling network 2000–2001, and their environmental characteristics

SITE	LOCATION	GEOLOGY	DOMINANT VEGETATION
Motueka River (at Gorge)	Main stem, upper catchment	Ultramafics and old sediments	Native forest, scrub
Motueka River (upstream of Motupiko)	Main stem, upper and middle catchment	Ultramafics, old sediments, Moutere gravel	Native and exotic forest
Motueka River (upstream of the Wangapeka)	Main stem, upper and middle catchment	Moutere gravel, ultramafics, old sediments	Native and exotic forest, pasture
Motueka River (at McLeans Reserve)	Main stem, upper and middle catchment	Complex basement rock, Moutere gravel, ultramafics, old sediments, granite	Native and exotic forest, pasture
Motueka River (at Woodstock)	Main stem, middle and lower catchment	Moutere gravel, complex basement rock, ultramafics, old sediments, granite	Native and exotic forest, pasture
Motueka River (downstream of the Graham)	Main stem, middle and lower catchment	Moutere gravel, complex basement rock, ultramafics, old sediments, granite	Native and exotic forest, pasture
Motueka (at Woodmans Bend)	Main stem, lower catchment, closest site to the coast	Moutere gravel, complex basement rock, ultramafics, old sediments, granite	Native and exotic forest, pasture
Wangapeka (at Walters Peak)	Major tributary	Complex basement rock and granite	Native forest, exotic forest, scrub
Wangapeka River (upstream of the Dart)	Medium/large catchment	Complex basement rock	Native forest
Baton River	Major tributary	Complex basement rock	Native and exotic forest, scrub
Pearse River	Major tributary	Karst (marble), complex basement rock, granite	Native and exotic forest, scrub
Graham River	Major tributary	Karst (marble), complex basement rock, granite	Native and exotic forest, scrub
Motupiko River (at Christies)	Major tributary	Moutere gravel	Pasture, exotic forest
Motupiko River (at Quinneys Bush)	Major tributary	Moutere gravel	Pasture, exotic forest
Stanley Brook (at Barkers)	Major tributary	Moutere gravel	Exotic forest, pasture
Sherry River (upstream of Cave Creek)	Small/medium catchment	Granite and mudstone	Exotic forest
Sherry River (at Blue Rock)	Medium-sized catchment	Granite and mudstone	Pasture (dairying), exotic forest
Lower Riwaka (at Hickmotts)	Medium-sized catchment	Marble and complex basement rock	Horticulture, pasture, native forest
Kikiwa Stream	Small catchment	Moutere gravel	Pasture
Hunters Gully	Small catchment	Moutere gravel	Native forest
Graham Creek	Small catchment	Moutere gravel	Exotic forest
Waiwhero Creek	Medium-sized catchment	Moutere gravel	Pasture
Little Sydney Stream	Small catchment	Complex basement rock and granite	Horticulture, scrub, native forest

Fig. 24 Motueka Catchment showing water quality sampling sites. The main sites are shown in red and additional sites in green (d/s = down stream, u/s = upstream).



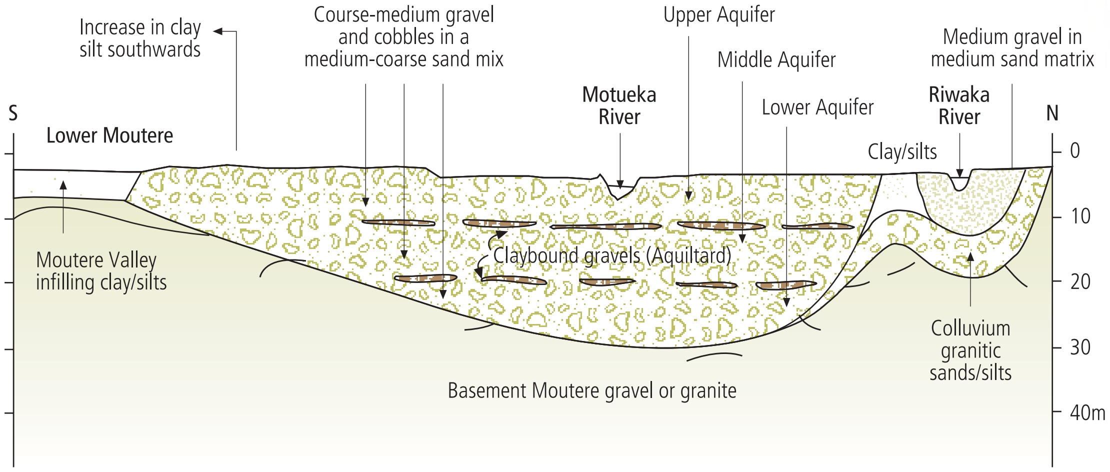


Fig. 25 Schematic cross-section through the Motueka–Riwaka Plains aquifers (from Thomas 2001).

suspended sediment, water clarity). Longitudinal patterns, in response to changing proportions of the catchment in different land use and/or geology, were also evident. Nutrient and suspended sediment concentrations in the Motueka Catchment appeared to be relatively low compared to other parts of the New Zealand. However, relatively high concentrations of harmful bacteria were found associated with dairy farming and horticulture (the latter influenced by a leaky septic tank). Conductivity of the water was much higher in the streams draining parts of the catchment with marble geology. Water clarity tended to be lower in the small streams draining pasture and horticultural land than in those draining native forest or pine forest. Water clarity also tended to be lower in the streams draining granite catchments. The highest clarity water was found in the upper parts of the Motueka and Wangapeka rivers, and water clarity tended to decrease downstream. Some water clarities recorded at the Motueka Gorge are amongst the highest recorded at any wholly riverine site in the country. Nutrient concentrations were relatively low in the Motueka Catchment compared with some other parts of the country, but within the catchment were highest in the small streams draining pasture and horticultural land.

2.8.4 Groundwater

There are three main groundwater systems exploited within the Motueka Catchment:

- the floodplain and fans of the Motueka Plains near the coast (Thomas 1991a; Robb 1999; Tasman District Council 1995a, 2000b)
- the terraces and floodplains in the upper Motueka around Tapawera (Tasman District Council 2000c)
- parts of the Waiwhero, Orinoco and Dove catchments that form the recharge zone for the Moutere groundwater system (Thomas 1989, 1991b, 1992; Tasman District Council 2000d)

Thomas (2001) summarises the characteristics of all three groundwater systems.

Groundwater in the Motueka Plains groundwater system is contained within alluvial gravels (known as the Motueka gravels) forming the coastal delta of the Motueka and Riwaka rivers (Fig. 25). This system is the principal source of water for irrigation, industrial and domestic use on the Motueka Plains, supplying 85% of the current water used (Thomas 1991a). The Motueka gravels are thinnest (c. 6 m) at the inland margins of the plains, and thicken to 30 m in the central plains area. They are underlain by granite in the west and north, and by Moutere gravels in the south. The gravels are cleanest and most permeable in the central plains, and become less permeable where mixed with fines (from Moutere gravels) to the south and with colluvium and organic materials to the west and north.

Three water-bearing units occur within the Motueka gravels (Fig. 25), with some leakage of water between them:

- the upper aquifer lies between 1 and 10 m below ground surface and has a transmissivity of 2000 m^2/day;
- the middle aquifer lies between 10 and 16 m depth and has a transmissivity of >4000 m^2/day. This is the main water-bearing unit and the most exploited;
- the lower aquifer lies below 16 m, has a transmissivity of >2500 m^2/day, and is the least-exploited aquifer.

The groundwater system is strongly connected hydraulically to both the Motueka and Riwaka rivers, and is weakly connected to the Moutere River. The principal recharge to the Motueka gravel aquifers is directly from the Motueka River downstream of Woodmans Bend, from the Riwaka River, and from rainfall on the plains. Flow from the aquifers occurs along the coast, through springs in the lower plains, or back into the Motueka River.

Groundwater quality is generally good, with low quantities of dissolved solids and a chemical composition similar to river water. However, elevated nitrate levels occur in the southern Motueka Plains (as a result of leaching of fertiliser and animal waste), and areas in the west towards the foothills of Riwaka have high iron, manganese, and sulphate levels (typical of a swampy environment). Pesticides (simazine, diazinon, terbuthylazine) have been detected in groundwater on the Motueka–Riwaka Plains but at concentrations well below the Ministry of Health maximum acceptable value for drinking water (Tasman District Council 2000e)

Tasman District Council (1995a, 2000b) has established seven zones (Riwaka, Swamp, Umukuri, Central Plain, King Edward, Hau, Transition) for groundwater management. In the Tasman Resource Management Plan (Tasman District Council 2001a) Hau and Transition have been merged into a Hau Plains Zone. The zones are based on hydrogeology and aquifer yields, and Tasman District Council's aim is to manage the zones in an integrated manner. Groundwater levels are monitored at six sites on the Motueka–Riwaka Plains to assist management. In 1999, the council allocated a total of 1298 L/s for abstraction from groundwater (Tasman District Council 2000b). Irrigation represents >96% of the pumping demand on these aquifers – with a total allocation of 110,000 m^3/day in the irrigation season, compared with 3000m^3/day for industrial use and 3000m^3/day for domestic use (Robb 1999; Fenemor et al. 1999). Much (63%) of the irrigation water re-enters the aquifers in an average year, but only 3% does so in a 1-in-20-yr drought. The water allocated for irrigation is greater than predicted irrigation demand (in a 20-yr drought this averages 65,500 m^3/day with a maximum demand of 105,000 m^3/day). Irrigation pumping has little influence on river flows in the Motueka and Riwaka rivers. Its major effect is significant lowering of groundwater levels in the Hau Plains Zone during droughts, which increases the likelihood of saltwater intrusion in this zone. Similarly, drying up of springs or flows in the Little Sydney and Brooklyn streams is more likely to be due to naturally low aquifer levels in drought years than to irrigation pumping.

Modeling of this groundwater system (Robb 1999) established that:

- most of the water entering the system from the Motueka River stays within the Central Plains Zone and exits to the sea;
- the amount of water pumped from the aquifer represents <10% of the total water flowing through the aquifer system in an average year. However, in the summer months during a 20-yr-drought simulation, pumping extracted 20% of

the water flowing through the system (and 13% in a 10-yr drought);

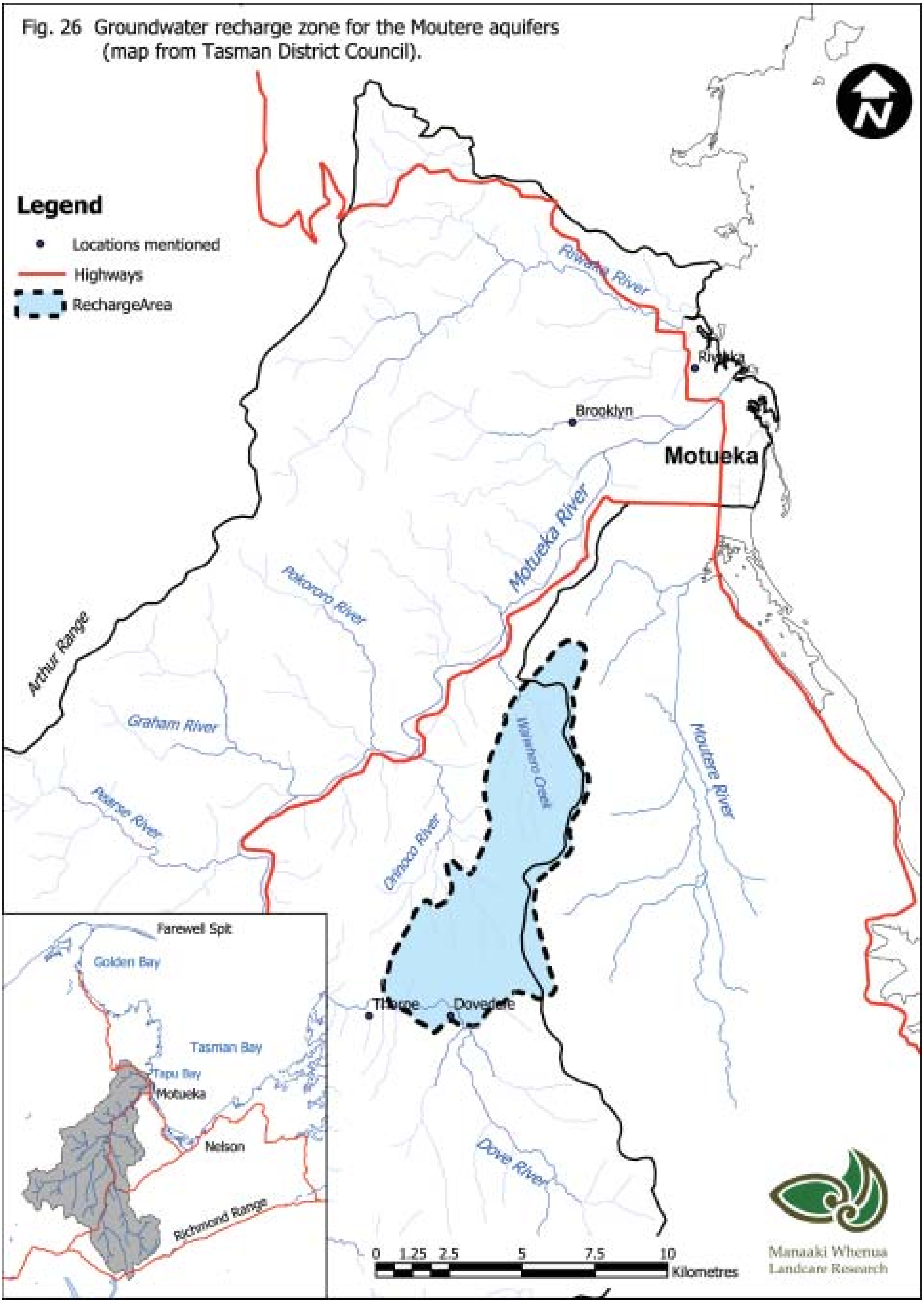
- pumping demand and recharge flows cause variation in groundwater levels on a day-to-day scale, but the base groundwater level is set by the Motueka River;
- the natural variation between years in average summer values of spring flows, aquifer–river flows, and sea outflows is greater than the variation caused by irrigation pumping;
- if the Motueka riverbed level lowered, summer recharge to the aquifers would reduce significantly (a 0.5-m lower riverbed would reduce summer recharge by 24%).

Significant groundwater resources also occur in the terraces and floodplains of the upper Motueka, especially around Tapawera, although the characteristics of the aquifers are poorly known (Tasman District Council 2000c). Historically groundwater in this area has been extracted from the lower alluvial terraces, which are believed to be recharged primarily from the Motueka River, with some direct rainfall input. However, little information is currently available on the size and character of the aquifers or on the relationship between river flow and groundwater levels. Current investigations are aimed at determining groundwater availability and recharge sources by mapping the aquifers, determining their characteristics, measuring groundwater levels in existing wells, dating the groundwater, and analysing the effect of groundwater abstraction on river flow. Initial results show significant groundwater resources beneath both the high and low terraces, and indicate that the water is older than previously thought. The latter suggests flow through the aquifer is reasonably slow or that the river is not well connected to the groundwater nearby, and may indicate it is safe to pump the groundwater during low-flow periods without major reductions in river flows. As at March 2002, Tasman District Council allocated 455 L/s for abstraction from groundwater above Woodstock (Fenemor 2002b).

In addition to these two groundwater systems, the upper reaches of the catchments of Waiwhero Stream and Orinoco Creek, and the middle reaches of the Dove River (Fig. 26) are important for recharge of deep aquifers in the adjacent Moutere Valley (Thomas 1989, 1991b, 1992). Rain falling in the recharge area moves through unconfined aquifers in the Moutere gravels underlying the eastern margin of the Motueka Catchment to confined aquifers underlying the Moutere Valley (Fig. 27). Water from these aquifers provides the major source of irrigation water for land users in the adjacent Moutere Valley. The location of the recharge zone is controlled by the outcropping of a more permeable unit within the Moutere gravels at the surface in the recharge zone.

The amount of recharge occurring through this precipitation–infiltration–recharge process is thought to be affected by vegetation cover. For rainfall to percolate into the aquifers, any soil moisture deficit needs first to be overcome before surplus water becomes available to run off or to recharge groundwater. Changes from short to tall vegetation reduce the total surface water yield (as outlined in section 2.8.2), and this same effect is likely to apply to the amount of water available for groundwater recharge. Hence, Tasman District Council has instituted land-use controls within the recharge area (Fig. 26) to limit afforestation and protect recharge of the Moutere aquifers (Tasman District Council 2000d, 2001). However, it is not clear whether recharge occurs uniformly across the recharge zone or whether there are preferred pathways for infiltration recharge. The recharge zone mainly comprises hilly terrain underlain by soils and regolith that have very slow permeability, and there may be a slow rate of recharge through these soils. Alternatively losses of water from streamflow in the valley bottoms, or from soils in lower slopes, may be the preferred pathway since these areas tend to be underlain by more-permeable soils than the hilly terrain, and by more freely draining gravels. Current research aims to answer these questions.

Fig. 26 Groundwater recharge zone for the Moutere aquifers (map from Tasman District Council).



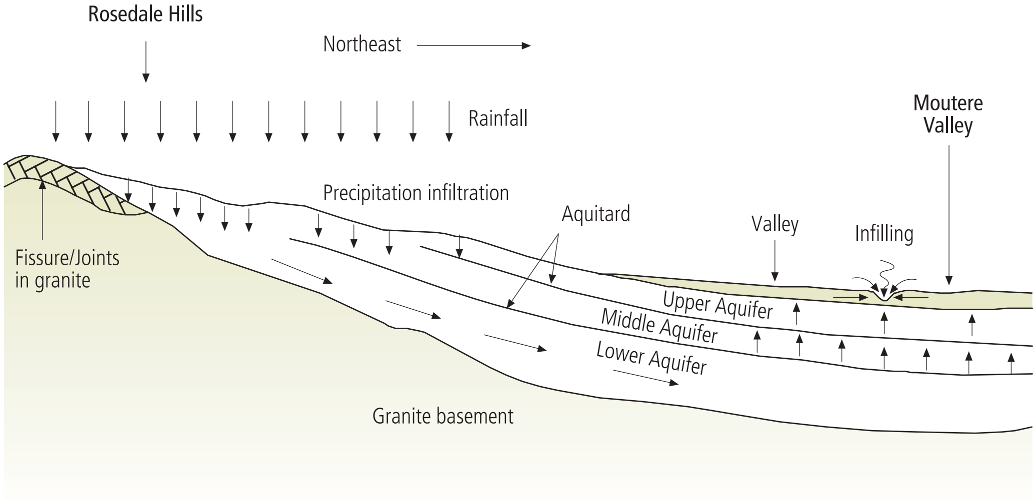


Fig. 27 Schematic recharge model for the Moutere aquifers (from Thomas 2001).

2.9 FRESHWATER ECOLOGY

2.9.1 *Native fishes*

The distribution and abundance of native fish species in the catchment were initially described by Bruce et al. (1987) and Ward (1990). The distribution of selected native fish species, derived from the New Zealand Freshwater Fisheries database (July 2002), are shown in Figs 28–31. The Motueka has a moderately diverse range of native fish species (as a function of the diversity of habitats and relatively unpolluted water) with 14 of New Zealand's approximately[25] 40 native fish species (Table 6). These include three migratory (kōaro, giant kōkopu, inanga) and two non-migratory (Canterbury galaxias, dwarf galaxias) galaxiids, common smelt, three migratory (bluegill, redfin, common) and one non-migratory (upland) bully, torrentfish, two eels (longfin and shortfin), and the lamprey. Five estuarine and marine species (black flounder, kahawai, yellow-eyed mullet, stargazer, cockabully) have also been reported in lower reaches of the river (Deans 2002).

Both species of eel are strong migrants and are found throughout the catchment (Fig. 28). Non-migratory species such as the dwarf galaxias (Fig.29) and upland bully (Fig. 30) tend to be found in the upper parts of the catchment, while many of the other species are only found in the lower reaches of the catchment. The Canterbury galaxiid has been reported once in the catchment, and if still present represents one of only two populations of this species found west of the Main Divide (McDowall 2000). The dwarf galaxias population found in the Motueka has been discovered to be genetically distinct from other *Galaxias divergens* populations (Allibone 2002). The Motueka is an important recreational and commercial fishery for whitebait (inanga), and would have supported a larger fishery before drainage of the wetlands between the Motueka and Riwaka rivers (Kelly 1988).

2.9.2 *Introduced fish species*

Until recently, brown trout were the only introduced species recorded in the catchment, and are widespread and abundant (Fig. 32). Brown trout were released in the Motueka River

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[25] Genetic studies of our native freshwater fish are still in progress therefore the total number of species present is dependent on the results of these studies.

	SCIENTIFIC NAME	COMMON NAME
Native freshwater fishes	*Anguilla australis*	Shortfin eel
	Anguilla dieffenbachii	Longfin eel
	Cheimarrichthys fosteri	Torrentfish
	Galaxias argenteus	Giant kōkopu
	Galaxias brevipennis	Kōaro
	Galaxias divergens	Dwarf galaxias
	Galaxias maculatus	Inanga
	Galaxias vulgaris	Canterbury galaxias
	Geotria australis	Lamprey
	Gobiomorphus breviceps	Upland bully
	Gobiomorphus cotidianus	Common bully
	Gobiomorphus hubbsi	Bluegill bully
	Gobiomorphus huttoni	Redfin bully
	Paranephrops planifrons	Kōura (freshwater crayfish)
	Retropinna retropinna	Common smelt
Introduced fishes	*Salmo trutta*	Brown trout
	Carassius auratus	Goldfish
	Gambusia affinis	Western mosquitofish
	Scardinius erthropthalmus	Rudd
	Tinca tinca	Tench
Estuarine and marine fishes	*Aldrichetta fosteri*	Yellow-eyed mullet
	Arripis trutta	Kahawai
	Forsterygian nigripenne	Cockabully
	Leptoscopus macropygus	Stargazer
	Rhombosolea retiaria	Black flounder

Table 6 Fish species found in rivers of the Motueka Catchment and the estuary

before 1879, and releases of fish continued until the early 1960s. Since then the fishery has been supported by natural wild stock replacement. The Motueka River is recognised as a nationally important recreational fishery for brown trout and is renowned for the abundance and size of the trout (Richardson et al. 1984). In a national survey of drift-dived rivers in New Zealand, the Motueka River ranked very highly for trout numbers and biomass (Teirney and Jowett 1990). The Motueka at Woodstock had the highest trout biomass of all purely riverine sites surveyed in New Zealand. The Wangapeka is recognised as a regionally important river and is noted for relatively abundant trophy-sized trout (Richardson et al. 1984).

Food (primarily invertebrates) and availability of suitable physical habitat are the primary controls on trout biomass (Jowett 1992); therefore, maintaining high-quality fish and invertebrate habitat is fundamental to maintaining the fishery. Critical factors for fish habitat in the Motueka include:

- maintenance of adequate flow of high-quality water;
- natural fluctuations in river form creating:
  - a sequence of runs (the feeding areas for adult fish), riffles (where most of the invertebrates live, and which provide cover and habitat for small fish), and pools (provide cover and resting areas for larger fish),
  - natural cover in the form of boulders or bedrock, submerged logs, overhanging

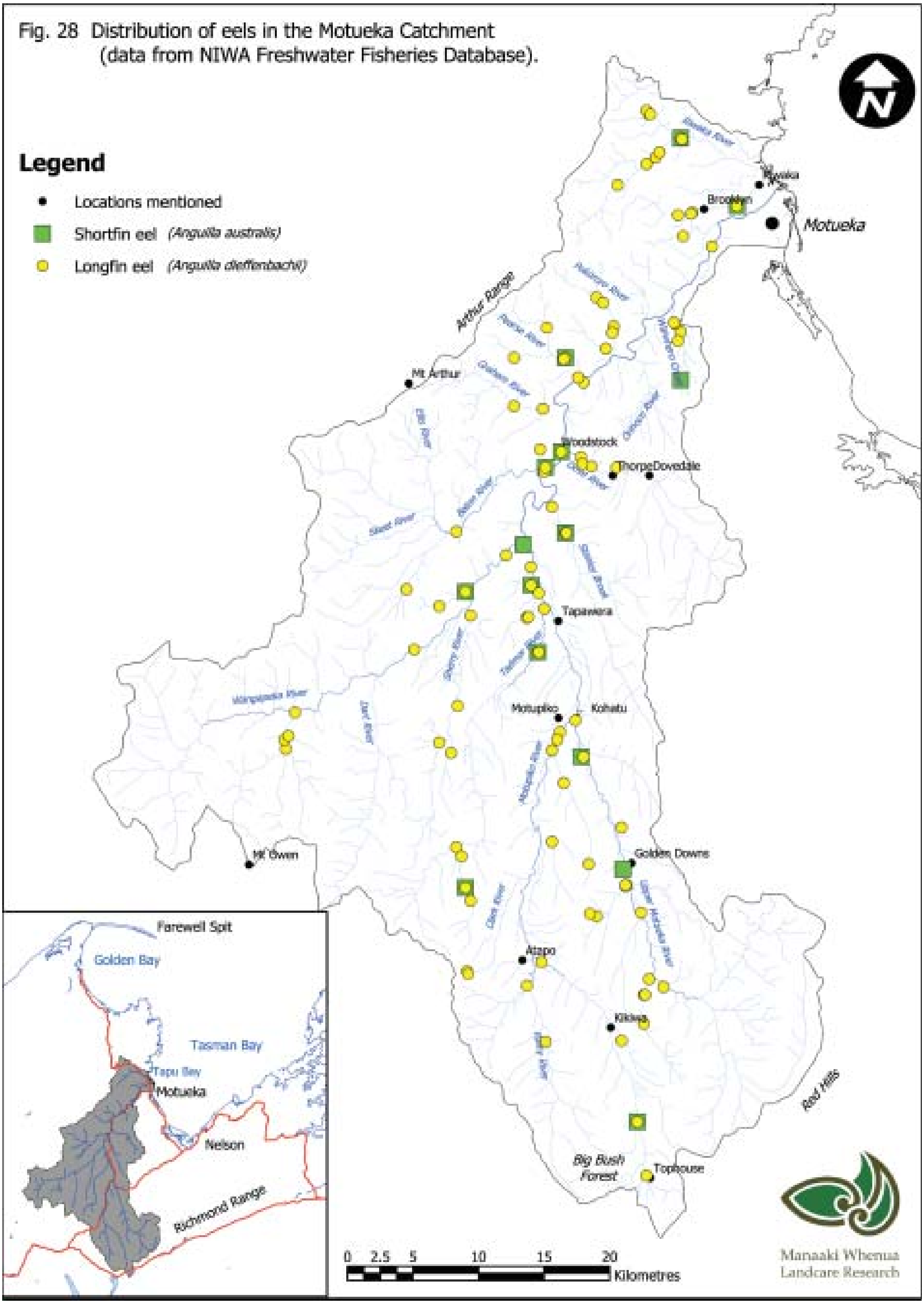


Fig. 28 Distribution of eels in the Motueka Catchment (data from NIWA Freshwater Fisheries Database).

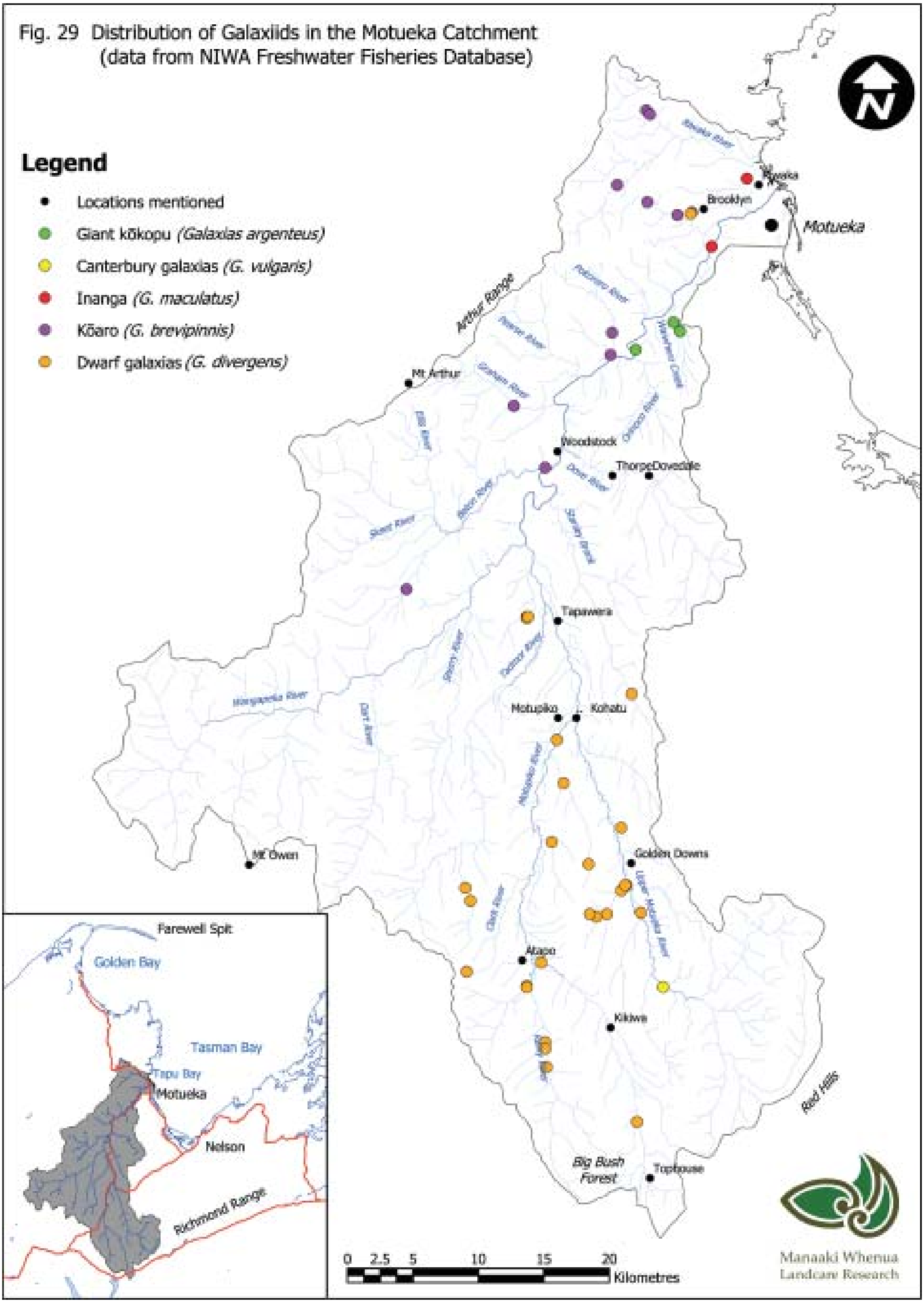


Fig. 29 Distribution of Galaxiids in the Motueka Catchment (data from NIWA Freshwater Fisheries Database)

Fig. 30 Distribution of bullies in the Motueka Catchment (data from the NIWA Freshwater Fisheries Database).

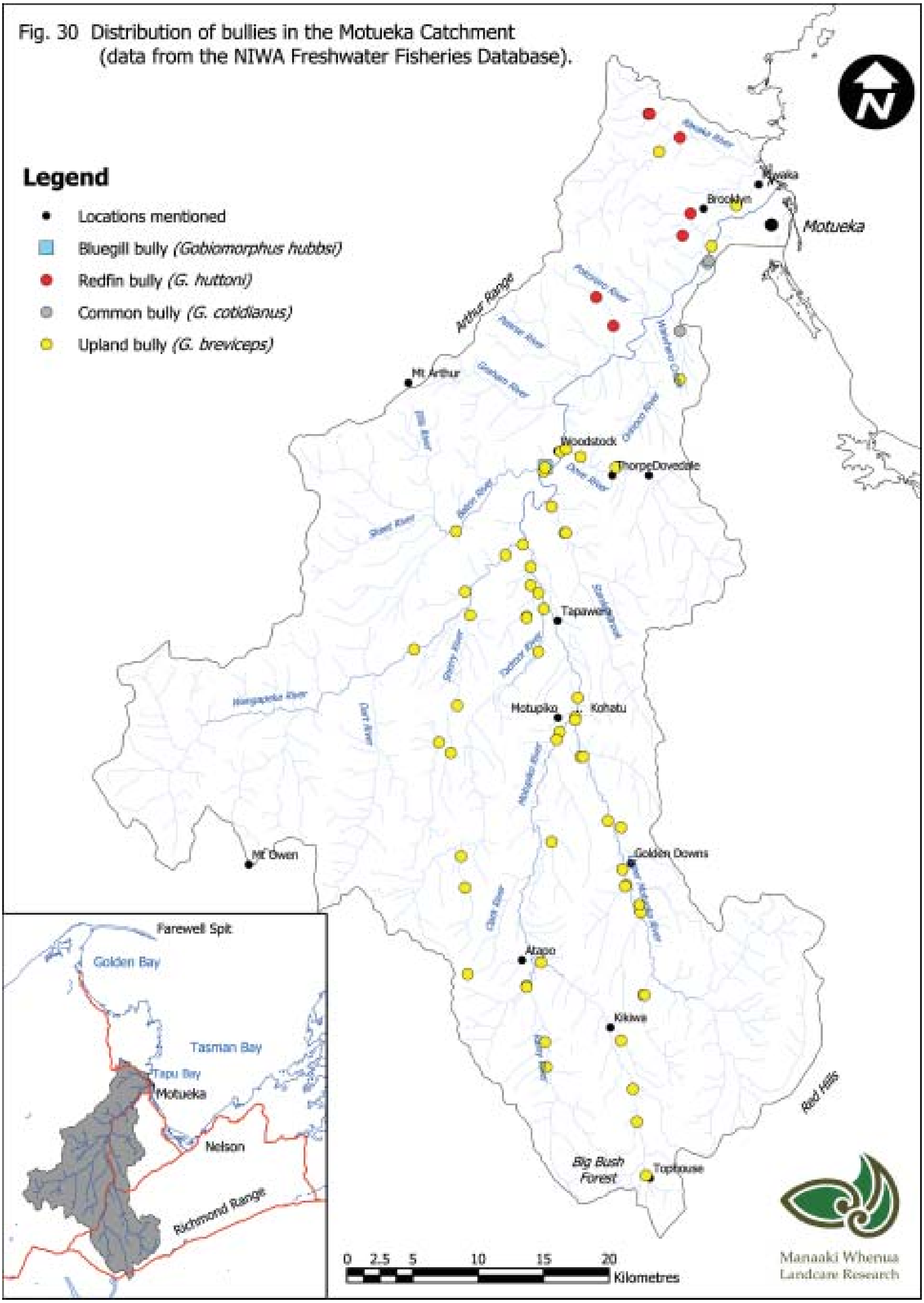


Fig. 31 Distribution of kōura, torrentfish and lamprey in the Motueka Catchment (data from the NIWA Freshwater Fisheries Database).

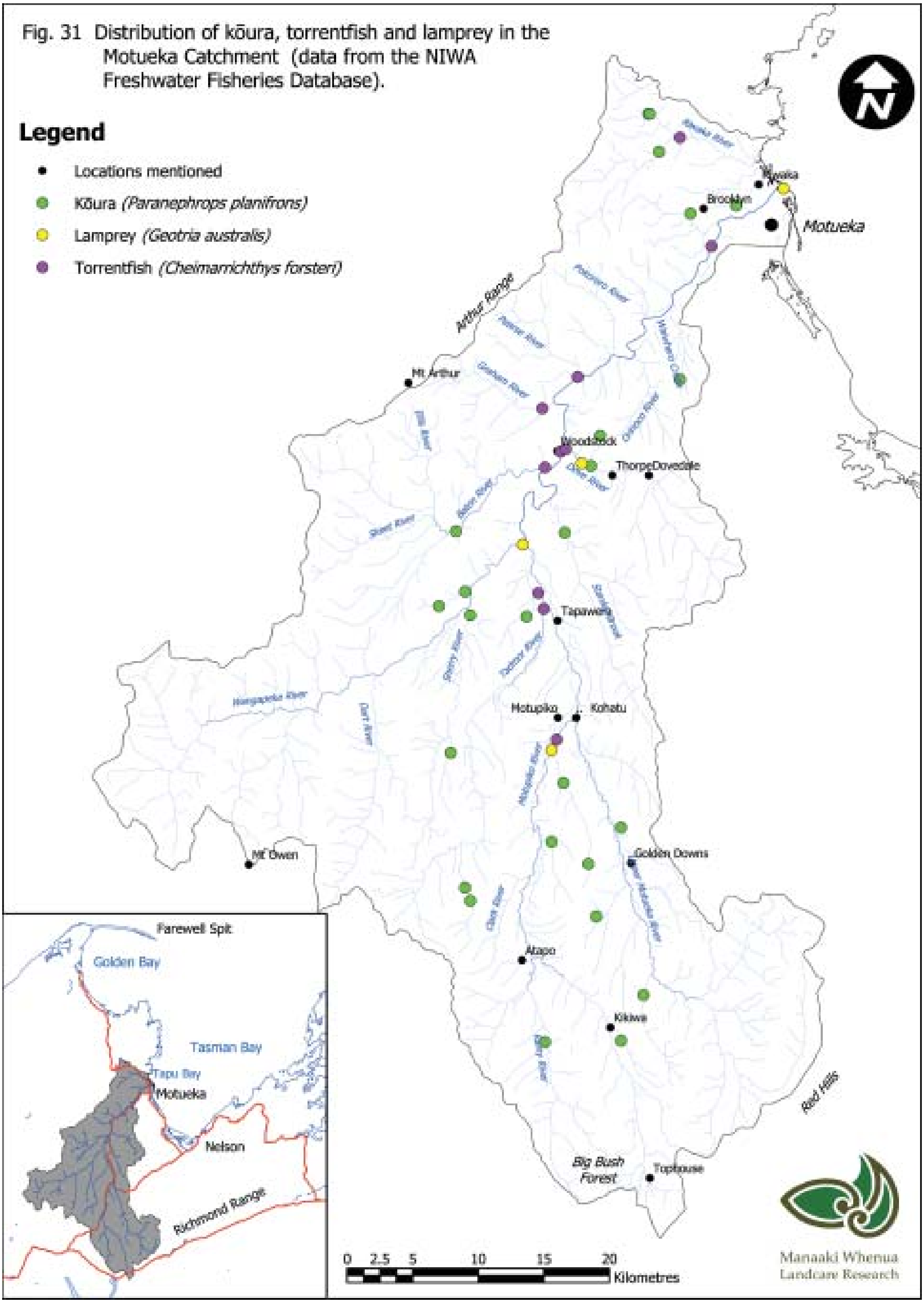
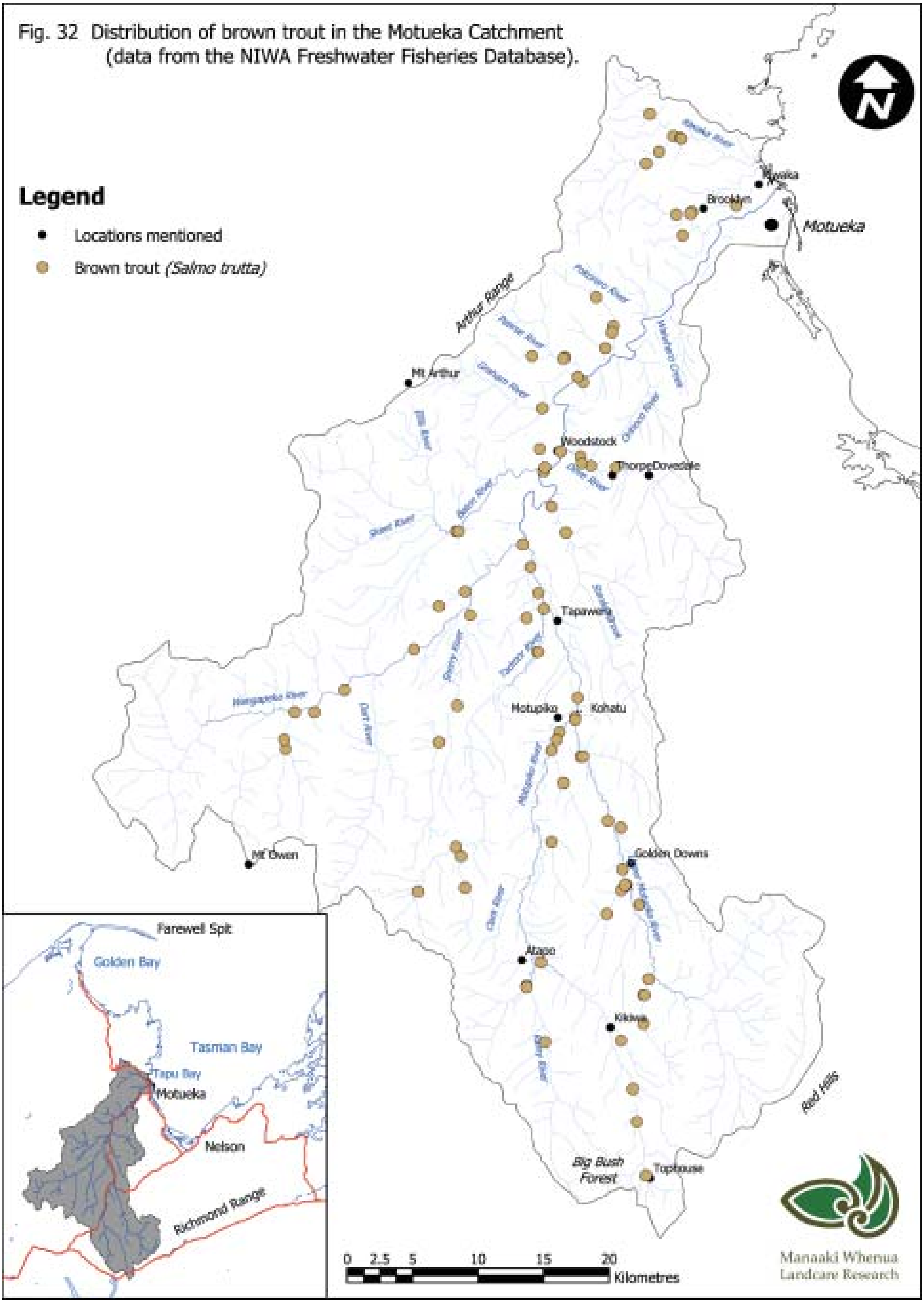


Fig. 32 Distribution of brown trout in the Motueka Catchment (data from the NIWA Freshwater Fisheries Database).



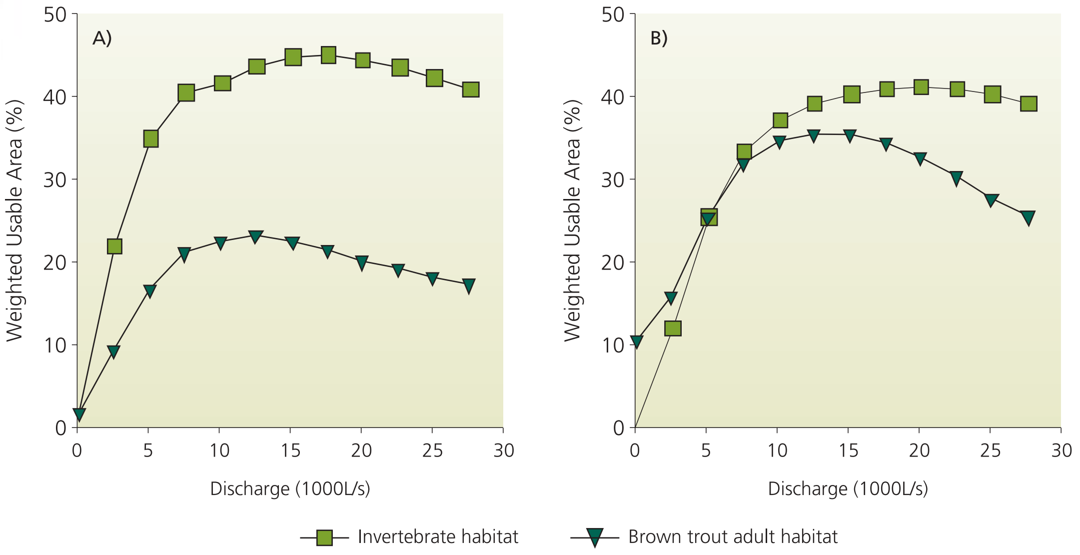


Fig. 33 Relationship between river flow and habitat for adult trout and trout food (invertebrates). Analysis for the Motueka River at (a) Woodstock and (b) Woodmans Bend, using Instream Flow Incremental Methodology (unpublished data provided by John Hayes, Cawthron Institute). Weighted usable area (WUA) is an index of habitat suitability for adult trout and invertebrates.

vegetation, or white water (which enable fish to avoid predators);

- unimpeded fish passage for spawning or to avoid floods, high water temperatures, low flows, or poorer water quality;
- the amount of fine sediment on the riverbed or in the water column[26], which has effects on both trout and invertebrate abundance;
- maintenance of spawning tributaries (including the Blue Glen, Motupiko, Rainy, Tadmor, lower Stanley Brook, lower Dove, lower Graham, Pokororo and Little Pokororo, and Motueka upstream of the Wangapeka confluence) with good water quality, cool water (<10.5ºC), high oxygen levels, low sediment levels, stable flow, and protection from predators (such as eels and shags).

The impact of variation in water depth and water velocity with flow has been evaluated at Woodstock and Woodmans Bend using the Instream Flow Incremental Methodology (IFIM), which analyses the relationship between trout and invertebrate habitat (expressed as weighted usable area, WUA) and flow (Fig. 33). At both sites the river ranks very highly for trout and invertebrate habitat (Hayes 2002). A special characteristic of the lower Motueka River is that optimal trout habitat occurs at the mean annual low flow (MALF). The amount of available trout habitat at the MALF is thought to be critical for trout population abundance (Jowett 1992); therefore, it is not surprising that the Motueka River has a very good trout population.

The trout fishery has been assessed by drift diving since 1985. At the main reference site at Woodstock there was a reduction in trout biomass around 1995 (Fig. 34a), possibly as a result of a severe flood in the upper Motueka in February 1995 and subsequent sedimentation from a large slip (Deans pers. comm. 1992). The fish population has remained reduced, possibly exacerbated by

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[26] Vertical section through a water body.

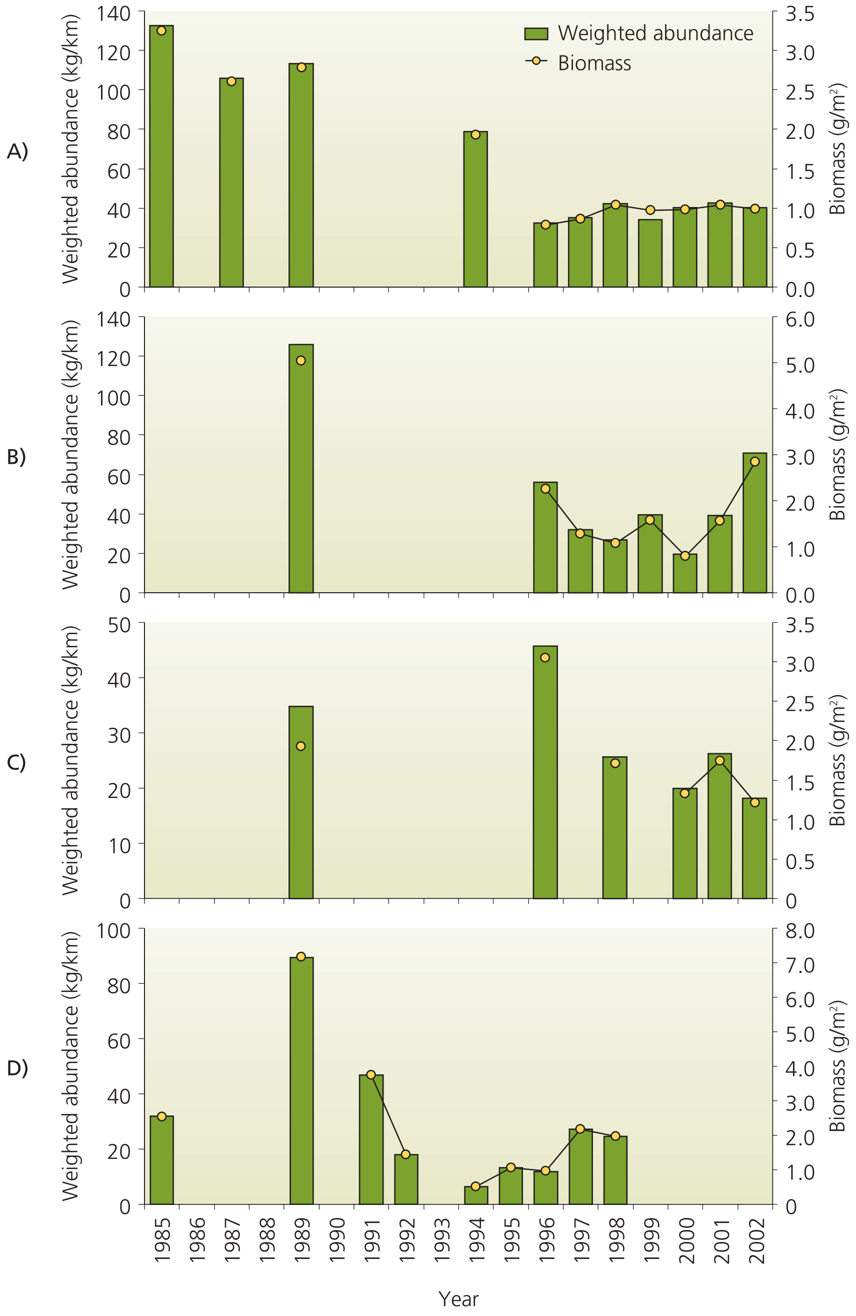

Fig. 34 Changes in weighted abundance and biomass of trout over time at (a) Woodstock, (b) Wangapeka River at Walters Peak, (c) Wangapeka River at Chummies Creek (above the Dart River), and (d) Riwaka River at Moss Bush (data provided by Neil Deans, Nelson Marlborough Region, Fish & Game New Zealand). Note different scales on the *y* axes.

winter floods affecting spawning or low river flows over subsequent summers. A similar decline is seen in the lower Wangapeka (at Walters Peak – Fig. 34b), but is not so marked in the upper Wangapeka (at Chummies Creek above the Dart confluence – Fig. 34c). It is also evident in the Riwaka River (Fig. 34d).

Recently four other species of introduced fish have been recorded in the Motueka River catchment (Table 6). These include four populations of Western mosquitofish, and single populations of the carp species tench, rudd, and goldfish. Western mosquitofish, in particular, presents a significant threat to native fish populations and the Department of Conservation has been attempting to exterminate any populations found in the South Island.

2.9.3 Macroinvertebrates

Macroinvertebrates[27] are key indicators of water quality and provide the key food source for trout. Macroinvertebrate communities are generally dominated by animals characteristic of unpolluted habitats, unmodified streams, and high aquatic habitat quality (Bruce et al. 1987; Stark 1990a,b). At least 119 taxa (dominated by caddisflies, true flies, mayflies, and stoneflies) have been recorded, with 15 of these contributing more than 90% of the community composition. Most common are the mayfly *Deleatidium*, the hydropsychid caddisfly *Aoteapsyche*, orthoclad midges, the cased caddisfly *Pycnocentria evecta,* and elmid (riffle) beetles. Most of the abundant taxa are widely distributed through the catchment. Species richness is generally high (average >28 taxa per site), with smaller headwater streams having a greater variety of taxa than the main stem. Macroinvertebrate densities average 3600 animals/m^2, with a range from <200 to >12,000 animals/m^2. Smaller rivers and headwater streams have the highest densities. Macroinvertebrate community index values (Stark 1985) range from 107 to 135, and are generally >120, which is indicative of unpolluted conditions.

As part of the National River Water Quality Network, macroinvertebrate samples were collected at Woodstock and the Gorge annually from 1989 to 1996 (Scarsbrook et al. 2000). The only trend present in the data from these sites was a weak decline in the proportion of mayflies, stoneflies, and caddisflies in the macroinvertebrate community at Woodstock.

As part of the ICM project macroinvertebrates have been sampled at 43 sites covering the range of combinations of land use, geology, and stream sizes found throughout the catchment. Results will be used to assess how land use, geology, and sediment influence stream health in the Motueka Catchment. A survey of hyporheic[28] invertebrates has also been carried out at five sites (Motueka at Gorge and Woodstock, Motupiko at Christies, Wangapeka at Walters Peak, Riwaka at Hickmotts) as part of a national survey.

2.9.4 Algae/Periphyton

At least 30 taxa of algae[29] have been recorded from the Motueka Catchment (Bruce et al. 1987). Four genera (*Oscillatoria*, *Stigeoconium*, *Oedogonium*, *Spirogyra*) are widely distributed in the lower reaches of the main stem and tributaries. Algal growth is prolific during periods of low flow and approaches nuisance levels in the lower reaches at times. Biggs and Gerbeaux (1993) sampled water quality and periphyton monthly for a year at five sites down the Motueka River and one site in the Riwaka River. They found the periphyton community was dominated by diatoms[30] (*Gomphoneis herculeana, Synedra ulna, Cymbella kappii*). *Melosira varians* was also common and more prominent at the Riwaka site. Filamentous algae (*Stigeoclonium* sp., *Ulothrix zonata*) were also common. Periphyton biomass (measured as chlorophyll-*a* levels) after an extended period of low flows ranged from 30 mg/m^2 in the upper reaches of the river to 355 mg/m^2 at Woodstock.

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[27] Animals that have no backbone and are visible without magnification.

[28] The zone below the bed of the river containing water.

[29] Algae are plant-like organisms that live in water and lack stems, roots or leaves. May be single cells or multicellular.

[30] Single-celled algae.

Mean monthly periphyton biomass was higher in the lower reaches of the river than the upper reaches, and appeared to be nitrogen-limited for much of the year, but phosphorus-limited during periods of low flow (Biggs and Gerbeaux 1993).

As part of the ICM programme rates of algal production have been measured at 10 sites from the headwaters of the Motupiko and Wangapeka rivers, down to Woodmans Bend near the coast. Preliminary analyses (Young 2002) indicate that the lower reaches of the river have very high rates of algal production compared with other rivers around the country, while algal production in the forested headwaters is limited by shading from streamside vegetation. The high rates of algal production in the lower reaches may be a mixed blessing. During long periods of low flow, algal biomass may reach nuisance levels and degrade the habitat quality for macroinvertebrates. However, high rates of production (particularly of diatoms) will provide a large source of high-quality food for macroinvertebrates, thus fuelling abundant macroinvertebrate and fish populations in the river, and perhaps also shellfish off the coast.

2.9.5 Land-use effects on freshwater ecology

Graynoth (1979, 1992) described the short- and long-term effects of forest harvesting on stream environments and faunas at Golden Downs Forest. Comparisons were made between a control stream with an unmodified forest catchment and three streams whose catchments had been affected by different logging practices. Measurements were made of streamflow, water temperature, streambed sedimentation, suspended sediment and dissolved solids concentrations, and the abundance of benthic[31] invertebrates and fish.

Clearfelling to the stream’s edge, together with inappropriate roading and bridging techniques, caused large changes in stream environments and faunas. Excessive amounts of waste timber and soil had entered streams, with stream bedloads, suspended sediment and dissolved solid concentrations increasing. In comparison to the control stream, water temperatures increased in summer by up to 6.5ºC and decreased in winter by as much as 2.5ºC. As a consequence the benthic invertebrate fauna was greatly modified (with a reduction in the abundance of Plecoptera and certain Ephemeroptera nymphs, and an increase in the abundance of oligochaetes, chironomids, and *Deleatidium* nymphs) and fish numbers were reduced. In January 1971 numerous brown trout and other fishes died in the Motueka River, and there are indications that this was due in part to low dissolved oxygen concentrations following excessive sedimentation of the riverbed caused by unsatisfactory logging practices. Where a riparian buffer strip of unlogged vegetation was left alongside one stream and the remainder of the catchment was clearfelled, there was relatively little change in the aquatic environment and fauna.

Sixteen years after the original survey, brief surveys were undertaken to collect samples of fish and invertebrates from the original study sites. At this time streamflows in the previously logged catchments were exceptionally low and long sections of the streambeds were dry, probably because of increased transpiration and interception rates from maturing pine forest. Low streamflows probably accounted for the lack of upland bullies and juvenile brown trout, and influenced the distribution and abundance of dwarf galaxias. Provided flows were satisfactory, streams in the logged catchments generally had similar invertebrate species and numbers to pre-logging populations. Graynoth (1992) suggests that on the Moutere gravels reduced streamflows caused by forest regrowth may have more serious impacts on the aquatic fauna than the

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[31] Refers to the bed of a river, lake or sea.

short-term changes caused by road construction, timber harvesting, and other logging practices, and the short cutting cycle (25–30 years) makes it unlikely that any stable equilibrium will be established in either physical or biotic conditions.

At Donald Creek in Big Bush Forest similar results were found by Cowie (1984) and Anthony and Winterbourn (1998). Invertebrate faunas in three streams whose catchments had been logged in different ways (clearfelling and skidder logging, clearfelling and skyline hauler logging, selection felling and skidder logging) were compared with an undisturbed control catchment. In each catchment forest was left as riparian strips and/or in the lower reaches of the catchment. Little effect of logging and subsequent afforestation was found and this was ascribed to the lack of large storms following logging, and the retention of riparian strips and unlogged forest in the lower reaches of each catchment.

2.10 MARINE HYDROLOGY AND WATER QUALITY

Tasman Bay is a shallow, open embayment with a low seafloor gradient and dominantly silty bottom (Mitchell 1986, 1987). The delta region off the Motueka River mouth has a relatively steep gradient down to a water depth of 10–20 m, and has a sandy and gravelly bottom. Beyond the delta, water depth increases offshore to a depth of 40–60 m, the seafloor has a very low gradient and is dominantly silty. The fine-grained nature of bottom sediment reflects the relatively low wave and current activity in the bay. Under some wind conditions (particularly northerly) sediment may be resuspended and transported laterally by weak tidal and oceanic currents. Circulation patterns in Tasman Bay are influenced by circulation in both Golden Bay and Cook Strait, with strong hydrological linkage between the two bays.

Current flows in the Tasman Bay – Golden Bay system are primarily forced by tidal processes and local winds. Typical speeds for tidal flows are 2–5 cm/s in the bays, although significantly stronger currents occur in shallower regions. There is no general consensus on the direction of tidal residual flows[32] in the Tasman Bay – Golden Bay system. Heath (1976) suggested that a residual anticlockwise circulation in Tasman Bay exists; however, the limited data used in that study do not support any general conclusions about residual circulation in the bays.

The speed and direction of local winds over the Tasman Bay – Golden Bay system varies considerably as a result of the system's large spatial scale and the high mountains on adjacent land. The predominant pre-frontal north-westerly and post-frontal south-westerly winds observed over the West Coast of the South Island can be considerably modified over the Bay system. In particular, weaker-gradient winds from the west and south-western quadrants often end up as winds from the north in the southern part of Tasman Bay. This is reflected in the often-significant differences in wind speed and direction from the meteorological stations located at Farewell Spit and Nelson Airport.

In Tasman Bay in summer, water temperature and salinity values are typically 20ºC and 35 PSU (practical salinity units), respectively, and the water is normally thermally stratified. In winter, water temperatures fall to 11ºC and surface salinities are periodically reduced by freshwater runoff, producing vertical salinity and density gradients (water column stratification – see Fig. 35). As a result of the influence of freshwater runoff, nutrient levels often increase towards the shore, while salinity decreases (Fig. 36). These differences are heightened during floods, particularly during the winter when nutrient uptake by phytoplankton[33]

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[32] The long-term mean flow generated by the tides.

[33] Microscopic plants.

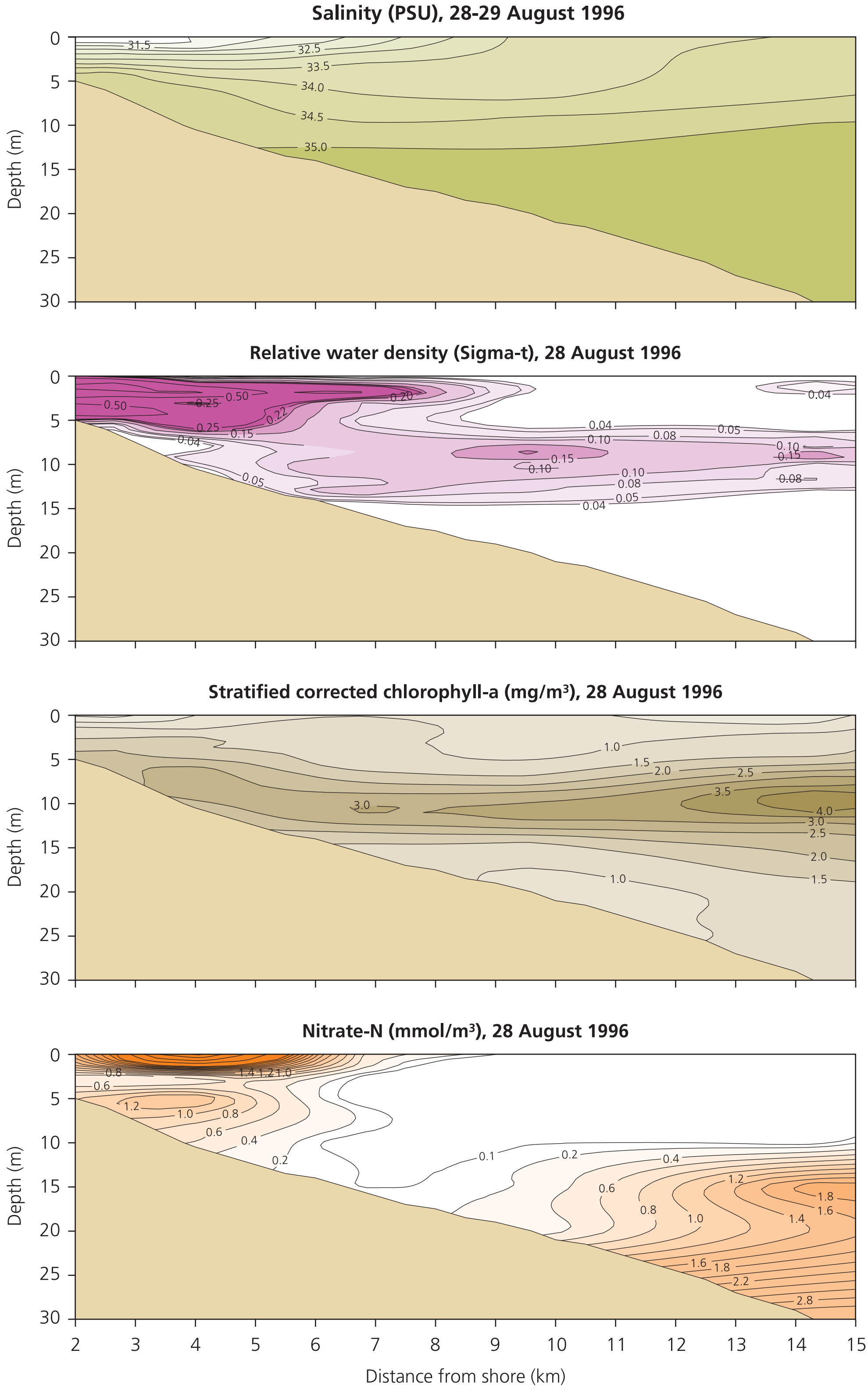

Fig. 35 Offshore transects of physical and chemical characteristics illustrating water column stratification in Tasman Bay (Lincoln MacKenzie, Cawthron Institute, unpublished data).

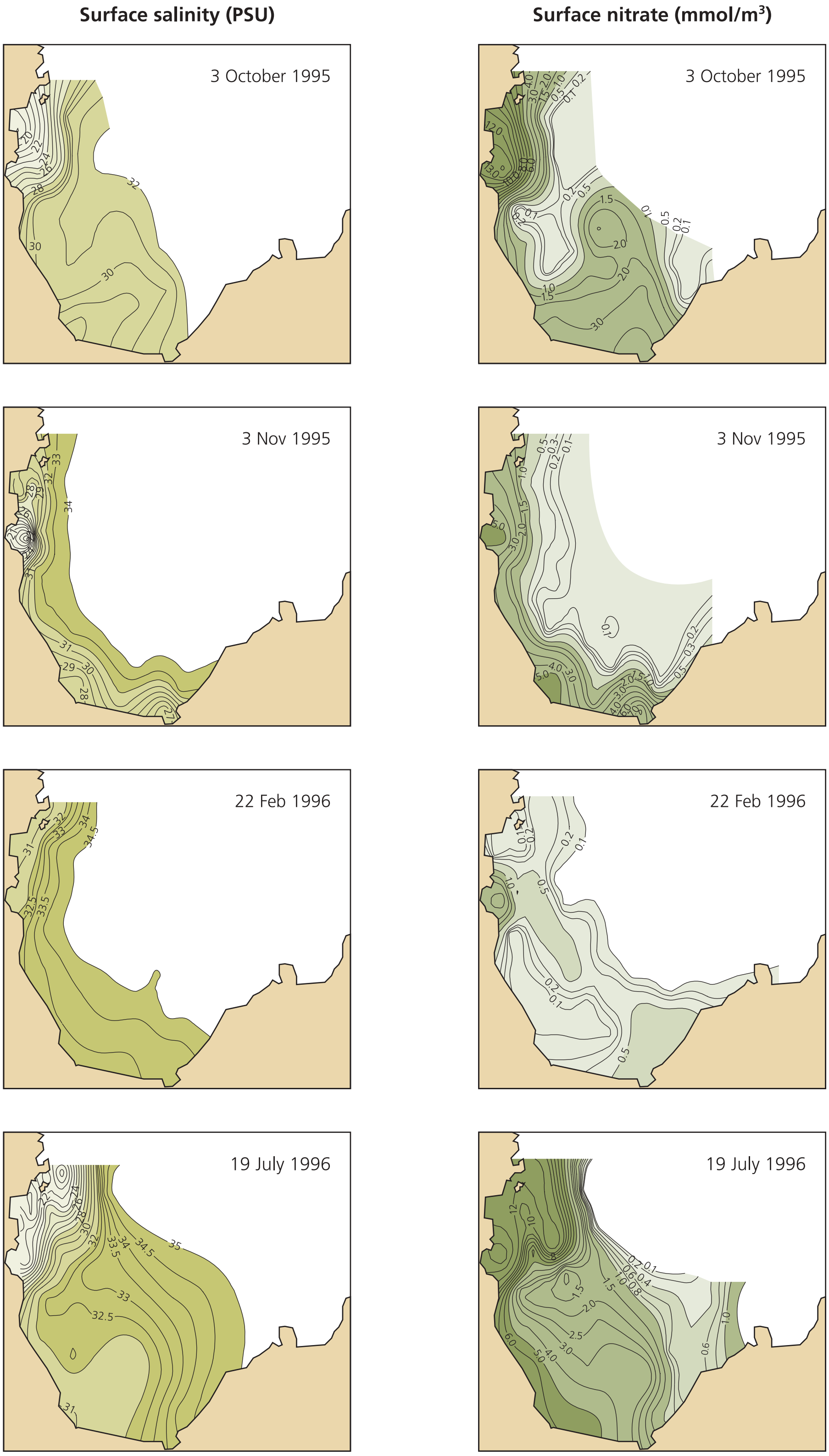

Fig. 36 Seasonal patterns of salinity and nitrate in Tasman Bay illustrating the influence of freshwater inflow from the Motueka and Riwaka rivers (maps provided by Lincoln MacKenzie, Cawthron Institute, unpublished data).

may be limited by light and river flow is greatest (Mackenzie and Gillespie 1986).

About 62% of the total freshwater inflow to Tasman Bay is provided by the Motueka River. Following heavy rainfall, the Motueka freshwater plume covers nearly the entire western side of Tasman Bay, extending more than 18 km offshore. It is a major contributor of sediment and nutrients into the bay, causing stratification of the water column and spatial and temporal variation in nutrient concentrations. Surface salinities, water column stratification characteristics and nutrient concentrations (Fig. 36), and consequently phytoplankton production, are affected to various distances seaward from the Motueka rivermouth. As the river waters flow into Tasman Bay, they spread out in a surface layer of low-salinity water over the more dense seawater below (Fig. 35). This density stratification stabilises the water column and reduces the vertical mixing processes that keep nutrients well distributed for phytoplankton nourishment. Uptake by phytoplankton can then result in a depletion of nutrients in surface waters. This is typical in mid- to late summer.

The delivery of sediment by the river also affects light penetration, photosynthetic activity. and seabed animal communities in a variety of ways. Past work has led to the discovery of a near-bottom layer of high turbidity within the Motueka plume, which could have profound ecological implications. Sediment input provides a dynamic delta region of sandspit development that is habitat for a variety of shellfish.

2.11 COASTAL AND MARINE ECOLOGY

The Motueka River flows into highly productive coastal and shallow marine ecosystems in Tasman Bay, providing a major source of freshwater and nutrients and influencing the ecology of a large area of western Tasman Bay. The estuarine and coastal area around the mouth of the Motueka River is an important area for a range of fish and shellfish, with cockles being commercially harvested near the mouth of the Riwaka River. Tasman Bay supports a wide variety of planktonic and benthic organisms and fish. Scallop harvesting is a major recreational activity and commercial industry in Tasman Bay, and there have been recent applications to establish mussel farms. The location of existing and proposed new aquaculture areas near the Motueka rivermouth is shown in Fig. 37. The Abel Tasman National Park and associated Tonga Island Marine Reserve, which supports significant fish stocks and marine mammals (seals and dolphins), are relatively close to the mouth of the Motueka River and are influenced by the Motueka River plume. A comprehensive review by Bradford-Grieve et al. (1994) provides an overview of knowledge of primary production in Tasman Bay, from plankton ecology and the benthic food web to the scallop and snapper commercial fisheries. Much of the information presented here is derived from that review.

The phytoplankton community is typical of a shallow-water, temperate environment (Bradford-Grieve et al. 1994) and is the main contributor to primary production in Tasman Bay. It is dominated for much of the year by dinoflagellates[34], with considerable seasonal and annual variation in species composition and productivity. These variations are controlled by changes in light and air and sea temperatures, which affect rates of photosynthesis and water column stratification, and by floods introducing nutrients into the bay. Diatoms are almost completely absent for considerable periods of time, and are usually only dominant during a late winter to spring bloom, coincident with maximum concentrations of dissolved inorganic nutrients. The sedimentation of diatoms following this bloom provides the main annual nutritional input for benthic fauna. Potentially toxic and

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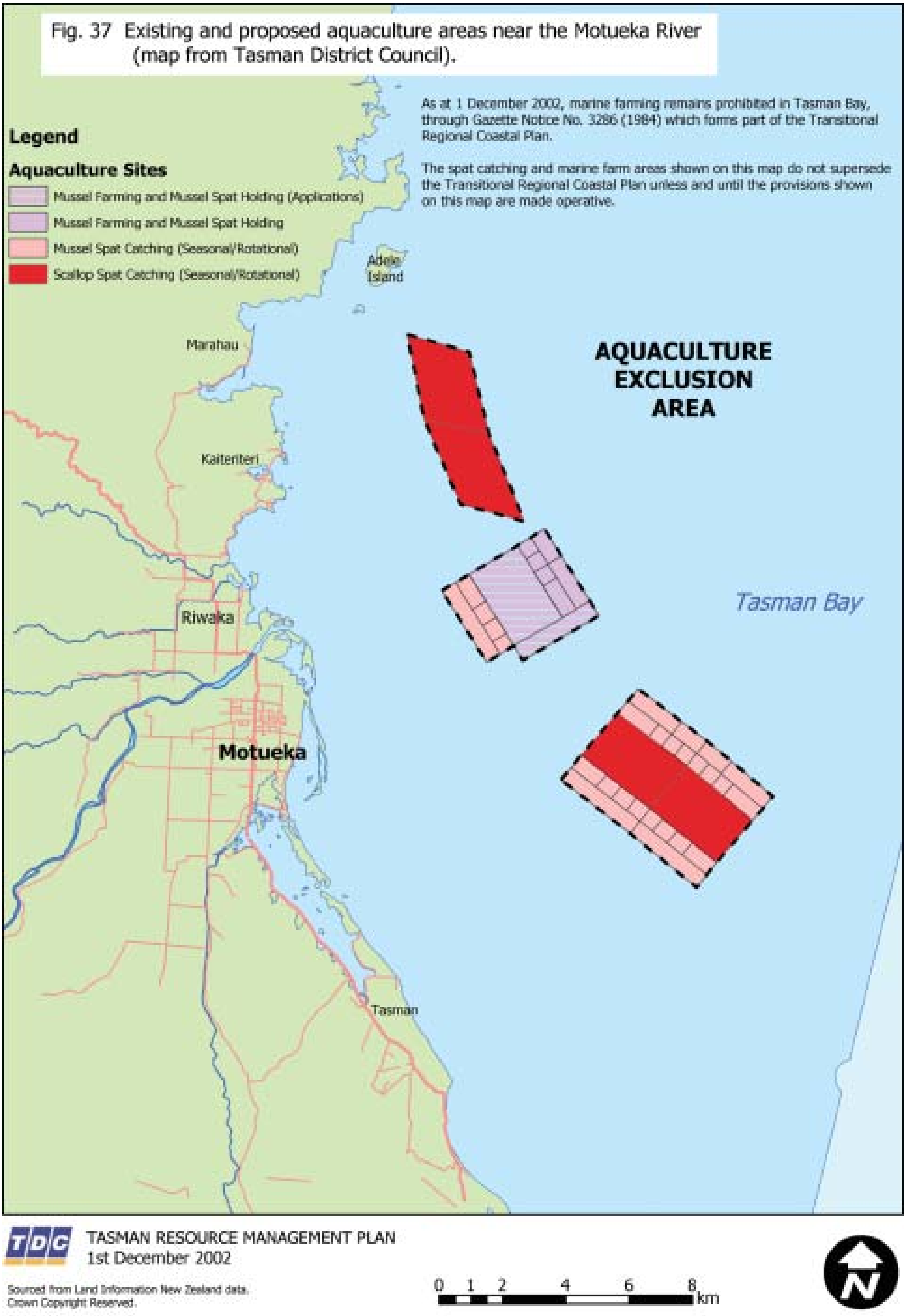
[34] Single-celled marine organisms.

Fig. 37 Existing and proposed aquaculture areas near the Motueka River (map from Tasman District Council).



As at 1 December 2002, marine farming remains prohibited in Tasman Bay, through Gazette Notice No. 3286 (1984) which forms part of the Transitional Regional Coastal Plan.

The spat catching and marine farm areas shown on this map do not supersede the Transitional Regional Coastal Plan unless and until the provisions shown on this map are made operative.

TDC TASMAN RESOURCE MANAGEMENT PLAN
1st December 2002

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noxious phytoplankton blooms occur periodically in Tasman Bay, and may occasionally create problems for aquaculture. Their origin and causes are poorly known at present. Little is known of the ecology and productivity of the zooplankton[35] (Bradford-Grieve et al. 1994), and there is some indication of a link between phytoplankton and zooplankton productivity (Mackenzie and Gillespie 1986).

MacKenzie and Gillespie (1985, 1986) describe plankton ecology and productivity from intensive sampling of the water column at a single nearshore location in Tasman Bay between April 1982 and March 1984. The phytoplankton community structure and phenology (seasonal and cyclic patterns) was typical of a temperate shallow-water environment, though considerable year-to-year variations occurred in the composition of species and magnitude of production. Periods of relative abundance of some potential nuisance species were documented. Small nanoplanktonic (<10 µm) species were always an important and frequently dominant component of the photosynthetic community. The winter–spring diatom bloom was the most productive event. In surface waters, phytoplankton biomass ranged from 19 to 208 mg C/m^3. *In situ* rates of photosynthesis ranged from 202 to 1981 mg C/m^2/d. The magnitude of phytoplankton blooms appeared to be related to preceding high-rainfall events. Unusually large floods during the winter of 1983 led to a major peak in productivity by a mixed diatom–*Mesodinium rubrum* bloom. Annual net productivities of 121 g C/m^2/yr and 171 g C/m^2/yr during 1982 and 1983, respectively, were estimated.

Benthic organisms in Tasman Bay reflect the relatively shallow water (<60 m), grain size of sea-floor sediments (dominantly terrigenous mud and sandy mud, with isolated patches of calcareous gravel in areas such as the Motueka delta), and primary production. The benthic fauna is a soft-bottom fauna characterised by bivalves (molluscs such as scallops, oysters and mussels) and echinoderms (e.g., starfishes, sea urchins). Although its composition and distribution is relatively well known, except for sponges and cnidarians (e.g., jellyfish, sea anemones), quantitative data are limited and little is known about the species that make up the microfauna[36] and meiofauna[37] (Bradford-Grieve et al. 1994). Faunal associations comprise assemblages of both deposit and suspension feeders. Small crustaceans (e.g., crabs, barnacles) have been poorly studied even though they are a significant part of the diet of juvenile fish such as snapper. Probert and Anderson (1986) provide limited data on the biomass, faunal density, and faunal composition of the benthic macrofauna in Tasman Bay. Gillespie et al. (2000) describe microphytobenthic communities from intertidal and shallow-water environments in Tasman Bay and comment on their important contribution to the benthic food web. Bryozoan coral are present off Abel Tasman National Park.

There is a large population of scallops (*Pecten novae zelandiae*) and a smaller population of oysters (dredge oyster or Bluff oyster, *Tiostrea chilensis*), both of which support dredge fisheries. The scallop fishery is particularly important, having been commercially dredged since 1959. Scallops are suspension-feeding bivalves that rely on suspended detrital material and phytoplankton as their food source. Initially (until 1980) managed as a natural fishery, the fishery is now enhanced by reseeding scallop spat to maintain desired harvest densities. Spat catching for scallops (and mussels) has been conducted off the Motueka rivermouth for about 8–10 years. Bradford-Grieve et al. (1994) suggest that although scallop population dynamics have

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[35] Plankton consisting of microscopic animals.

[36] Microscopic animals.

[37] Tiny animals living on the sea bed.

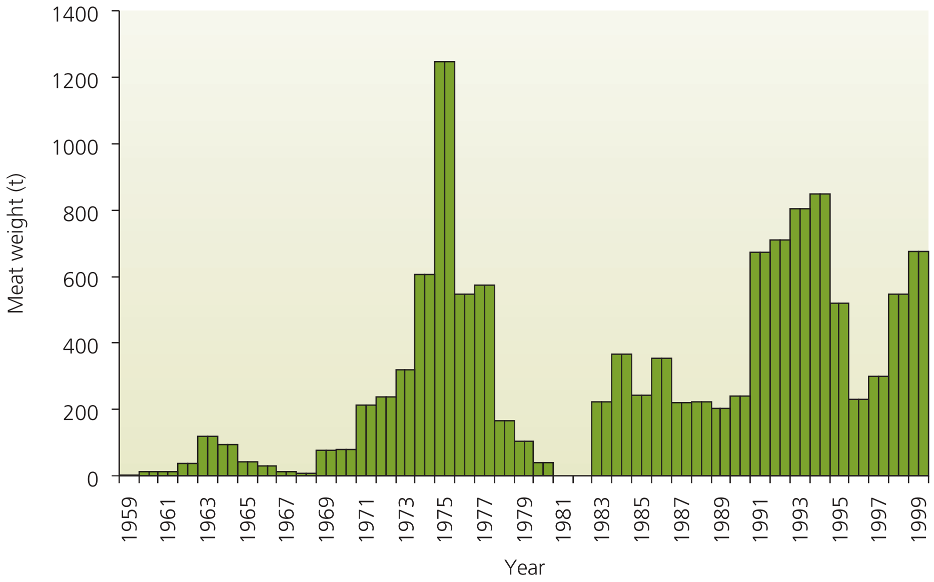

Fig. 38 Scallop harvest figures for Tasman Bay 1959–1999 (data provided by Russell Mincher, Challenger Seafoods).

been well established and shellfish stocks are regularly assessed, little is known about the life and requirements of scallops, and how they interact with their environment (e.g., sediment and nutrient inputs into the bay). The scallop fishery experiences large variations in both numbers and condition of scallops harvested (Fig. 38) and food availability is probably a major cause (Gillespie 1987). During a good year, winter–spring phytoplankton blooms may provide food for scallop growth. Later on, when food in the water column becomes scarce, microscopic algae living on the seabed seem to be a critical part of their diet. Scallop biomass may be linked to variation in production from these two main food sources. High sediment loads during floods in the Motueka River are believed to be associated with poor recruitment and growth of scallops in the plume of the river. Conversely, organic matter and other nutrients from terrestrial sources may play an important role in shellfish nutrition.

The other major commercial fishery in Tasman Bay is the snapper (*Pagrus auratus*) fishery. Snapper spawn each summer in Tasman Bay with the young fish schooling in shallow (<15 m) waters before moving to deeper water in winter and as they mature. They have been fished commercially since at least 1945, with catches increasing through to the 1970s and 1980s. Since the advent of commercial fishing, snapper numbers have been greatly reduced, resulting in reduced yields and management steps to restore the fishery. However, recovery is hampered by lack of quantitative data on key biological questions (e.g., the causes of erratic juvenile recruitment, the level of snapper biomass that can be supported, when and where juvenile snapper should be released, the requirements of post-larval snapper, and the impact on snapper of hydrological, nutrient, and primary productivity patterns in Tasman Bay).

2.12 MĀORI AND EUROPEAN HISTORY

Aspects of the Māori and European history of the Motueka Catchment are described in Peart (1937), Newport (1962), Allan (1965), Challis (1978), Motueka and District Historical Association (1982–89), and McAloon (1997).

Archaeological evidence suggests that Māori groups first settled the coastal Motueka River area before AD 1350 and more-permanent camps and fortifications (pā) were gradually established (Challis 1978). Traditional Māori tribal history depicts the Motueka – Tasman Bay area as affected by many invasions and conflicts that displaced previously occupying iwi (including Ngai Tahu, Ngai Tara Pounamu, Poutini Ngai Tahu, Ngāi Tu-Mata-Kokiri, and Ngāti Apa). Each successive iwi in turn achieved dominance and occupation over newly acquired land and resources. Intertribal conflicts decimated the local tribes in 1828–1830, about 10 years before the first European settlers arrived. Today four iwi, Ngāti Rarua, Te Ati Awa, Ngāti Tama, Ngāti Kuia, and their respective hapū, claim collective authority, significant cultural values, and an intimate spritual and physical relationship with the Motueka – Tasman Bay area.

Settlement was largely restricted to the coastal areas, although Māori travelled through the catchment in search of valued greenstone (pounamu) and argillite, and to hunt and fish. The Motueka Valley via Motupiko was a well-used inland route to the Wairau and Buller catchments for transport of greenstone and gathering of argillite washed downriver from the Motueka headwaters. The sea provided ample kaimoana (seafood) including fish and shellfish, the rivers and streams provided eels, kōkopu, and whitebait, and the bush and swamp provided materials for building, weaving, food, medicines, and a plentiful supply of birds. The better coastal areas were cultivated and soils were enriched for growing kūmara (and later potato) by addition of charcoal, fine gravel, and coarse sand (Challis 1976). In the early 1840s, 200–300 Māori were cultivating potato gardens between the Motueka and Moutere rivers (Challis 1978). Māori settlements were typically sited near the sea or river channels for access by canoe. Coastal camps were gradually replaced by fortified coastal pā following raids by displaced North Island tribes.

There is little evidence of Māori settlement inland in the Motueka Catchment except at Pokororo and the Sherry–Wangapeka confluence, although there are many records of argillite working sites, middens, burial sites, ovens and other artefacts (Challis 1978). Parts of the catchment had already been burned by Māori when European settlers arrived, but little is known of the extent of pre-European forest removal.

Europeans visited the Motueka area as early as 1840, and by 1842 sections were being surveyed at the Motueka township and the first settlers had arrived (McAloon 1997). At the end of 1847 the European population was about 100 (Allan 1965). The first European house in the Motueka Valley was built at Little Pokororo River in 1853. Planned settlements at Stanley Brook, Dovedale, and other sites in the Motueka Valley began in the 1860s, and at this time much of these areas were covered in tōtara, rimu, kahikatea, and beech forest. Gold and grazing were the main reasons behind European exploration of the Motueka Catchment. Graziers were running stock in the upper Motueka by 1843, the Wangapeka by 1846, the upper Motupiko and Baton by 1855 (Newport 1962), and would have deforested large areas to support grazing. By 1878 there were about 70 permanent settlers in the Motueka Catchment above Woodstock. Major gold finds at Baton Flats in 1855 and in the Wangapeka at Rolling River in 1859 (Newport 1962) caused a short-term influx of people. Gold mining continued in the area until the early 1900s and evidence of tailings, machinery, and house sites remain today.

Flooding of the larger rivers was a considerable hazard for transport, and establishment and maintenance of the roading network was a major cost to local government in the early days of settlement. The Motueka River was first bridged at Motupiko in 1887 and at Pokororo in the 1890s. The village of Tapawera originated as a railway camp for the Nelson–Buller railway connection in the 1890s, with the Tapawera road-rail bridge completed by 1906.

The early settlers cleared and burnt large areas of bush, which caused erosion and worsened flooding. The worst flood thought ever to have occurred in the catchment was the "Great Flood" that peaked on 7 February 1877. The Motueka River is reported to have covered the entire area between the hills and Pokororo. The flood was described as an "earth flood" rather than a water flood because of the slips that blocked tributaries then broke releasing torrents of mud, rock and trees (Brereton 1947; Fenemor 1989; Beatson and Whelan 1993). The sediment brought down by this flood is said to have raised riverbed levels by more than 3 metres in the lower Motueka. The earliest stopbank on the Motueka River was built in 1889 on the west side of the Motupiko River at the Motueka confluence to protect the road and now there is an extensive stopbanking system on the river.

First World War provided an impetus to pastoral farming with soldiers returning from the war being settled on farm blocks in the upper Motueka; but many of these farms were unsuccessful. The difficulties of farming included poor soil fertility, scrub reversion, low and unreliable rainfall, and steep slopes (Nelson Catchment Board 1952; Rigg et al. 1957). As a result the Government purchased land and planted exotic trees to begin what is now Golden Downs Forest and other forests. Golden Downs Forest began with the planting of about 10,000 hectares in 1926–27 and the planted area expanded rapidly (Ward and Cooper 1997). By the 1950s forestry was a major land use in the Motueka Catchment. Plantation forests were stocked primarily with exotic species such as Monterey pine (*Pinus radiata*) and Douglas fir (*Pseudotsuga menziesii*) and were established on less-fertile steeplands and hill country, particularly on Moutere gravel and Separation Point granite. Forestry remains a major land use, with some forests into their third rotation.

Horticulture (particularly hops and tobacco) has long been an economically important land use in the catchment, although it occupies a relatively small area of land. Tobacco began to be planted in the more fertile valleys in the 1920s and very soon Motueka became the centre of tobacco growing in New Zealand (O'Shea 1997). By 1941 tobacco accounted for 40% of Motueka's horticultural income (McAloon 1997). The area in tobacco production peaked in the mid-1960s (at c. 2500 hectares) and declined rapidly from the mid-1970s, before ceasing in 1995. Much of the land formerly used for tobacco growing is now used for fruit trees (apples, kiwifruit), berry fruit, and hops. More recently, vineyards, marine farming, and tourism have added substantially to the diversity and productivity of the local economy.

2.13 RECREATION

The Motueka Catchment is widely used for recreational activities. These include trout fishing, eeling, whitebaiting, tramping, canoeing, rafting, hunting, jet boating, swimming, picnicking, camping, caving, rock and fossil hunting, and scenic drives. Kahurangi National Park, Mt Richmond Forest Park and the Motueka River itself are especially important recreational areas. Many thousands of people visit and enjoy the river and its catchment each year.

The Motueka River is a nationally important recreational fishery for brown trout, with a reputation for producing high numbers and large size of trout, while the Wangapeka is notable for producing relatively abundant trophy-sized trout (Photo 7). A survey of angler numbers showed that the Motueka River was by far the most popular fishing river in the Nelson region, with of the order of 18,000 visits per year at that time (Richardson et al. 1984). The most heavily fished reach of the Motueka is from the confluence of the Wangapeka to the sea and this reach is considered a nationally important recreational fishery (Richardson et al. 1984). The Wangapeka is regarded as a regionally

A)

B)

Photo 7 The Motueka River is an important fishery noted for the quality of (a) the fishing experience and (b) the fish caught (photos courtesy of Terry Duval).

important fishery, being highly rated for its scenic beauty, easy access, large area of fishable water, and a high level of solitude. There have been no creel surveys conducted on the Motueka River to determine exactly how many trout are taken by anglers. Nevertheless, indications from angler surveys are that most anglers catch few fish and the ones that do, release a fairly large proportion of the ones that they catch. The general view among fisheries scientists is that anglers, and predators like shags, are unlikely to limit population size given the potential overwhelming natural production of trout in most river systems (R. Young pers. comm. 2002). Habitat degradation is much more likely to be the cause of trout population declines.

Recreation has had negligible impact on water quality and no effect on water quantity. Although there are occasional conflicts between uses such as boating and angling, recreational uses have not reached a point where controls on access to the catchment need consideration. However, recreation activity in the Motueka is increasing and there is scope for much greater usage of some areas.

2.14 HERITAGE AREAS

There are a wide variety of heritage areas within the Motueka Catchment. These include areas of significant native vegetation and habitats for native fauna, freshwater ecosystems (rivers, wetlands and their fauna), riparian zones, outstanding natural features and landscapes, and historic sites (Tasman District Council 1993b, 1995b).

Large areas of native vegetation are currently protected (c. 55% of the catchment area), primarily in Kahurangi National Park, Mt Richmond Forest Park, and Big Bush Forest. A few lowland sites with remnant native vegetation are protected in reserves (e.g., Thorp Bush, Fearon's Bush, Kumeras wetland, Moss Bush, Quinneys Bush), but many significant sites are not currently protected (see Park and Walls 1978; Walls 1985). Walker (1987) provides an inventory of both protected and unprotected sites for native fauna (Appendix 2).

Davidson et al. (1993) list and rank important coastal sites, based on ecological and geomorphic criteria. The Motueka delta (see Photo 1a), from Tapu Bay to Motueka wharf, is rated as having national importance. It is notable for its large delta and intertidal area, rich biodiversity (plant and animal), and archaeological/cultural/spiritual significance. The intertidal area is rich in shellfish (mostly cockles) and is an important feeding area for birds (particularly for wading birds and migratory birds). The Motueka sandspit is the largest in Tasman Bay and has >10,000 birds present in summer. It also has a large area of rushland and is thought to be an important whitebait spawning ground. Saltmarsh occurs around the river and creek mouths. There is a small area of pīngao (*Desmoschoenus spiralis*).

The Motueka has a rich and complex geological heritage. Consequently Kenny and Hayward (1993) list a relatively large number of sites in the catchment that are significant for protecting outstanding natural features and landscapes. Six of the listed sites are internationally important (Nettlebed Cave, the Pearse Resurgence, Mt Owen karst, Baton River Devonian fossil fauna, Tomo Thyme cave system, Bulmer caverns), seven are nationally important, and thirteen are regionally important (Appendix 3).

The Motueka also has a rich archaeological heritage. Tasman District Council (1995b) summarises the archaeological resource (using the Historic Places register, NZ Archaeological Association records, consultation with iwi) and sites of significance to Māori, from a computer database, but comments on the limitations of this database both for archaeological and Māori sites. Challis (1978) lists a large number of archaeological sites within the Motueka. However, few of these have any form of protection and most are not listed on the Historic Places Act register of historic places. Fenemor (1989) suggests a number of sites that are worthy of preservation.

2.15 SOCIO-ECONOMIC CHARACTERISTICS

There are approximately 12,000 people living in the Motueka Catchment (2001 Census). The largest town is Motueka with a population of about 7000 people (2001 Census) and there are small villages at Tapawera, Brooklyn, and Riwaka. Rural population density is about 2/km^2. Population growth is estimated at about 2% per annum. Figures for the whole of Tasman District (2001 Census) show:

- a male/female ratio of 1001 females per 1000 males;
- a median age of 37.8 years, with 13.1% of the population >65 years and 12.1% <15 years;
- a life expectancy of 77.6 years;
- 96.2% of the population identify themselves as European and 7.0% as Māori[38];
- a median income of $16,100;
- primary sources of income were from salary and wages (57%), 23% were self-employed, and 23% received some form of benefit;
- an unemployment rate of 3.7%;
- of those people over 15 years, 53% are married, 24% have never married, 7% are divorced, 3% are separated and 6% are widowed.

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[38] Some of the population identify themselves as having dual ethnicity.

3. Metadata for the Motueka Catchment

A wide variety of information and data are available for the Motueka Catchment, including maps, air photos, electronic and paper databases, books, published and unpublished reports. A comprehensive bibliography of publications on the Motueka has been compiled as part of the ICM Programme and this is available on the ICM website[39]. A more complete listing of metadata is also included on the website.

The main types of data available for the Motueka Catchment are summarised below.

3.1 MAPS, PHOTOS, SATELLITE IMAGERY

- NZMS260 topographic maps (1:50,000 scale) in paper and digital form (from which a 25-m-resolution digital elevation model (DEM) has been generated using the 20-m contours). Derivative products (e.g., shade map, aspect, slope, topographic index) can also be generated.
- Earlier maps include the NZMS1 1:63,360 scale maps and 1:15,840 compilation sheets, plans of the Motueka District in 1842, 1851 and 1895, Motueka town area 1929, Big Bush District 1906, Wangapeka District 1896, Tadmor District 1902. Copies are held at the Nelson Provincial Museum and the Motueka Museum.
- Various old photos of the river and catchment dating back to the late 1800s are held in the Nelson Museum, mainly in the Guy and Tyree collections but also some others, and in the Motueka Museum.
- Aerial photo coverage, taken by NZ Aerial Mapping (Hastings) and Aerial Surveys (Nelson), is available from 1937 onwards. Available extensive surveys include: Motueka River (1937, SN65, 1:10,843 scale), Tobacco surveys Motueka (1940, SN141, 1:16,176 scale), Motueka State Forest survey (1940, SN142, 1:16,176 scale), Golden Downs–Moutere–Nelson (1948, SN379, 1:17,647 scale), Golden Downs State Forest

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[39] http://icm.landcareresearch.co.nz/ – see the library of resources.

(1956, SN886, 1957, SN1022, 1:11,029 scale; 1966, SN1861, 1:10,508 scale; 1972, SN3443, 1:16,176 scale), Farewell Spit–Runanga–Amberley (1968, SN2033, 1:82,758 scale), Kaiteriteri–Mount Richmond (1969, SN3196, 1:24,264 scale), Upper Motueka River (1979, SN108158, 1:40,000 scale), Tasman Bay rivers 1983 flood series (SN10992, 10993, 10994, 10996, 10998, 11001A, 11002A,11003A, 11004A, 11006, 11007, 11008, 11009, 11010, 11011, 11012, 11013, 1983, 1:15,000 and 1:10,000 scale), Mt Richmond State Forest Park (1983, SNC8294, 1:25,275 scale), Motueka River catchment (1984, SN11019, 1:57,000 scale), Nelson Regional Survey (1997, 1:27,500 scale), SN12391 (1996–98, 1:50,000 scale), SN12391B (1998, 1:50,000 scale). Copies of many of the available photos are held by Tasman District Council, who also hold a variety of oblique aerial and ground photographs in a physical image library, including some video footage of floods (e.g., 1995). Tasman District Council holds many detailed vertical aerial photos (1:1000–1:4000 scale) of the Motueka River and its tributaries from the 1950s onwards.

- Tasman District Council has recently commissioned a complete series of aerial photographs at 1:25,000 scale, from which digital orthorectified images are now available.
- Satellite images include a SPOT image from February–March 1996 (from which the Land Cover Database was generated) and some recent Landsat data.

3.2 CLIMATE

- NIWA’s climate database (CLIDB) holds current (Riwaka, Graham River, Motupiko, Tapawera, Lake Rotoiti) and historical data (Motueka, Dovedale, Thorpe, Stanley Brook, Baton, Wangapeka, Golden Downs, Atapo, upper Sherry River, Kikiwa, Tophouse, Long Gully, Graham Creek, Hunters) on climate (mainly rainfall, but including temperature, wind run, and evaporation data).
- Tasman District Council currently records rainfall at Woodmans Bend, Woodstock, upper Motueka Gorge, Baton Flats, the Wangapeka at Walters Peak, the Tadmor at Mudstone, the Motupiko at Christies Bridge, Waiwhero, and two sites in the Riwaka. Tasman District Council have synthesised the rainfall data into a map of mean annual rainfall isohyets (Fig. 14).
- Rainfall has been measured by Forest Research Institute and Landcare Research at several sites in Donald Creek (in Big Bush Forest) since 1975.

3.3 HYDROLOGY/WATER QUALITY

- The catchment and subcatchment boundaries can be generated from the DEM.
- The stream network is contained in the 1:50,000 digital topographic data and can also be generated from the DEM.
- Tasman District Council currently records flow data for the Motueka at Woodmans Bend, Woodstock, and upper Motueka Gorge, the Baton at Baton Flats, the Wangapeka at Walters Peak, the Tadmor at Mudstone, the Motupiko at Christies Bridge, the Waiwhero, Hunters Creek, and at three sites in the Riwaka (the south branch at Moss Bush, the north branch at Littles, and the main stem at Hickmotts).
- NIWA and Tasman District Council also hold historical data for the Motueka at Blue Gum Corner and Alexander Bluffs, Wangapeka at Swimming Hole and Swingbridge, Kikiwa at Weir, Graham Creek at Weir, Roughn’s at Weir, Long Gully at Meads Road, Stanley Brook at Barkers, Rocky River, Rainy River below Big Gully, Clark River at State Highway bridge, Dart River at Devils Thumb, Sherry River at Blue Rock, Ellis River at Baton confluence, Skeet River at Baton confluence, Dove River at Motueka confluence, Pearse Stream at Caves, Pearce Stream at Motueka confluence, Graham River below

forks, Little Pokororo at Motueka confluence, Pokororo at Motueka confluence, Orinoco at Ngatimoti, Herring Stream at Motueka confluence, Shaggery River at Tom Evans, Little Sydney Stream at bridge, and the Brooklyn Stream at DSIR. From these sites estimates of flow statistics can be derived (e.g., mean flow, median flow, low flows at varying recurrence intervals, flood flows).

- Flow has measured by Landcare Research from four small catchments in Big Bush Forest (Donald Creek) since 1977. One of these catchments is a control catchment in beech forest and in the other three the beech was harvested by different techniques and then the catchments were replanted in pines.
- The Motueka Museum holds a folder with newspaper articles describing large historical flood events. Tasman District Council holds a file with similar material.
- Water quality has been regularly monitored by NIWA at Woodstock and upper Motueka Gorge since 1989. Short-term water quality data is available (from the Environmental Sampling Network) for a larger number of sites within the Motueka (see Roger Young, Cawthron Institute).
- River and stream classifications have been undertaken for the Motueka as part of the ICM Programme (see Chris Phillips, Landcare Research), and in the forestlands of Weyerhaeuser New Zealand Inc. The latter classifies streams in one of four classes (streams of special significance, fish streams, streams with high potential stream power, and small streams), and provides a set of management guidelines and standards for each major forestry activity and each class of stream.
- Groundwater is monitored at a number of sites on the Motueka and plains (Riwaka Hall, Wratts, Rossiters, Horrells, Smiths, Old Wharf Road), the Moutere Valley (for wells that are recharged by rain falling in the Motueka Catchment) and monitoring has recently begun in the Tapawera area. Groundwater quality trends are available from key bores.

3.4 RIVER CROSS-SECTIONS

- River cross-sections periodically surveyed by Tasman District Council are located in two reaches of the Motueka River. In the lower Motueka, cross sections are located approximately every 0.25–0.5 km from the mouth to Alexander Bluff bridge (a total of 53 sections), and records extend back to 1957. In the upper Motueka, cross sections are located approximately every 0.5–1 km from the Wangapeka confluence to Norths bridge (a total of 30 sections), and records extend back to 1960.
- The earliest well-surveyed cross sections begin in about 1957 (some cross sections were surveyed in 1937) and data are available up to 2001. The period between measurements at any site is variable.
- Detailed cross-sectional data are also available at river gauging stations (taken for flow ratings).

3.5 GEOLOGY

- Paper and digital copies of the Nelson QMAP (Rattenbury et al. 1998) compiled at 1:50,000 scale and published at 1:250,000 are available from the Institute of Geological and Nuclear Sciences and Tasman District Council.
- Lithology data are also listed in the NZLRI, available from Landcare Research.

3.6 SOILS

- Soil map units are included in the NZLRI, available from Landcare Research (see http://www.landcareresearch.co.nz/databases/nzlri.asp). These data are based on the Waimea County survey (Chittenden et al. 1966), compiled at 1:126,720 scale, and the General Survey of Soils of the South Island at 1:250,000 scale (New Zealand Soil Bureau 1968.) The NZLRI data were originally compiled at a scale of 1:63,360. The NZLRI data are available as map unit data or as soil property data for 16 attributes, including available water capacity, rooting depth, permeability, depth to a slowly permeable horizon, pH, total carbon, P-retention (see http://www.landcareresearch.co.nz/databases/fdls.asp).

- Unpublished maps (1:15,840) of the plains and terraces compiled by the Cawthron Institute around 1930–40 show soil map units, soil suitability for tobacco, and land use about 1940. These data are currently being compiled by Tasman District Council.
- The National Soils Database, available from Landcare Research (see http://www.landcareresearch.co.nz/databases/nsd.asp), contains detailed data on soil properties (most data are soil chemistry, with limited soil physics and mineralogy). There are few data for soils sampled in the Motueka Catchment, but there are data for many of the mapping units, including Mapua fine sandy loam, Dun silt loam, Haupiri steepland, Hope silt loam (hill soil), Hope fine sandy loam (rolling phase), Kaihiku, Kaiteriteri sandy loam, Korere silt loam (hill soil), Lewis steepland, Matiri steepland, Motupiko loam, Pelorus steepland, Pikikiruna steepland, Spenser steepland, Wakamarama steepland, Whitcombe steepland soil.
- A detailed classification of productive land in Tasman District (Agriculture New Zealand 1994), based on soils, climate and topography, is available from Tasman District Council.

3.7 VEGETATION AND TERRESTRIAL ECOLOGY

- The Land Cover Data Base (LCDB) records vegetation cover, classified into 16 classes. These data are derived from SPOT satellite imagery taken in 1996 at 25-metre spatial resolution. Available from Terralink Ltd and Tasman District Council.
- The NZLRI includes map-unit description of vegetation classes in the late 1970s. Available from Landcare Research.
- The National Vegetation Survey database includes descriptions of permanent vegetation plots in native forests, scrublands and grasslands within the Motueka Catchment. Available from Landcare Research (see http://nvs.landcareresearch.co.nz).
- The inventory of tall forest stands on lowland plains and terraces in Nelson and Marlborough (Park and Walls 1978) includes many sites in the Motueka Catchment. The Department of Conservation (Nelson) are currently updating this to an electronic database and are developing a threatened plants database.
- The ecological district classification (McEwen 1987) broadly describes the former native vegetation and current vegetation cover.
- Wetlands are identified in a Tasman District Council/Fish & Game MS Access database and Department of Conservation “Wetlands of Ecological and Representative Importance” database.
- Department of Conservation BIOSITE and Index databases includes information on sites of special wildlife interest, bird distribution (blue duck, falcon, kea, kākā, kiwi), land snail, amphibian and reptile distribution.
- Tasman District Council maintain a pest control database that includes the locations of weeds (e.g., giant buttercup, gorse, broom, hawthorn, buddleia, old man’s beard) and maps of management areas for weeds and pests.

3.8 AQUATIC BIOLOGY

- Nelson–Marlborough Fish & Game maintain a Waterbody Database that describes ecological and recreational values, fish species present, water quality class, and management issues in defined reaches of the Motueka. They also maintain a database recording trout numbers at several locations in the Motueka through time (derived from drift-dive data and spawning surveys).

- NIWAs New Zealand Freshwater Fish Database records the occurrence of fish (native and introduced) in freshwaters of New Zealand. Data include the site location, species present and their abundance, as well as information such as the fishing method used and a qualitative physical assessment of the site. (see http://www.niwa.co.nz/rc/prog/freshbiodiversity/tools#new).
- Information on macroinvertebrates, species richness and density, macroinvertebrate community index, and native fish distribution in 1988/89 is included in Bruce et al. (1987) and was updated by Ward (1990).

3.9 COASTAL

- Coastal areas important for conservation are listed by Davidson et al. (1983).
- Department of Conservation has completed a coastal resource inventory survey (Department of Conservation 1990).

3.10 HAZARDS

- Tasman District Council maintain a hazards register, which includes information on earthquakes and faults, flooding, land instability, and coastal erosion.
- Contaminated sites are listed in a Tasman District Council Contaminated Site Register.

3.11 Statistical

- Statistical data are compiled by the Department of Statistics for census purposes based on geographically defined meshblocks (see http://www.stats.govt.nz/). Tasman District Council also holds much of this data.

3.12 LEGAL

- The Digital Cadastral Data Base (DCDB) is the standard legal boundary database maintained by Land Information New Zealand (LINZ) and includes the legal definition of all roads, railways, hydrographic features, and all surveyed property boundaries (see http://www.linz.govt.nz/). It is constantly being updated as new subdivisions and developments occur.

3.13 PLANNING

- Tasman District Council maintains a consents database that lists all controlled activities (e.g., discharges to water, permits to abstract water).
- The Tasman Resource Management Plan includes many planning maps, which identify features such as planning zones, land disturbance areas, water management zones, groundwater recharge and surface water yield protection areas, areas subject to various hazards, aquaculture exclusion zone, heritage buildings and trees, archaeological sites.

3.14 HERITAGE AREAS

- The national register of the Historic Places Trust lists all protected historic places (archaeological sites, buildings, trees, cemeteries, gardens, shipwrecks, landscapes and many other types of places), historic areas (groups of related historic places), wāhi tapu (places sacred to Māori), and wāhi tapu areas (groups of wāhi tapu). Tasman District Council also maintains a local register.
- The New Zealand Archaeological Association operates a site-recording scheme for all surveyed archaeological sites, irrespective of any form of protection. The scheme is based on paper records for each site (location and nature of the

site) and supplementary information such as maps and photographs. The files for Nelson are maintained by Steve Bagley (Department of Conservation, Nelson), and the Department of Conservation also maintain a computerised index to these sites.

- Significant geological, soils, and landscape sites are listed in the New Zealand Geological Society Geopreservation Inventory (Kenny and Hayward 1993).

4. Statutory framework for integrated catchment management

4.1 TASMAN DISTRICT COUNCIL RESPONSIBILITIES

Tasman District Council serves 45,000 residents, and alongside Nelson City Council, acts as a unitary council with both regional and district council responsibilities under the Resource Management Act 1991 (RMA). This combination of local government roles integrates all resource management within a single authority, and encourages strong links between service delivery and environmental management. Thus the Tasman District Council is a ‘one stop shop’ for local government in its region.

Tasman District Council is responsible for sustainable management of land, water and other natural and physical resources of the Motueka catchment, and its coastal resources up to 19km offshore, under the RMA. The Act has the objective of promoting the sustainable management of natural and physical resources. It has particular emphasis on protecting the life-supporting capacity of resources, safeguarding the foreseeable needs of future generations and avoiding, remedying or mitigating effects on the environment. Rather than controlling activities such as land use, the RMA emphasises avoiding or limiting the environmental effects of those activities.

Tasman District Council has a range of functions relevant to catchment management, including a mandate for integrated resource management, control of the effects of land use, control of land subdivision, water management, contaminant management, coastal management (shared with the Department of Conservation), river and lake management, and natural hazards and hazardous substances management. Tasman District Council undertakes these functions through:

- preparing and implementing a Regional Policy Statement and regional and district plans, the latter two now being amalgamated under the umbrella of the Tasman Resource Management Plan (TRMP);
- granting or declining resource consents,

comprising land use consents, water permits, discharge permits and coastal permits;
- investigating and monitoring resources, and reporting on the state of the environment (e.g. Tasman District Council 2000e);
- monitoring and enforcing compliance of resource uses with their resource consents or relevant permitted activity rules in planning documents;
- advocating good environmental practice, and in some cases providing funding or services for supporting this; for example, funding for riparian fencing, soil conservation or wetland protection.

Tasman District Council's Resource Management Plan must be consistent with any national regulations (such as fisheries regulations), national policy statements (such as the New Zealand Coastal Policy Statement), water conservation orders (such as the draft National Water Conservation (Motueka River) Order 1991), and any relevant iwi planning document. Tasman District Council plans must also have regard to any management plans and strategies prepared under any other Act (e.g., Conservation Management Strategy for Nelson/Marlborough, and the management plan for Kahurangi National Park prepared by Department of Conservation).

Tasman District Council has prepared the Tasman Regional Policy Statement (Tasman District Council 2001b), which provides a general overview of significant resource management issues, resource management objectives, and policies and methods to achieve integrated management of resources. Resource management issues are being dealt with in detail through preparation of the Tasman Resource Management Plan, which includes both regulatory and non-regulatory methods for managing land, water and coastal resources. The Tasman Resource Management Plan (Tasman District Council 1996) is divided into six parts, which are at various stages of development (see Table 7). Plans such as the TRMP outline policies and specify how the policies will be implemented. This includes the setting of rules, which may require people to carry out their activities in accordance with these rules or to apply for a resource consent. Other methods of implementing plan policies are monitoring and investigations, financial incentives, education and advocacy. Rules in the plan control activities such as:

- subdivision of land;
- effects of land use;
- land disturbance;
- discharges to water, land and air;
- water takes from rivers and groundwater;
- damming and diversion of rivers;
- diversion and discharge of water from wetlands and land.

Management of the coastal marine area is shared between Tasman District Council and Department of Conservation. Under the RMA, responsibility for the final approval of provisions of Regional Coastal Plans that relate to the coastal marine area rests with the Minister of Conservation. In the case of Tasman District Council, the Regional Coastal Plan simply comprises Part III of the TRMP and that section of Part VI (Discharges) relating to the Coastal Marine Area. Tasman District Council is responsible for assessment and approval of coastal resource consents, with the exception of activities that exceed specific thresholds that are provided for as restricted coastal activities. The Minister of Conservation makes the final decisions on these, although the hearing process remains with the Tasman District Council.

4.2 THE MOTUEKA RIVER WATER CONSERVATION ORDER

Water conservation orders are national policy instruments gazetted under the Resource Management Act to preserve or protect water bodies with outstanding – normally nationally important – habitats, fisheries, wild and scenic character, scientific or ecological values. In 1990 the Nelson Acclimatisation Society (now Nelson–Marlborough Fish & Game Council) and Council of South Island Acclimatisation Societies (now New Zealand Fish & Game

PART OF TRMP	CONTENT
Part I - Introduction	Purpose, scope, structure and effect of Tasman Resource Management Plan, including definitions of terms.
Part II - Land	Issues, objectives, policies and rules relating to: site amenity; urban and rural environments; margins of rivers, lakes, wetlands and the coast; landscape; significant natural values and cultural heritage; land transport; land disturbance; natural hazards, reserves and open space. *Part II was nearing operative status as at 2002. Land disturbance policy and rules replace those in the Regional Plan (Land) made operative 30 June 1998.*
Part III - Coastal Marine Area	Issues, objectives, policies and rules relating to: boats; structures and aquaculture management; natural hazards, hazardous substances and noise in the Coastal Marine Area. *Part III was nearing operative status as at 2002 but aquaculture management issues were before the Environment Court.*
Part IV - Rivers and Lakes	Issues, objectives, policies and rules relating to: activities on the water surface and in river and lake beds, including channel maintenance, gravel extraction, and dams. *Part IV had not been drafted or notified as at 2002, so rules in the TDC Transitional Regional Plan 1991 continue to apply.*
Part V - Water	Issues, objectives, policies and rules relating to: taking, using, damming and diverting water *Part V had been notified but awaited decisions on submissions as at 2002. Of relevance to the Motueka catchment, Part V when operative will supercede the Motueka and Riwaka Plains Water Management Plan (a regional plan, operative 16 January 1995, the Moutere Water Management Plan (operative 31 October 2001) and the informal Motueka and Riwaka Catchments Water Management Plan 1989*
Part VI - Discharges	Issues, objectives, policies and rules relating to: discharges to land, fresh water, air and the coastal marine area. *Part VI was nearing operative status as at 2002*

Table 7: Tasman Resource Management Plan outline.

Council) applied for a National Water Conservation Order for the whole of the Motueka and Riwaka rivers to protect the brown trout fisheries in these rivers. The Minister for the Environment decided that only the Motueka River merited an inquiry, while the Riwaka should be managed under the Tasman District Council's plans. Public submissions were heard by the Minister for the Environment's Special Tribunal in Motueka in 1991 and a draft Order was released later that year. However, a decision on appeals on the draft Order was postponed until the decision on a similar application for the Buller River had been resolved.

A callover on the Motueka River Water Conservation Order was held in 1997 and the application was reconsidered in the light of the decision on, and provisions of, the Buller River Water Conservation Order. The form of the Order on the Motueka was modified to consider only those specific parts of the Motueka River considered nationally outstanding, to identify parts of the river (rather than the whole catchment) to which the Order would apply, what features of the river were being protected, and what specific measures were needed to protect the identified reaches of the river. The parties to the appeal negotiated a compromise during 1997-2002. The main parties involved were Fish & Game, Tasman District Council, Department of Conservation, Weyerhaeuser New Zealand and a group of upper Motueka irrigation interests (the Land Owners Water Action Group) supported by Federated Farmers. The most contentious issue to resolve was the minimum flow needs for protecting the brown trout fishery, when compared with the current and future water needs for irrigation throughout the Motueka catchment. The parties agreed to a maximum reduction in Motueka River flow of 12% of the flow as measured at Woodstock and related limits for the Wangapeka, Motupiko, upper Motueka and Tadmor tributaries. Affidavit evidence supporting a Water Conservation Order (e.g. Fenemor, 2002b, Hayes 2002, Deans 2002) was presented to the Environment Court in July 2002 and resulted in a recommendation from the Court (Environment Court Decision W7/2003) that the Minister for the Environment gazette the National Water Conservation (Motueka River) Order.

In summary what is recommended is an Order that identifies:

- the outstanding characteristics and features that the Order would protect (the wild and scenic character of the Wangapeka above the Dart confluence, several streams providing blue duck habitat, the karst systems of Mt Arthur and Mt Owen, the brown trout fishery of the main stem between the Wangapeka and Shaggery confluences, and the Wangapeka River and parts of the river that may contribute flows or spawning waters to support the brown trout fishery);
- which waters would be preserved in their natural state (all the Wangapeka above the Dart confluence, all those nominated rivers and streams on conservation lands managed by Department of Conservation);
- which waters would be protected (by setting of water flow and quality conditions on regional rules and consents, and prohibition of dams on the river and its tributaries);
- which waters would be protected due to their contribution to outstanding features, particularly various tributaries where brown trout spawn.

Future decisions by Tasman District Council on any of the waters covered by the Order must comply with its provisions.

4.3 DEPARTMENT OF CONSERVATION RESPONSIBILITIES

The Department of Conservation is directly responsible for managing conservation lands within the Motueka Catchment, including Kahurangi National Park and Mt Richmond Forest Park, and also has functions that apply to land and water resources not directly managed by the Department. Management of conservation lands is controlled by a series of Acts including the National Parks Act 1980, the Conservation Act 1987 (and its amendment in 1996), a series of Ngai Tahu Acts, the Resource Management Act 1991, and the Crown Minerals Act 1991. In addition to its land management role, the Department has responsibility to advocate for the protection of wildlife under the Wildlife Act 1953, freshwater fisheries under the Conservation Act and Freshwater Fisheries Regulations 1983, and to advocate for conservation generally through the statutory planning process. Department of Conservation also administers authorisations for the introduction of aquatic species.

The National Parks Act 1980 requires national parks to be preserved in their natural state, and for their value as soil, water and forest conservation areas to be maintained. The Act requires the preparation of a management plan for Kahurangi National Park that sets objectives for biodiversity and landscape management, preservation of historic resources and of the park (Dyson 2001).

Under the Conservation Act, Department of Conservation has the following functions relevant to catchment management that apply to both conservation and other land:

- management for conservation purposes of all land, and all other natural and historic resources held as conservation lands (and other land where the owner agrees that it should be managed by Department of Conservation);
- preservation of native freshwater fisheries (including the whitebait fishery), and protection of recreational freshwater fisheries and freshwater fish habitats (especially spawning grounds and migratory access);
- advocacy for the conservation of natural and historic resources generally.

For conservation lands in the Motueka Catchment, these functions are implemented through the Conservation Management Strategy for the Nelson–Marlborough Conservancy (Department of Conservation 1996), which has amongst its objectives:

- to attain better representation of the diversity of lowland ecosystems and better quality in those already protected (no priority areas are identified in the Motueka);
- the promotion of sound management of coastal and marine ecosystems, including development of a network of protected coastal and marine areas (the Motueka delta – Kumeras spit is identified as a priority area);
- to protect and enhance the natural qualities of freshwater ecosystems and to maintain and improve fish and wildlife habitat and recreational fisheries (protection of the Motueka River is identified as a priority).

Specific objectives, management strategies, and threats are identified for upland ecosystems (Mt Arthur, Mt Owen, and Richmond Range), coastal and marine ecosystems, freshwater ecosystems, and karst and cave ecosystems.

The Department of Conservation advocates for the protection of natural, historic, and recreational values in areas where it does not manage the land and resources. The RMA is the main vehicle for this statutory advocacy, which is undertaken through the statutory planning procedures of local authorities. Section 6 of the Conservation Act provides for Department of Conservation to advocate for the protection of natural and heritage values. This advocacy role is undertaken primarily under the RMA, but also under other legislation, including fisheries and forest management legislation. For its conservation advocacy under the RMA, Department of Conservation has a particular focus on management of freshwater resources (in particular native freshwater fisheries and protecting recreational freshwater fisheries and freshwater fish habitats) and the coastal environment including (but not restricted to) the coastal marine area. The Minister of Conservation supported the application for the Water Conservation Order on the Motueka River.

The Minister of Conservation has an oversight role under the RMA for the management of natural and physical resources in the coastal environment. This role includes responsibility for approving that part of the regional coastal plan that relates to the coastal marine area; being the final consent authority for activities for coastal permits exceeding specified thresholds that are defined as being restricted coastal activities; and in monitoring the implementation of the New Zealand Coastal Policy Statement. Department of Conservation provides advice and administrative support to the Minister of Conservation in fulfilling these statutory responsibilities.

4.4 Tangata whenua interests

Tangata whenua are recognised by all Crown agencies as having special status within the Motueka through their long-standing connections with the natural resources in the area, and through the Treaty of Waitangi. A number of agencies, including Tasman District Council and Department of Conservation, have a responsibility to work with tangata whenua on all matters concerning the environment and heritage. Under the RMA the most important sections for tangata whenua are:

- sections 6e, *“recognise and provide for ... the relationship of Māori and their culture and traditions with their ancestral lands, waters, sites, waahi tapu and other taonga”*;
- section 7, *“have particular regard to kaitiakitanga (stewardship or guardianship)”*;
- section 8, *“take into the account the principles of the Treaty of Waitangi”*. This requires all those exercising powers and functions under the RMA to recognise and provide for tangata whenua interests and values, and to achieve good practice in the relationship with tangata whenua;
- section 33 provides a transfer of power from any local authority to tangata whenua for the purposes of achieving sustainable use of natural and physical resources;
- section 62 requires local authorities and others to recognise iwi management plans.

In addition, the Historic Places Act (1993) provides for the protection of registered archaeological and other heritage sites, as do most district plans under the RMA, and the Conservation Act (1987) gives effect under section 4 to “the principles of the Treaty of Waitangi”. Various other types of national legislation and international conventions recognise and protect indigenous rights, and provide status to tangata whenua for collective decision-making, on a range of issues. Many local iwi and hapū have included aspirations, issues, policies, and values in iwi management plans and other planning documents. Tangata whenua are active in environmental monitoring and processing resource consents in the Motueka Catchment. They have been an integral part of the regional and district consultation–submission process, and have participated in lengthy debate and discussion on issues such as waste management, site contamination, the Regional Policy Statement, and the Tasman Resource Management Plan.

5. Land, freshwater and marine resource management issues

A consultation process (by meetings and questionnaires) with stakeholders identified a series of key, closely interlinked resource management questions that relate to the management of land, freshwater, and marine resources (see Philips 1999; Dunne and Likens 2000). They are not an isolated series of questions, but rather a complex set of questions that connect the physical and chemical state of the catchment and associated waters with their biological diversity and functions, and involve an understanding of air–land–freshwater–Tasman Bay interactions and the critical factors that determine these interactions (Fig. 39). These questions also have social and economic dimensions arising from the recognition that resource management issues are not solely technical issues, but community issues as well (Fenemor and Bowden, 2001).

The "big picture" questions are:

- What maintains the productivity and biodiversity of the land and its associated waterways, the near-coastal and marine environment?
- How do biophysical and socio-economic conditions affect productivity and biodiversity of the land, waterways, and the near-coastal and marine environment?

Tangata whenua issues have been specifically identified for the ICM Programme by Harmsworth (2001) and largely reflect relationships, history, politics, legislation, and cultural and spiritual values. Their issues focus on the quality and quantity of the river and its resources, and the health of the surrounding catchment and coastal environment. Key tangata whenua issues were grouped into: (1) relationships and partnerships for planning and policy; (2) loss of mauri (life force) of rivers, streams, and the coastal environment; (3) sustainable resource use; (4) pollution, sediment and contaminated sites; (5) coastal and marine issues; and (6) biodiversity/biosecurity matters.

Resource management issues for all stakeholders can be grouped, for convenience not functionally, into six broad categories: water quantity, sediment,

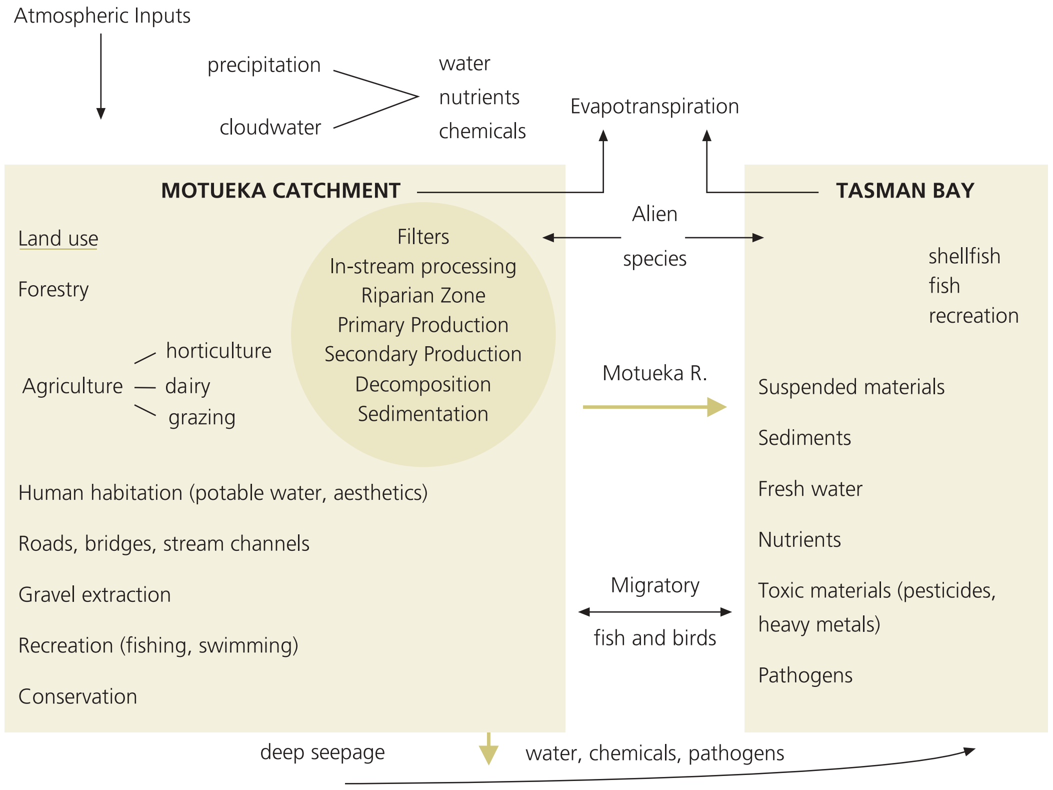


Fig. 39 Conceptual summary of the issues and processes being addressed in the Motueka Integrated Catchment Management Programme (from Dunne and Likens 2000).

water quality, aquatic ecology, riparian management, and Motueka Catchment – Tasman Bay interactions. There is a strong element of linkage between most of these issues.

5.1 WATER QUANTITY ISSUES

Water availability has been a major concern in the Tasman District for many years, and it is likely to become increasingly important in the Motueka Catchment as land use intensifies, and population and water demand grow. In much of the eastern and lower elevation areas of the catchment the demand for water exceeds natural supply and there is a reliance on irrigation water to sustain intensive, productive land uses such as horticulture. The importance of rivers for their environmental values has been increasing, against a backdrop of increasing extractive demand. Groundwater is an extremely important source of irrigation water and protection of groundwater recharge is fundamental to maintaining this resource. Forestry occupies a large part of the catchment, with potential to occupy considerably more, and is known to reduce total water yield (compared to pasture) at the small-catchment scale. Current policies set restrictions on the expansion of forestry in some areas because this could reduce water availability for existing water users.

Key research questions concern the influence of land use on water yield and sustainable allocation limits for surface and groundwater:

- How do individual, local land-uses affect the availability of ground and surface water locally and over the entire catchment?
- What is the influence of tall woody vegetation on the total and seasonal amount of streamflow, and groundwater recharge, particularly at larger-catchment scale?

- What is the influence on streamflow of groundwater pumping from the valley floor?
- What are the mechanisms of groundwater recharge (particularly in the upper Motueka and Moutere groundwater recharge areas) and how are they influenced by land use? Have these effects changed over time?
- What are the historical and likely future trends in water use and water demand?
- What is the most defensible way to plan for the allocation of water resources among alternative uses in the event of shortages, and between in-stream and abstractive uses?
- What is the best minimum-flow regime to protect the trout fishery?
- How can water that is surplus to in-stream needs most efficiently be allocated between users?
- Are there options for increasing the amount of water available for users, or the efficiency of water use?

how can we best balance

competing out-of-stream and

in-stream water needs?

5.2 SEDIMENT ISSUES

The west bank of the Motueka River has large areas of steep terrain underlain by the highly erodible Separation Point granite. Much of this area is currently covered in plantation forest, with some to be harvested in the near future. The erosion associated with timber harvest may result in a major increase in sediment delivery to the Motueka River and the Tasman Bay coastal system, affecting water and habitat quality, biodiversity and fisheries. Land-use controls on vegetation modification and forest-harvesting practices are in place on the granite terrain. Erosion can also be a significant issue on Moutere gravel terrain. Forest harvesting can result in elevated sediment concentrations in streams (Graynoth 1979). Much of the soil conservation work under the Motueka Catchment Control Scheme has been targeted at streambank stabilisation and gully control on Moutere gravel in pastoral areas. While there have been a number of studies examining the impact of forest harvesting on erosion rates, little is known of the relative magnitude of longer-term erosion rates under forestry (through a full rotation) and pasture, or of the relative magnitude of natural and induced erosion.

Gravel has traditionally been taken from many areas of Motueka riverbed. Natural gravel supply to the river is low due to geological factors, with the Wangapeka and Baton catchments being the major sources of gravel to the lower reaches of the river. The Moutere gravel and granite subcatchments do supply gravel, but it breaks down quickly in the river. The limestone and marble subcatchments supply little gravel to the river. Progressive changes in policy implemented during the 1990s have incrementally restricted both the amount of gravel that can be extracted and the places where it can be extracted. Despite evidence to the contrary, there is concern among some members of the community that the changes in policy are not only limiting their gravel supply but also making the riverbed shallower and potentially increasing the chances of flooding. However, river cross-section surveys indicate overall that the opposite is occurring. As well, bank stabilisation and gravel extraction activities have led to channel deepening and thus the need for more bank stabilisation. Gravel removal in the upper and lower part of the river has likely reduced the supply of gravel downstream and has been identified as the cause of bank erosion in both the upper and lower reaches of the river. There is sufficient evidence to indicate that adverse economic and environmental effects will result in the longer term if gravel is extracted at a rate significantly greater than the sustainable level. The changes in riverbed morphology may also influence habitat quality for trout, native fish and invertebrates. It is possible that gravel extraction in the river also exacerbates coastal erosion of the gravel beaches at Kina and Ruby Bay, although this effect is considered likely to be minor.

Key research questions relate to fine-sediment supply, and gravel supply and extraction:

- What are the relative rates of long-term erosion on Separation Point granite, and other rock types, under different land uses?
- What is the relative influence of occasional severe rainstorms, geology, and land use in determining sediment generation and delivery?
- Under what conditions does forestry on the Separation Point granite increase erosion rates, and what are the best management practices to minimise the risk of accelerated erosion?
- How strongly connected are the hillslope sediment supply and fluvial sediment transport systems?
- What is the time scale for sediment movement through the fluvial system?
- What effect does fine-sediment supply, gravel supply, and gravel extraction have on the quantity and quality of in-stream habitat, and on the trout fishery?
- Is riverbed morphology, and channel and bank stability influenced by gravel extraction?

- Are alternative gravel extraction and/or supply strategies available to reduce downstream impacts?
- Are coastal erosion problems related to gravel extraction?

what are the key sources of sediment, and how does sediment influence fish populations?

what determines water quality, and is it changing through time?

5.3 WATER QUALITY ISSUES

Although streamwater quality in the Motueka Catchment is generally good, there is concern among some residents and marine resource managers about concentrations of nutrients (primarily nitrogen) and faecal indicator bacteria (and associated pathogens) in the downstream reaches of the river and Tasman Bay. Increased concentrations of human pathogens are a potential issue in Tasman Bay with respect to shellfish quality, not only in the delta region where cockles and a variety of clams occur, but also further offshore where scallops and dredge oysters are harvested commercially. Aquaculture management areas that have been established in the Motueka plume region for the development of mussel farming could also be affected by a reduction in bacteriological water quality. Specific sources have not yet been identified, but the pastoral industry and irrigated horticulture (at least partly due to leaking septic tanks) are suspected, direct human sources may be important (e.g., sewer pipe breakage has impacted cockle harvest in the past), and the role of dairying (particularly in view of the potential for expansion of dairying) may also be crucial. Other potential contaminants (e.g., pesticides, hydrocarbons, heavy metals), although not a particular water quality issue at present, could also theoretically become significant in conjunction with changing land-use practices.

Key research questions concern the impact of land use on water quality:

- How much does water quality vary throughout the Motueka Catchment and the receiving waters of Tasman Bay?
- What are the relative influences of geology and land use in determining water quality?
- How important are headwater and tributary conditions in influencing water quality and quantity throughout the catchment?
- Are there any trends in water quality of the Motueka River and its tributaries?
- In which parts of the rivers are changes occurring?
- Are these changes associated with land use or management, and do they impact on downstream freshwater and marine ecosystems, resources and values?
- What are the most effective mitigation measures?

5.4 AQUATIC ECOLOGY ISSUES

The Motueka River has a world-famous trout fishery, but in the last decade trout numbers appear to have declined. However, there is no consensus on the reasons for this decline. Prior to European settlement and the introduction of trout, the Motueka probably sustained a diverse and abundant native fish fauna. Populations of native fish and of invertebrate biota are receiving attention as an increasing number of scientists and community groups are joining iwi in placing great value on the older, more diverse, biota of the river.

Key research questions concern both the introduced trout fishery and native fauna (vertebrate and invertebrate):

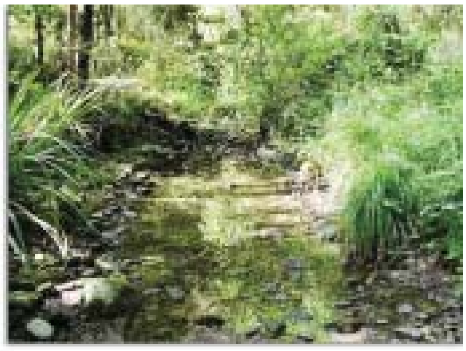
- What are the reasons for the decline in the trout fishery?
- What have the trends in riverbed morphology and substrate composition been and how have they affected the trout fishery?
- How does fishing pressure affect the trout fishery?
- What is the spatial and temporal distribution of native fauna, and how are these patterns influenced by land use?
- What is the variation in the amount and quality of aquatic habitat and biodiversity throughout the Motueka Catchment and how is this variation affected by land use and climatic events?
- How important are headwater and tributary conditions in influencing water quality, water quantity and aquatic habitat throughout the catchment?
- What are the main sources of food (energy) that drive the ecological community in the river?
- How important is organic matter from land and/or freshwater for the functioning of the coastal marine ecosystem?
- Are small areas of unsustainable land use having large effects on the whole catchment?

how does land use

affect native and

introduced species?

can riparian management be used to improve water quality?



5.5 RIPARIAN MANAGEMENT ISSUES

Riparian zones provide habitat for terrestrial fauna, and through their supply of shade, organic debris, and bank complexity they can affect aquatic habitat, both positively and negatively. The nature of the riparian zone and its use by landowners can also influence influxes of sediment, nutrients, and microbial contaminants to streams. There is increasing recognition among some residents, river users, and regulators about the benefits of riparian vegetation along river channels in the Motueka Catchment. Floodway management has also affected riparian zones in the major tributaries and main stem. There is little agreement on, or even information about, the distribution of various riparian zone conditions, their effect on water quality and the quality and functioning of aquatic ecosystems, or their role in providing habitat for birds, pests and other terrestrial biota. No consensus has yet developed about preferred conditions for the riparian zones in various parts of the catchment. There is no doubt that the state of the riparian zone has altered dramatically with the widespread vegetation clearance and river management that has occurred in the Motueka River since European settlement.

Key questions concern the nature, distribution and functioning of riparian zones:

- What are the values of near- and in-stream habitats and how are these affected by land and river management?
- What types of riparian zone occur in the Motueka Catchment, what is their distribution and biological (terrestrial and aquatic) significance, and how does the width and structure of the riparian zone affect its function?
- Which areas could benefit from changed riparian management and which are presently satisfactory?
- How can weeds and pests be managed if farm animals are excluded from riparian areas?
- What would be the benefits of improved riparian management, what improvements should be given priority, and where should rehabilitation be focused?
- Which native plants can be used for the dual role of bank stabilisation and riparian function?

5.6 CATCHMENT – TASMAN BAY INTERACTIONS

The Motueka Catchment is the major source of freshwater and land-derived nutrients into Tasman Bay, and is therefore a major influence on productivity in the bay. The coastal and marine waters influenced by the Motueka plume of fresh water have significant existing fishery values (scallops, fin fish, cockles), and the potential for an increase in marine farming activities (for scallops, mussels, oysters).

Key research questions concern the influence of land use on the quantity and quality of freshwater delivered to the marine environment; understanding the functioning of the food web within Tasman Bay; and the opportunity for, and effects of, marine farming on water quality:

- How important are organic matter, sediment, and nutrients delivered from the land for the functioning of the coastal and marine system?
- What are the risks to marine farming from activities on land?
- What are the factors that control primary and secondary production in Tasman Bay (notably fish and shellfish)?
- What are the dynamics of water circulation and biogeochemical processing in the near-coastal and coastal zones?
- What is the sustainable carrying capacity for marine farming?
- Where and how could marine farms be most sustainably developed?

how does land-use

influence marine water

quality and fish?

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Appendix 1 Key characteristics of the soils of the Motueka Catchment (from Chittenden et al. 1966; New Zealand Soil Bureau 1968)

SOIL MAP UNIT NAME#	SOIL CLASS*	AREA (km^2)	PARENT MATERIAL	ANNUAL RAINFALL (mm)	FERTILITY	DRAINAGE CLASS
SOILS OF THE FLOODPLAINS AND LOW TERRACES						
Riwaka zl and sl (98a)	RFW (Recent)	40	Alluvium (from greywacke, granite, limestone, quartzite, and basic igneous rocks)	1000–1300	Moderate to high	Well drained
Riwaka zl (wet phase) (98a)	GOO (Gley Recent)	2	Alluvium (from greywacke, granite, limestone, quartzite, and basic igneous rocks)	1000–1300	Moderate to high	Poor
Sherry s&sl (98c)	RST (Recent)	31	Alluvium (from granite)	1000–2500	Low	Well drained
Wangapeka st sl (99c)	RFW (Recent)	11	Alluvium (from greywacke, argillite, quartzite, limestone, granite)	1500–2000	Low to moderate	Well drained
Tapawera sl (33g)	RFW (Recent)	13	Alluvium (from greywacke, argillite, sandstone, ultrabasic rocks, Moutere gravels)	890–1150	Low to moderate	Well drained
Motupiko l (33g)	RFAW(Recent-YBE)	64	Alluvium (from Moutere gravels, greywacke, argillite, sandstone)	890–1150	Low	Well drained
Braeburn sl (89d)	RFMA (Gley)	2	Alluvium (from Moutere gravels)	890–1150	Very low	Imperfect
Braeburn cyl (89d)	GRA (Gley)	1	Alluvium (from Moutere gravels)	890–1150	Very low	Poor
Dovedale grl (33g)	RFAW (Recent-YBE)	30	Alluvium (from Moutere gravels)	890–1150	Low	Well drained
Motukarara zl (92)	GRQ (Saline Gley Recent)	1	Alluvium and marine sediments	635–1000	Low (and saline)	Poor
SOILS OF THE INTERMEDIATE AND HIGH TERRACES						
Matariki zl (33g)	BOA (YBE)	4	Alluvium (from greywacke, argillite, quartzite, granite)	890–1150	Very low	Well drained
Matariki zl, rolling phase (33g)	BOA (YBE)	6	Alluvium (from greywacke, argillite, quartzite, granite)	890–1150	Very low	Well drained
Hau st sl (27c)	BOT (YGE-YBE)	0.7	Alluvium (from greywacke, argillite, quartzite, limestone, granite, basic igneous rocks)	1000	Low	Well drained
Graham zl (33g)	BOT (YBE)	2	Alluvium (from granite)	890–1150	Low	Well drained
Kikiwa zl (34b)	BOA (YBE)	20	Alluvium from Moutere gravels	1000–1500	Low	Imperfect
Kikiwa zl, rolling phase (34b)	BOA (YBE)	23	Alluvium from Moutere gravels	1000–1500	Low	Imperfect
Atapo st zl (33g)	BOT (YBE)	6	Alluvium (from greywacke)	890–1150	Low to moderate	Well drained

SOIL MAP UNIT NAME#	SOIL CLASS*	AREA (km²)	PARENT MATERIAL	ANNUAL RAINFALL (mm)	FERTILITY	DRAINAGE CLASS
SOILS OF THE FANS						
Tophouse zl (52a)	BLA (HCYBE)	13	Alluvium (from greywacke)	1500	Low	Well drained
Katrine sl, zl, st sl (53b)	BLA (HCYBE)	2	Greywacke till	1300–2500	Low	Well drained
SOILS OF THE COASTAL SANDS						
Tahunanui s s&gr (68c)	RST (YBS)	2	Sand and gravel from greywacke and granite	900	Low	Well drained
SOILS OF THE ROLLING AND HILLY LANDS						
with a subhumid climate						
Mapua sl (32)	UEM (YGE-YBE)	0.5	Moutere gravels	890–1000	Very low	Imperfect
with a humid climate						
Rosedale zl (37H)	BFA (YBE)	0.9	Moutere gravels	1150	Very low	Moderately well drained
Rosedale hill (37H)	BFA (YBE)	60	Moutere gravels	1150	Very low	Well drained
Stanley zl (35cH)	BFA (YBE)	10	Moutere gravels	1150–1270	Moderate to low	Moderately well drained
Stanley hill (35cH)	BFA (YBE)	65	Moutere gravels	1150–1270	Moderate to low	Well drained
Spooner hill (37aH)	BFA (YBE)	143	Moutere gravels	1150–1270	Low	Well drained
Korere hill (45H)	BOA (YBE)	194	Moutere gravels	1270–1400	Very low	Well drained
Hope hill (45bH)	ZXP (YBE)	165	Moutere gravels	1500–1780	Very low	Well drained
Howard zl, cy l and Howard hill (45a, 45aH)	BOA (YBE)	5	Alluvium and till (from greywacke and basic igneous rocks)	2000	Low to moderate	Moderately well drained to well drained
Orinoco zl (37bH)	BMT (YBE)	4	Granodiorite and diorite (of Separation Point suite)	1000–1140	Moderate	Well drained

SOIL MAP UNIT NAME#	SOIL CLASS*	AREA (km^2)	PARENT MATERIAL	ANNUAL RAINFALL (mm)	FERTILITY	DRAINAGE CLASS
Orinoco hill (37bH)	BMT (YBE)	8	Granodiorite and diorite (of Separation Point suite)	1000–1140	Moderate	Well drained
Tadmor zl (44cH)	BOA (YBE)	5	Siltstone and sandstone (Miocene-Eocene)	2000–2500	Moderate to low	Moderately well drained
Tadmor hill (44cH)	BOA (YBE)	71	Siltstone and sandstone (Miocene-Eocene)	2000–2500	Moderate to low	Well drained
Kaiteriteri sl (37cH)	UYT (YBE)	7	Weathered granite (Separation Point suite)	1300–2000	Very low	Well drained
Kaiteriteri hill (37cH)	UYT (YBE)	41	Weathered granite (Separation Point suite)	1300–2000	Very low	Well drained
Brooklyn hill (77dH)	BMT (BGC)	14	Basic igneous rocks (gabbro, diorite – Riwaka metavolcanics)	1000–1500	High	Well drained
Pelorus hill (65c)	BOA (HCPYBE)	7	Old greywacke, argillite, sandstone (Permian – Maitai Group)	2000–2500	Low	Well drained
Kairuru complex (44d)	ERT (YBE)	7	Marble	1270–1520	Low to moderate	Well drained
SOILS OF THE STEEPLANDS						
Ngatimoti steepland (37bH)	EMT (YBE)	34	Granodiorite and diorite (of Separation Point suite)	1000–1150	High	Well drained
Kawatiri steepland (47e)	BOA (YBE)	6	Diorite, granodiorite	2000–2500	Low	Well drained
Brooklyn steepland (77d)	BMT (BGC)	88	Gabbro, diorite (gabbro, diorite – Riwaka metavolcanics)	1000–1500	High	Well drained
Heslington steepland (74b)	BOT (Rend-YBE)	3	Calcareous sandstone and shale (Mt Arthur Group)	890–1000	Moderate	Well drained
Wakamarama steepland (65d)	BLAD (HCPYBE)	205	Old greywacke (montane; Greenland Group)	1500–5000	Low	Well drained
Lewis steepland (65)	ZOT (HCPYBE)	4	Greywacke (montane; Torlesse Group)	1800–3800	Very low	Well drained
Spenser steepland (58)	ZOT (HCPYBE)	28	Greywacke (subalpine; Maitai Group, Mt Arthur Group)	2000–4000	Very low	Well drained
Whitcombe steepland (67)	BAM (HCPYBE)	30	Greywacke and schist (Mt Arthur Group)	2500–7500	Very low	Imperfect
Patriarch steepland (57g)	BLA (HCYBE)	22	Old greywacke, argillite, sandstone (Permian – Maitai Group)	1500–2500	Very low	Well drained
Haupiri steepland (65b)	BOA & ZPT (HCPYBE)	89	Old greywacke, argillite, quartzite (Devonian – Mt Arthur Group)	2000–2500	Low to moderate	Well drained
Pelorus steepland (65c)	BOA (HCPYBE)	97	Old greywacke, argillite, sandstone (Permian – Maitai Group)	2000–2500	Low	Well drained

SOIL MAP UNIT NAME#	SOIL CLASS*	AREA (km²)	PARENT MATERIAL	ANNUAL RAINFALL (mm)	FERTILITY	DRAINAGE CLASS
Pikikiruna steepland (74c)	ERW (Rend-YBE)	121	Marble and limestone (Mt Arthur Group)	1000–3050	Low to moderate	Moderately well drained
Matiri steepland (65f)	ZOH (HCPYBE)	25	Sandstone and mudstone (Miocene-Oligocene)	1500–3800	Low	Well drained
Dun steepland (79)	BMG (BGC)	74	Ultramafic rocks (Dun Mountain ultramafics)	1000–2000	Very low	Well drained
Hohonu steepland (67b)	ZOT (HCPYBE)	10	Weathered granite (subalpine-alpine; Separation Point suite)	1500–5000	Extremely low	Well drained
Pokororo steepland (41e)	BOA (YBE)	134	Weathered granite (montane; Separation Point suite)	1270–1500	Very low	Well drained
Glenhope steepland (66a)	BOA (HCPYBE)	120	Weathered granite (montane; Separation Point suite)	2000–5000	Very low	Well drained

Key

# Texture	zl = silt loam, sl = sandy loam, cyl = clay loam, l = loam, gr = gravel, st = stony. Numbers are map unit numbers shown on maps in New Zealand Soil Bureau (1968).
* Soil class	RFQ = Weathered Fluvial Recent, RST = Typic Sandy Recent, RFAW = Acidic-weathered Fluvial Recent, RFMA = Mottled-acidic Fluvial Recent, GRA = Acidic Recent Gley, GRQ = Saline Recent Gley, GOO = Peaty Orthic Gley, BOA = Acidic Orthic Brown, BOT = Typic Orthic Brown, BFA = Acidic Firm Brown, BLA = Acidic Allophanic Brown, BMG = Magnesic Mafic Brown, BMT = Typic Mafic Brown, BLAD = Acidic-pedal Allophanic Brown, BAM = Mottled Acidic Brown, UEM = Mottled Albic Ultic, UYT = Typic Yellow Ultic, ZXP = Placic Pan Podzol, ZOT = Typic Orthic Podzol, ZOH = Humose Orthic Podzol, ZPT = Typic Perch-gley Podzol, EMT = Typic Mafic Melanic, ERW = Weathered Rendzic Melanic, ERT = Typic Rendzic Melanic (Hewitt 1992) YBE = Yellow Brown Earth, YBS = Yellow Brown Sand, HCYBE = High Country Yellow Brown Earth, HCPYBE = High Country Podzolised Yellow Brown Earth, YGE = Yellow Grey Earth, Rend = Rendzina, BGC = Brown Granular Clay (New Zealand Soil Bureau 1968)

Appendix 2 Sites of special wildlife interest, Motueka Catchment (Walker 1987)

Walker (1987) identifies and ranks the following sites within the Motueka:

FOREST SITES

- Kahurangi National Park (outstanding value): wide variety of birds (including kākā, yellow-crowned parakeet, falcon, kiwi, blue duck, fernbird, robin, rock wren, kea, long-tailed cuckoo) and large land snails (*Powelliphanta*).
- Big Bush (high value): 18 recorded species of bird including kākā, yellow-crowned parakeet, falcon, fernbird, and robin.
- Donald Creek (high value): 16 recorded species of bird including kākā, parakeet, falcon, and robin.
- Mt Richmond Forest Park (high value): 25 recorded species of birds (including kākā, yellow-crowned parakeet, falcon, blue duck, robin, kea) and large land snails (*Powelliphanta*).
- Many other sites of moderate-to-high value that are generally smaller in size or have been modified but still contain a wide variety of birds, and some have large land snails. Many of these are lowland sites.

FRESHWATER WETLAND SITES

- The middle braided reaches of the Motueka riverbed around Tapawera (moderate-to-high value). Used seasonally for breeding by coastal species including the banded dotterel, pied stilt, Paradise shelduck, South Island pied oystercatcher and black-fronted tern.
- Golden Downs village wetland with fernbird and other common birds (moderate value).
- Motueka rivermouth sites with waterfowl and other common birds (moderate value).
- Waiwhero Creek and other forest wetlands with fernbird, waterfowl, pūkeko and other common birds (moderate value).

COASTAL WETLAND SITES

Three sites on the Motueka River delta are listed: the rivermouth and sandspit (high value) and the Kumeras tidal flats and saltmarsh (moderate-high value). At the Motueka rivermouth 42 bird species have been recorded, with 31 recorded at the sandspit, and 25 at the Kumeras. This area is the most important feeding area in western Tasman Bay, has the largest high-tide roost site (with over 10,000 birds in midsummer), the most birds in Tasman Bay, and is an important feeding area for a variety of birds (including international migratory waders). It provides roosting and breeding areas for a large variety and number of birds, including estuarine-edge species (banded rail, and South Island fernbird until recently), waders (South Island pied oystercatcher, Eastern bar-tailed godwit, turnstones, banded dotterel, wrybill, New Zealand dotterel, royal spoonbill, white heron), coastal species (shags, gannets, gulls, white-fronted tern, black-fronted and Caspian terns). These coastal areas are some of the most threatened (from stock grazing, drainage and land development) wildlife areas in the catchment. The Department of Conservation regards the Motueka delta as being of national importance (Davidson et al. 1993).

Appendix 3 Outstanding natural features and landscapes in the Motueka Catchment (Kenny and Hayward 1993)

INTERNATIONAL IMPORTANCE

- Nettlebed Cave (the deepest and second-longest cave in Southern Hemisphere, with the largest chamber and deepest karst circulation in New Zealand; a multiple-level phreatic system with speleotherms)
- Pearse Resurgence (a large spring that drains water from under Mt Arthur and including all the caves there)
- Mt Owen karst (one of the two best examples of glaciated karst in the Southern Hemisphere)
- Baton River Devonian fossil fauna (classic Devonian-age sequence for New Zealand with very diverse fauna)
- Tomo Thyme cave system (third-longest cave system in New Zealand, a complex system linked to the Pearse Resurgence, with multiple shaft entrances intersecting horizontal phreatic passages on several levels).
- Bulmer caverns (longest and second deepest cave in New Zealand, large and varied speleotherms, complex cave system).

NATIONAL IMPORTANCE

- Falcon Cave (fifth-deepest cave in New Zealand, with a series of shafts from a single entrance)
- HH Cave (third-deepest cave in New Zealand, with vadose development)
- Moutere gravel glacial/interglacial sediment sequences at Hope Saddle (allows correlation with key sequences in the Wanganui area)
- Mt Patriarch to John Reid Hut Paleozoic fossil fauna (unique section through upper Cambrian and lower Ordovician carbonate facies rocks, with conodonts, trilobites and molluscs).
- Ellis Basin and Horseshoe Basin karst (glaciated karst with superb solution features).
- Owen ice cavern (best ice cave in New Zealand).
- Riwaka wollastonite (one of largest known occurrences of wollastonite).

REGIONAL IMPORTANCE

- Graham Valley pyroxenite (most-common rock type in the Cretaceous Riwaka igneous complex)
- Graham Valley nickel (example of nickel mineralisation in the Riwaka igneous complex)
- Rolling River gold mining area (good example of early attempt at quartz gold mining)
- Upper Tadmor Valley Eocene–Oligocene sediments (sequence of marine and non-marine sediments on basal unconformity, and an example of stream capture)
- Baton River–Moran Creek Paleozoic sediments (only-known exposure of the base of lower Paleozoic Baton Group rocks)
- Beebys conglomerate Cretaceous terrestrial sediments (remnants of late Mesozoic terrestrial fluviatile sediments)
- Blue Creek cave (excellent example of phreatic maze development)
- Kaka clay mine (active underground kaolin mine)
- Kaka lime kiln and quarry (brick kiln built into a rock face to burn local limestone)
- Gogoroth Cave (a deep shaft system of caves from two adjacent entrances).
- Mt Patriarch limestone summit folding (large folds and thrusts in calcareous rocks of Eastern Belt of Nelson)
- Waimea Fault, Tophouse (offset of Tophouse surface along Waimea Fault).
- Waimea Fault, faulted terraces (small graben along offset of Waimea Fault in Motupiko valley).

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